Web Usability or Accessibility:
Comparisons between people with and without intellectual disabilities in viewing complex naturalistic scenes using eye-tracking technology

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By

Nancy Sceery Bazar
Master of Education
Mount St. Mary's University, 2005

Director: Frederick Brigham, Associate Professor
Department of Special Education

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George Mason University
Fairfax, VA

DEDICATION

This is dedicated to my loving husband, Leonard S. Bazar, Ph.D., who has promised to include a qualified Instructional Technologist in all his future grant applications. It is also dedicated to my mother, Beverly Sceery, who successfully defended her Ph.D. proposal at the same age as I am today, and who has strongly encouraged me to become the first *woman* in the family with a Ph.D.

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ABSTRACT

WEB USABILITY OR ACCESSIBILITY: COMPARISONS BETWEEN PEOPLE WITH AND WITHOUT INTELLECTUAL DISABILITIES IN VIEWING COMPLEX NATURALISTIC SCENES USING EYE-TRACKING TECHNOLOGY

Nancy Sceery Bazar, Ph.D.

George Mason University, 2009

Dissertation Director: Dr. Frederick Brigham

The purpose of this primarily quantitative study was to compare how young adults with and without intellectual disabilities examine different types of images. Two experiments were conducted. The first, a replication and extension of a classic eye-tracking study (Yarbus, 1967), generated eye gaze patterns and data in response to questions related to the famous painting, *The Unexpected Visitor*. Both groups exhibited goal-directed behavior based on the judgment of eight independent raters, an extension to the original study, but there was a statistically significant difference between the two groups, based on the judgment of two cooperating raters. Raters could not differentiate between the scan paths of the young adults with and without intellectual disabilities. Yarbus' study was also extended by the inclusion of an interview with the participants. There was a statistically significant difference in the word count and recollection of major elements from *The Unexpected Visitor* between the groups.

The second experiment used eye-tracking technology and a current saliency model that predicted salient points in images (Walther & Koch, 2006) under two sets of saliency features. Participants rapidly viewed 30 images of Web sites and other natural scenes from three different sources. This study found no statistically significant differences between people with and without intellectual disabilities for teacher created pictures from a fourth grade geomorphology course and award winning Web sites, leading to a strong recommendation of a usability rather than accessibility for people with intellectual disabilities.

Finally, the relative merits of two methods of saliency prediction were compared. The more recently developed Walther model (Walther & Koch) proved to produce similar results as the computationally intensive Itti model (Itti, Koch, & Niebur, 1998), under the conditions of this experiment. This suggests that researchers may use the simpler model in the future to compare groups.

1. Introduction

Background of the Problem

Section 508

The Rehabilitation Act of 1973 was the original civil rights law that prohibited discrimination against handicapped students in federally funded programs in the US (Section 504). Section 508 of the law was amended in 1998 to require all public federal web sites to conform to a set of standards to enable use of the Web by people with disabilities. The Access Board, an independent US federal agency, was tasked with creating and maintaining the web accessibility standards. Web accessibility standards are design rules such as: every time a non-text element (e.g., an image such as a photograph or a graph of data) is displayed on a Web site, a description of that element must be available for the reader. Depending on the browser, the description of the image will display as the mouse is passed over the image or the text can be read by a screen-reader. Section 508 standards have been adopted by many state governments and applied to educational technology purchased or used within those states. For example, Maryland was an early adopter of the standards and passed laws in 2000-2001 requiring all electronic and information technology purchased by school districts to meet the 508 standards and all teacher-created web sites to meet the standards by 2004 (Bazar, 2006).

World Wide Web Consortium

The World Wide Web Consortium (W3C, 2008a), a volunteer international organization founded and headed by Tim Berners-Lee, the inventor of the World Wide Web, has established a similar set of accessibility guidelines called the Web Content Accessibility Guidelines 1.0 (WCAG, 2008b). A new version, WCAG 2.0, is currently being developed.

TEITAC

In the fall of 2006, the Access Board created a group, the Technology and Electronic and Information Technology Advisory Committee (TEITAC, 2007), to review and refresh the Section 508 technical standards, including Web accessibility standards, that were introduced in 1998. TEITAC is co-chaired by two experts in the field, Jim Tobias and Michael Paciello. Jim Tobias has worked in the field of accessibility for twenty-five years, and is on the Advisory Council of CAST (2007), a non-profit organization, well known as the creators of the "Bobby" tool, a free web accessibility test tool and the creators of Universal Design for Learning. Michael Paciello, is credited with launching the Web Accessibility Initiative of the W3C and is the author of the book *Web Accessibility for People with Disabilities* (2000). They are supported by a highly qualified group of accessibility professionals who began their task by listing the shortcomings and problems with the current standards. The current standards focus primarily on disabilities related to sight and hearing and an early issue raised was insufficient support for people with cognitive disabilities (TEITAC, 2007), thus signaling need for more research in that area.

Cognitive Disability Movement

Berkowitz (1987) documented disability policy in the United States from the early 1900s through the 1970s, focusing on the broad impact of Section 504 of the Rehabilitation Act. He described how a few individuals involved in the "independent living movement" radically changed the nation's view on the meaning of disability. Today, there is a cognitive disability movement within the Web accessibility movement involving Seaman in the W3C and the TEITAC committee in the US.

Seeman (2002) at the 11th International World Wide Web Conference argued that cognitive disabilities should be included in the web accessibility movement, stating "There are an estimated 6.8 million people with mental retardation in the United States alone. (source: Batshaw, 1997). Mental retardation affects 100 times as many people as blindness (source: AAMR 1994 [*sic*])."

On June 20, 2006, Seaman wrote an "Objection to the Web Content Accessibility Guidelines 2.0" message (2006) protesting the claim of the WGAG 2.0 Guidelines to address the needs of those with learning difficulties and cognitive limitations. The letter was signed by over 50 people involved with disability organizations from around the world. The National Center of Disability and Access to Education (NCDAE), located at Utah State University is a member of the TEITAC committee. NCDAE sponsored a WebCast on January 31, 2007, on cognitive disabilities and the Web (NCDAE, 2007). The participants in this meeting also focused on the lack of research in the area of use of the Web for people with cognitive disabilities.

Batavia and Schriner (2001) suggested that in the twenty-first century, "the information age perspective must perceive disability as one of many human variations…and recognize the value of universal design" (p. 699). Universal design for learning considers both the variability of the human brain, the power of the Web and multi-media and the potential of technology to develop unique solutions for individuals with disabilities (Rose & Meyer, p.70). Web Accessibility and Section 508 are within the scope of the universal design for learning philosophy and important for the twenty-first century.

In summary, the purpose of this study is to examine the ways that people view images in order to inform Web site design to improve usability for all people or accessibility for people with cognitive disabilities.

Definition of Key Terms

The term *intellectual disabilities* is used in this study instead of *mental retardation* in all cases, except for published research titles, direct quotes, and definitions attributed to a person or an organization.

Disabilities

Disabilities is an umbrella term, covering impairments, activity limitations and participation restrictions. An impairment is a problem in the body function or structure; an activity limitation is a difficulty encountered by an individual in executing a task or action; while a participation restriction is a problem experienced by an individual in involvement in life situations. This disability is a complex phenomenon reflecting an interaction between features of a person's body and features of the society in which he or she lives… this definition ‘mainstreams’ disability and recognizes it as a universal human experience (World Health Organization, 2008).

Intellectual Abilities

The taxonomy of abilities of the World Health Organization (WHO) includes mental functions and under mental functions includes intellectual functions, that include: intellectual growth, intellectual retardation, mental retardation and dementia, but excludes memory functions, thought functions and higher level cognitive functions.

Disorders of Psychological Development

Disorders of psychological development as categorized under Mental and Behavioural disorders. Disorders of psychological development include Asberger’s Syndrome, and learning disabilities (WHO, 2007).

Usability

A quality attribute that assesses how easy user interfaces are to use. The word "usability" also refers to methods for improving ease-of-use during the design process. Usability is defined by five quality components:

- Learnability: How easy is it for users to accomplish basic tasks the first time they encounter the design?
- Efficiency: Once users have learned the design, how quickly can they perform tasks?
- Memorability: When users return to the design after a period of not using it, how easily can they reestablish proficiency?
- Errors: How many errors do users make, how severe are these errors, and how easily can they recover from the errors?
- Satisfaction: How pleasant is it to use the design (Nielsen, 2003)?

Accessibility

Section 508 of the Rehabilitation Act of 1973, as amended by Congress in 1998, defined Accessibility by stating "Web sites are accessible when individuals with disabilities can access and use them as effectively as people who don't have disabilities" (Slatin & Rush, 2003, p. 2).

Mental Retardation

This disorder is characterized by significantly sub average intellectual functioning (an IQ of approximately 70 or below) with onset before age 18 years and concurrent deficits or impairments in adaptive functioning (DSM-IV-TR, 2000).

Intellectual disabilities

Intellectual disabilities (previously termed *mental retardation*) is a developmental disorder with onset prior to age 18 years characterized by impairments in measured intellectual performance and adaptive skills across multiple domains (Usano, Kartheiser, & Barnhill, 2008).

Cognitive Disability

Online search of the American Psychiatric Association's publications (DSM-IV, 1994); DSM-IV-TR, 2000), and the *American Psychiatric Textbook of Psychiatry* indicated no use of the term *cognitive disability*. Clarkin, Howieson, and McClough (2008) referred to cognitive *abilities* that include, but are not limited to, attention, visual search, continuous performance, memory, language, and executive functions.

The term *cognitive disabilities* was used in the 2004 Amendments to the Individuals with Disabilities in Education Act (Public Law 108-446) three times:

> “preparing personnel who provide services to children with significant cognitive disabilities and children with multiple disabilities….Supporting the use of Internet based communications for students with cognitive disabilities in order to maximize their academic and functional skills….address the unique needs of children with significant cognitive disabilities” (United States Government, 2009).

However, there was no definition for cognitive disability within the text of the amendment. Cognitive Disability, in the only official definition of the term identified in the literature review, as “significantly sub average intellectual functioning that exists concurrently with deficits in adaptive behavior and that adversely affects educational performance” (Wisconsin Department of Public Instruction, 2008). This literature review has not included a detailed review of the Congressional Record for every version of the Individuals with Disabilities Education Act since its inception in 1975 to see whether the term cognitive disability has been defined. The law itself provided for services beyond intellectual disabilities (e.g., Attention Deficit Hyperactivity Disorder), that would not be included in the definition of intellectual disabilities unless the person had an IQ under 70. The working definition for cognitive disability during TEITAC discussions was located in *The Congressional Record* for February 3, 1998, Section 255 of the Telecommunications Act, which stated “Many individuals have reduced cognitive abilities, including reduced memory, sequence tracking, and reading skills” (United States Access Board, 1998). Note the term cognitive *disability* was not used, as it was also not used in psychiatric sources (e.g., DSM-IV, 1994; DSM-IV-TR, 2000) and the *American Psychiatric Textbook of Psychiatry*.

The conclusion was that cognitive disability is a concept, described by small numbers of examples, and the only official definition found was that of the state of

Wisconsin, which was closer to intellectual disabilities rather than cognitive disability. The most inclusive definition might be: An impairment, activity limitation or participation restriction (WHO, 2007) for any of the cognitive abilities included in the *American Psychiatric Textbook of Psychiatry* (Clarkin, Howieson, & McClough, 2008), noting it is also not inclusive, as it lists only cognitive abilities that have associated diagnostic tests.

Accessibility and Usability Resources

Considerable research has been done in the area of Web usability (e.g., Koyani, Bailey & Noll, 2004), and Web accessibility (e.g., Thatcher, et al., 2006). A search on Google Scholar on February 15, 2008, indicated there were 5,580 responses to "Web Accessibility" and 6,270 responses to "Web Usability." On January 25, 2009, the numbers had grown to 7,600 and 7,380. WebAIM, an organization associated with the National Center of Disability and Access to Education (NCDAE), published a list of 19 known papers on Accessibility for people with cognitive disabilities (WebAIM, 2008). However, they acknowledged that most of these papers were advocacy oriented, did not reference recent research in the field, and concluded there was little current research in the study of use of the Web by people with cognitive disabilities. There were a few exceptions, however, e.g., Davies, Stock, and Wehmeyer (2001) designed and developed a browser for first time Web users with cognitive disabilities.

The WebAIM group, which focused on education and use of the Web, appeared not to include within its domain the extensive literature on use of eye-tracking technology and special education. An extensive literature review (Brigham, et al., 2001) existed and the field has grown to include the study of reading and reading disorders (e.g., Oh, 2007), ADHD, (e.g., Olmeda, 2002), learning disabilities (e.g., Rabinowitz, 2004), autism (Denver, 2004), and mental and behaviors disorders, such as schizophrenia (e.g., Katsanis, Kortenkamp, Iocono, & Grove, 1997).

One of the papers identified by WebAIM (Mariger, 2006), discussed the differences between usability and accessibility using available literature that focused on that key issue. Should people with cognitive disabilities be supported within the fields of accessibility or usability? Jim Thatcher (2006), a leading expert in the field of accessibility, and author and editor of the most comprehensive book on Web Accessibility available, explicitly excluded discussion of accessibility for people with cognitive disabilities in the book, "There is an entire book to be written about cognitive accessibility; this book isn't that book" (p. xlvi).

Statement of the Problem

Although there has been considerable policy discussion on the need for research to support web accessibility for people with intellectual disabilities, there appears to be no awareness of data comparing individuals with and without intellectual disabilities in areas that could impact the design of a Web site and answer the first fundamental question. Is this an issue of accessibility or usability? If the only difference between people with intellectual disabilities is slower information processing speed, then usability is enough as the current Section 508 standards already include provision for changing any time limits incorporated into any electronic or information technology. Web sites are infinitely patient and generally forgiving of errors.

This study focused on visual attention as it is fundamental to Web use. This study replicated the classic Yarbus (1967) eye-tracking study using participants with and without intellectual disabilities. It focused on previous research on visual attention, and where differences between people with and without intellectual disabilities had been identified, tested them again in more ecologically valid circumstances using eye-tracking technology and a computer vision model (Walther & Koch, 2006).

Research Questions and Hypotheses

Using the *American Journal on Intellectual Disabilities and Developmental Disorders*' definition of intellectual abilities as stated above, the research questions were:

1) Do individuals with and without intellectual disabilities exhibit goal-directed behavior when viewing a picture of a complex scene?
2) Is there a difference between people with and without intellectual disabilities in viewing pictures of naturalistic scenes of different types?
3) Can the Walther (2007) model be used to study people with and without intellectual disabilities?

The first question was associated with a seminal study by A. L. Yarbus (1967) on visual attention and inspired by a recent study (Pieters & Wedel, 2007). The second question was inspired by a fairly recent study (Parkhurst, Law, & Niebur, 2002). The third question was inspired by very recent research in the vision field (Cerf, Frady, & Koch, 2008; Walther & Koch, 2006), as researchers have been developing and testing computer based models of human vision based on biologically plausible models. The proposition was that if people with intellectual disabilities were significantly different from people without intellectual disabilities, then they should be served in the field of accessibility, rather than usability.

Yarbus (1967) demonstrated that, given specific instructions (i.e., goals), people will view a scene differently. He used a reproduction of a Repin's painting *The Unexpected Visitor*, to prove this, demonstrating that vision is goal specific. This study is of interest because it was a seminal piece of research on visual attention (Rose & Meyer, 2002, p. 14) and presented in their book on universal design for learning, a philosophy, *Teaching Every Student in the Digital Age*. Universal design for learning seeks to design Web-based instruction that makes use of multimedia, including pictures, audio, and video. Yarbus' approach to understanding vision is called the top-down, goal-directed control approach, or the attentional phase within the field of visual attention research (Egeth & Yantis, 1997, p. 271). Based on the literature of intellectual disabilities and vision, it was expected that a person with intellectual disabilities would view *The Unexpected Visitor* differently depending on the questions asked, and there would be differences between the two groups, consistent with the original study.

Web accessibility and usability are the result of the design of a Web site. Grier (2004) replicated an early study done by Faraday (2000), the only theory ever produced on Web design, which leveraged Tufte's (1997) theories on print layouts. Grier described features such as motion, image, size, color, style, and position, to which Faraday postulated a hierarchical ordering (e.g., people will look at an element that moves first). Although Grier found no support for Faraday's theory, this approach to understanding vision is called the bottom-up, stimulus-driven control approach, or pre-attentional phase within the field of visual attention and is more recent within the field (Egeth & Yantis, 1997, p. 271). Norman Ellis' research (Detterman, Gabriel, & Ruthsatz, 1982) indicated a deficit in Very Short Term Memory for people with intellectual disabilities.

The creation and testing of computer models of visual attention (e.g., Itti, Koch, & Niebur, 1998; Walther & Koch, 2006) has been a leading edge in the field of vision science research. These models used a picture as input and produced a three dimensional saliency map based on the saliency features of orientation, color, and intensity (contrast) that was collapsed to two dimensional areas of interest, where people would be expected to look during the first few seconds they looked at a picture. By allowing the researcher to vary the saliency features and weights, they enabled a finer discrimination between differences, but were not expected to produce different results from traditional bottom-up studies.

Significance of the Study

This study was significant for many reasons. The first experiment, using *The Unexpected Visitor,* extended the classic study (Yarbus, 1967) by adding cooperating and independent raters to categorize the decisions that Yarbus must have made. The independent raters together determined that both groups exhibited goal-directed behavior and there were statistically significant differences in goal-directed behavior between the groups. As individuals, they could not differentiate the scan paths of the two groups, implying no cultural differences. Second, an interview was added to the study, so there is clear evidence there are significant differences between the young adults with and without intellectual disabilities in the areas of description and recollection of key elements in the picture. This gives future researchers two new tools to use.

There are five additional improvements. First, this study provided scientific evidence, in the form of eye-tracking data, rather than opinions, to the intellectual disabilities usability versus accessibility debate within the field of web accessibility. Second, it tied accessibility research to the intellectual disabilities literature, as Web accessibility researchers have developed new technology with little knowledge of their population (e.g., Sevilla, Herrera, Martinez, & Alcantud, 2007).

Third, this study incorporated new computer models of vision, specifically saliency models that were available in the public domain for non-commercial purposes. In the field of vision science, research studies have generally started with an existing model, extended it and tested it to see whether the new model explained the scanpath better than chance, or better than another model, typically using small numbers of participants to view large numbers of images. To date, only one similar study has been identified (Neumann, Spezio, Piven, & Adolphs, 2006) in the field of facial recognition, a field excluded from this study at the onset. The study used a saliency model to compare two groups. Fourth, this study used a more recent model (Walther & Koch, 2006) and naturalistic scenes, making it one of a kind, and exploratory in nature. A methodology was developed and proven to be a valid way of comparing two groups, but in a more parsimonious fashion than previous similar studies. Fifth, this study was general in the sense that it included top-down and bottom-up experiments, so it may be able to be replicated by using participants with other disabilities such as ADHD or Asberger's Syndrome.

The symbiotic relationship between eye-tracking and the vision models was not discussed in the literature, but this author sees that commercial companies with major Web sites regularly use eye-tracking technology to test and tune their Web sites. Eye-tracking technology is expensive and time-consuming, as the process entails eye-tracking scores of people. A vision model that accurately predicts a scanpath would replace eye-tracking technology for that purpose in the future. A vision model that accurately predicts a scanpath of a person with intellectual disabilities someday might facilitate the development of Web sites that were usable for people with intellectual disabilities.

Organization of this Study

This study consists of five chapters, which are chapter 1 Introduction, chapter 2 Literature Review, chapter 3 Methodology, chapter 4 Results, and chapter 5 Discussion. The fourth chapter, Results, has the major sub-headings of Participants, Data Collection and Analysis, Experiment 1 and Experiment 2. The first experiment is associated with one research question and the second experiment is associated with two research questions. Both Experiment 1 and Experiment 2 have three analyses and numerous sub-tasks associated with those analyses. The fifth chapter is Discussion with major sub-headings of Replication of The Unexpected Visitor Study, Web Accessibility and Usability, Individuals with and without Intellectual Disabilities Research, Implications for the Design of Instructional Materials, Implication for Future Research, and Conclusion.

2. Literature Review

General Summary of Relevant Literature Review

Literature for this study consisted of two independent sources – literature related to research on intellectual disabilities and second, vision science and eye-tracking technology literature. The first source was the extensive literature on people with and without intellectual disabilities initiated by a meta-analysis (Kavale & Forness, 1992) which reported the results of 268 studies on intellectual disabilities in the areas of learning difficulties and memory published within the previous twenty five years. Because 55% of the articles cited in the meta-analysis study came from the *American Journal on Mental Retardation*, now the *American Journal on Intellectual and Developmental Disabilities*, this journal was hand searched from the current issue back to 1992, looking for any article relating to vision. This yielded current researchers in the area of vision and intellectual disabilities and citations pointing to articles in other journals, which were retrieved, if deemed appropriate to this study. There were 16 articles retrieved in this search of the *American Journal on Intellectual and Developmental Disabilities*. In addition, Appendix B includes the specific search terms used on the Web of Science database to determine additional papers relevant to the topic that were retrieved, assessed for relevance, and read.

The vision and eye-tracking literature was discovered via an ancestor search starting with databases (Dissertation abstracts, Current dissertations), Google Scholar, books on Eye-tracking technology, (e.g., Duchowski, 2007; Henderson, 2004) and a review of eye-tracking literature (Brigham, et al., 2001) focusing on special education. See Appendix C for Ancestor Search documentation. The vision literature generally included research results emanating from vision labs in the US including, the Rochester Institute of Technology (e.g., Peltz, 1995), Clemson (e.g., Duchowski, 2007), California Institute of Technology (e.g., Cerf, Frady, & Koch, 2008), Johns Hopkins (e.g., Parkhurst, Law, & Neibur, 2002), and Michigan State (e.g., Henderson & Hollingsworth, 2003) and these sites have been checked. Researchers in the field of computer science have been supported by the special interest group ETRA (Eye Tracking Research and Applications Symposium) within the Association of Computing Machinery (ACM). Researchers in the field of engineering have been supported by SIGCHI (Special Interest Group for Computer-Human Interaction from the Institute of Electrical and Electronics Engineers, Inc. (IEEE). These vision researchers focus on basic research such as the development of computer models and algorithms to predict eye movements as well as applications of eye-tracking technology to other fields such as assistive technology, Web site design, and biometrics. While general searches of these databases have not been fruitful, many articles identified in the ancestor search and Google have been found in these databases.

General Observations on Literature Reviewed

There were four general observations noted in the research reviewed. They were lack of participant knowledge, the file drawer effect, lack of ecological validity, and minimal use of technology.

Lack of Participant Knowledge

This study referenced the intellectual disabilities research of the last forty years that makes it different from others which recommend accessibility solutions for people with intellectual disabilities, without really understanding their population (e.g., Sevilla, Herrera, Martinez, & Alcantud, 2007). That study consisted of 20 people ranging from the ages of 24 to 46 and degree of intellectual disabilities from borderline to severe. Nobody was a computer user, although six had had training. There were no references to any studies on intellectual disabilities, except for definitions.

File Drawer Effect

Inferential statistical analysis begins with a null hypothesis, i.e., there is no difference between two groups. Traditionally, if the results of statistical tests failed to reject the null hypothesis, the research was not considered to be of publishable quality, so was relegated to the bottom drawer of the researcher's desk (Rosenthall, 1979, as cited in Krathwohl, 1998, p. 558). While not *every* book and paper (e.g., Henderson & Ferreira, 2004), but most papers and books written on eye-tracking cite Yarbus (e.g,, Henderson & Hollingsworth, 2003; Duchowski, 2007; Noton & Stark, 1971). Lipps and Peltz (2004) was the only instance of a published replication I could find, which was published only as an abstract, noting that the results were similar to those of Yarbus, but the patterns were not as distinct. Another replication (Cunningham, 1998), was listed as a senior research project using new eye-tracking technology. However, considering the bottom drawer or file drawer effect, it may have been replicated many times without finding differences. Pieters and Wedel (2007) applied Yarbus' theory to advertising by hypothesizing that the goals suggested by Yarbus vary in terms of the attention required.

Lack of Ecological Validity

Traditional visual search experiments (Serna & Carlin, 2001) have been conducted in the laboratory using simple shapes (i.e., circles, triangles) as stimuli. The participant, for example, might be asked to identify those shapes that are a particular color and displayed in an array, as quickly as they can and without making a mistake. The colored symbols may "pop out" automatically or the participant may have to define and execute a serial search strategy to seek out shapes that are different. This has been often graphed as either a parallel line indicating pre-attentive effort or a line with an increasing slope, indicating attentional effort. The participant has been subjected to multiple trials, with two critical variables being manipulated – the number of stimuli present and the size of the array, usually between 2 and 32. One of the criticisms to this type of research has been that it is not ecologically valid, meaning it may not be representative of what happens in the real world (Benjafield, 2007, p. 32). A traditional cognitive psychology study (Carlin, Soraci, Goldman, & McIlvane, 1995) suggested that people with intellectual disabilities are not sensitive to saliency features other than orientation and color (e.g., form and size) in the pre-attentional stage of vision processing. By incorporating naturalistic (i.e., real-life) pictures of various types, including commercial and educational Web sites, this current study was more ecologically valid.

Minimal Use of Technology

This study made use of current eye-tracking technology and vision modeling technology. A search in the intellectual disabilities literature yielded only one paper on eye-tracking since 2000 and it was used only as a supplement to explain results of the study, rather than the being the basis of an experiment. Given the theory of selective attention (Broadbent, 1958, as cited in Duchowski, 2007) vision models have been implemented as software (Itti, Koch, and Neibur, 2003; Walther & Koch, 2006), but the literature on the models has been generally focused on improving them at this point, using only a very few participants and many images, rather than applying the models to solve problems, as has this study.

Intellectual Disabilities Literature

Meta-Analytic Findings

Kavale and Forness (1992) reported the results of a meta-analysis study of 268 studies on intellectual disabilities in the areas of learning difficulties and memory published within the previous twenty five years. Meta-analysis, a research approach which started in the field of education, is a quantitative methodology that compiles the results of many similar studies to arrive at more general conclusions, based on the Effect Size (ES) Statistic. "Cohen (1988) stated that an ES of 0 indicates no effect of treatment, ES = .20 indicates a small effect of treatment, ES = .50 indicates a medium effect of treatment, and ES = .80+ indicates a large effect of treatment" (Erford, 2008, p. 66).

The authors identified 462 studies initially, demonstrating that literally hundreds of studies had been done during the period on intellectual disabilities. Fifty-five percent of the studies included came from the *American Journal on Mental Retardation* (now called the *American Journal on Intellectual and Developmental Disabilities*). The authors stated:

> An enormous amount of research was conducted between the 1960s and 1980s on the cognitive abilities of people with mental retardation. Very little of this research is being conducted now. Did it serve any purpose? The answer to this question is an emphatic "yes." Before this research was conducted people with mental retardation were seen as incapable of learning even the simplest of material. The cognitive research boom of the last forty years has shown unambiguously that people with cognitive disabilities are capable of learning even remembering the most complex materials…..if it was so successful why isn't it being done? … The identification of deficits may require the coordination of the underlying biological processes with behavior measures and we believe this is the direction that research on mental retardation is headed. (p. 146 -147)

Kavale and Forness (1992) categorized and summarized the results by theorists, including Ellis, Spitz, Zeaman and House, Denny, and Baumeister. There were 172 studies involving the comparison of individuals with and without intellectual disabilities. General results indicated that performance by participants in studies based on Baumeister (ES = -.261) and Denny (ES = -.293) performed best, indicating that about 40% of those participants performed at the level of participants without intellectual disabilities. Studies by Zeaman and House (ES = -.681) and Ellis (ES = -.601) demonstrated poorer results for participants with intellectual disabilities with about a third performing as well as participants without intellectual disabilities.

Very Short Term Memory

Of particular interest to this study was the theory of Norman Ellis that recognized the existence of a Very Short Term Memory (VSTM), which is the sensory representation of the stimulus event (Kavale & Forness, 1992, p. 179). This construct, very short term memory, was critical to the theory underlying the fissure between the Stark (Noton & Stark, 1971) and Henderson (2003) views in the scan path/pattern theory in the eye-tracking literature.

Detterman, Gabriel, and Ruthsatz (1982, p. 144) in a history of intellectual disabilities research noted that Ellis proposed a model that consisted of a series of memory stores (very short term memory, primary memory, secondary memory, and tertiary memory) and a perpetual- attention process which allowed information to be passed from very short term memory to primary memory whereas rehearsal allows the maintenance of secondary memory. A current view (Galotti, 2008, p. 151), the modal model of memory, allows for sensory memory (similar to VSTM), short-term memory (STM) for periods of 20-30 seconds, and long-term memory. Ellis' secondary and tertiary memory types are aligned with long-term memory (Detterman, et al., 1982).

Other researchers tried to find out whether individuals who had intellectual disabilities were affected by one or more of these memory stores or the processes. Very short term memory (VSTM) has a very short duration and is important in the area of visual attention. Two types of studies have been used and studied with both Chronological Age (CA) and Mental Age (MA) participants. One type delivers the stimulus, but immediately cues the individual to attend to only a portion. Delayed times by people who have intellectual disabilities has been interpreted to mean that they have impaired VSTM. The other type of study is a masking effect where part of the stimulus is masked and the participants with intellectual disabilities are not able to recall the stimulus as well as the participants without intellectual disabilities. Overall, the information points to a deficit in VSTM. However, tests of Primary Memory where people are given a list of items and asked to recall the last few items on the list have demonstrated no difference between people who have intellectual disabilities and others and it is generally accepted that there is no difference between people with and without intellectual disabilities in the area of Primary Memory, aligns with short-term memory in the modal model of memory, however this finding is questionable (Detterman, et al., p. 144-145).

Chronological versus Mental Age

An issue in the intellectual disabilities literature is whether participants should be compared with others who are the same chronological age (CA) versus mental age (MA) (Kavale & Forness, 1992, p. 212).

The results of the meta-analysis were that overall, participants who had intellectual disabilities performed at a lower level than participants without intellectual disabilities irrespective of whether the participants were CA or MA, but MA performed higher than CA with three exceptions. Those were in the research of Ellis, whose CA subjects performed better (ES = -.523) than MA matched subjects (ES = -.668), where CA (ES = -.470) performed better than MA (ES = -.357) in serial learning tasks, and CA (ES = -.256) matched subjects across tasks exhibited fewer errors than did MA (ES = -.589) matched subjects. Of the 138 studies by Norman Ellis, 114 were done with CA participants. This study used chronological age.

Pre-Attentive and Attentive Processing

Attention processing of visual information in adolescents with intellectual disabilities has been categorized into two types of processing (e.g., Broadbent, 1977, as cited in Merrill, 2005). The first type is *pre-attentive* processing (Merrill, 2005), which has an unlimited capacity that is capable of processing stimuli in parallel and supports low level visual stimuli such as feature detection, color, orientation, or size. The second type was *attentive* processing, which is serial, but which requires allocation of attention, but does enable detailed analysis and synthesis of information. The cognitive systems which support both *pre-attentive* and *attentive* processing develop in infancy but the development of attentive processes continues into adolescence. Studies of adolescents and young adults of the same chronological age (CA) with and without intellectual disabilities that were associated with attentive processes show more differences than studies that involve *pre-attentive* processes. Merrill stated that there was a small amount of research which does not support this conclusion. Noting research which has identified differences in times for people with intellectual disabilities to encode sensory information, e.g., two studies which found a time difference of 100 ms; one where participants were required to encode pictures for the purpose of matching physical identity and another an activity to determine which of two lines were longer. Both of these studies matched subjects with CA and MA. However, lack of standardization in the field of intellectual disabilities makes it difficult to compare results according to Merrill.

Most Recent Research

Recent research (Roskos-Ewoldsen, Conners, Atwell & Prestopnik, 2006) examined mental imagery capabilities of young adults with and without intellectual disabilities coming to the conclusion that it took the students with intellectual disabilities longer to learn, but indicated no deficits in image inspection. Another study (Carlin, Soraci, Goldman, & McIlvane, 1995) compared 16 adult subjects with intellectual disabilities (average age of 27.5 years) and 16 without intellectual disabilities (average age 19.5 years) of in terms of their ability to search symbols which varied in terms of color, form, size, and line orientation (vertical or slanted).They came to the conclusion that the features color and line orientation were intact for people with intellectual disabilities, but not for form, and size. They found that individuals with intellectual disabilities responded more slowly, but the times didn't vary by the number of symbols, indicating that the processing was in parallel for both groups, thus indicating that the processes involved in "speeded visual search" were intact for people with intellectual disabilities.

A third study (Carlin, Soraci, Strawbridge, et al., 2003), was the closest to this study in that it used naturalistic scenes and supplemented the basic study with eye-tracking, although it dealt with change detection and use of the flicker paradigm (Resnick, O'Regan, & Clark, 1997), rather than the scanpath. People without disabilities often fail to notice changes in every-day scenes, called change blindness. However, by sequentially offering study participants two versions of the scene – one with and one without the change, the scene appears to flicker and the change can be seen. This study used naturalistic scenes with changes in color, presence or absence of features, and form, (e.g., the presence or absence of a window frame on the side of a house). They found that people with intellectual disabilities took longer to locate the change, spent more time viewing the center of the scene at the beginning and there was a difference between the group with and without intellectual disabilities with respect to detection of changes in the marginal areas. The study included a pre-test and participants who could not perform the pre-test were excluded. Only 21 out of 28 participants who had intellectual disabilities completed the study. Six subjects participated in an eye-tracking effort that indicated that people with intellectual disabilities viewed the middle of the picture longer than those without intellectual disabilities.

In summary, these recent studies suggested that, for people with intellectual disabilities, compared with those without intellectual disabilities of the same chronological age, there was no difference in their behavior with respect to color and orientation. There was however, a difference for size and form and, as well, the visual pre-attentive phase was delayed by 100 ms, suggesting impaired VSTM.

Vision Science and Eye-Tracking Literature

Introduction

There was no authoritative or general agreement on the definition of Vision Science, except that it is a multi-disciplinary field. An example of a broad view of vision science definition is the following:

> Vision Science is an exciting and expanding field at the crossroads of modern biology, neuroscience, physics, optics, bio-engineering, chemistry, psychology, epidemiology, and optometry. Investigators in Vision Science conduct human and animal research and modeling, yielding cutting-edge discoveries and applications in disciplines that include molecular genetics, clinical care, adaptive optics, neurobiology, cell biology, infectious disease, bioengineering, perception, and public health. (University of California at Berkeley, n.d.)

Another example of a definition is the following:

> Vision science is the science dedicated to the interdisciplinary study of visual perception and the visual system. Vision scientists study various aspects of vision from the perspectives of cognitive psychology, neuroscience, computer science, psychophysics, and ophthalmology. (Wikipedia, 2007)

This study referenced research results from vision science in the areas of cognitive psychology (visual attention and visual perception), computer science, neuroscience, and optometry. Eye-tracking technology has been a tool used in vision science. Duchowski (2007) reviewed the history of visual attention research and tied Yarbus (1967) to the scanpath theory (Noton & Stark, 1971).

Scanpath Theory

Stark, in an interview (Kreisler, 2000), described the important findings of his research. Asked to explain how the eye sees, or the mind's eye sees, and how this was done through his scan path theory. Stark explained that the eye makes around a million very fast movements a day called saccades. He started by viewing how people look at different pictures. He noted that people had done a lot of scene analysis already; but they didn't have the advanced equipment he had. He and a colleague noticed a person would look at five or six important points in the picture and then return later and again look in almost the same order those same five or six points. He called this the "scan path eye movement," which became the "scan path theory." He said that people naively think that they are seeing the picture with their eyes, but, in fact, they are only seeing a few points and the picture is actually in the brain, "the mind's eye." The schema, this 'internal spatial cognitive', which is the knowledge model in the brain, is actually driving the eye movement; the eye is picking up critical information; "the last thirty years we've done a lot of experiments to try to prove that beyond a doubt." People looking at the same picture may share the points, but they do not look at them in the same order. Like a fingerprint, people looking at different pictures will have different sequences and will look at different regions. He likened the eye to a TV camera. The retina, in the back of the eye picks up signals, but the high resolution component of the retina is the fovea. If we hold up a newspaper, we have the illusion that we can read it, but in fact the fovea has to be directed to a particular word to actually read it.

The Glimpse

John Henderson (2003) reported that the scan path theory was not accurate for two reasons. First, Stark's theory suggested that a memory of the scan pattern (Henderson's preferred terminology) was captured for each fixation, eye movements that stabilize the retina over an area of interest (Duchowski, 2007, p. 46), in a scanpath, so to allow the scanpath to be repeated. "It suggests that the subject's internal representation or memory of the pattern is an alternating sequence of sensory and motor memory traces, recording alternately a feature of the pattern and eye-movements required to read the next feature" (Noton & Stark, 1971, p. 310). Second, that research on the glimpse indicated that the gist of a scene was captured very quickly once in the first fixation and stored in conceptual short-term memory (Potter, 1999) rather than being re-structured every time a fixation occurred. Research grew out of the discovery that a very quick glance at a picture enabled people to get the gist of a scene, which provides both a perceptual and a conceptual view, including semantic information within 100-300 ms. Potter used a technique she called RSVP (rapid serial visual presentation) of pictures to simulate the way the eye sees – like a series a series of snap-shots, showing pictures at about 1 every 2 to 9 seconds, followed by a recognition test of the pictures. Researchers now believe, supported by primate research, that the conceptual view, called a saliency map, is stored in the primary visual cortex (Li, 2002).

Different viewers tended to fixate on similar regions, but the sequence over those fixations for an individual is highly variable (Mannan, Ruddock & Wooding, 1995). Mannan, Ruddock, and Wooding (1996) reported that for a brief (1.5 second) of a picture, there was considerable similarity between the viewer's fixations, but more variation with 3 second intervals, leading them to propose that examination of an unfamiliar image is performed automatically in response to the images' spatial features.

A well established principle has been that vision is suppressed during a saccade (e.g., Yarbus, 1967, p. 144). People see snap-shots made at a fixation, each lasting about 300 ms (Buswell, 1935, as cited in Henderson & Hollingsworth, 2003, p. 58). They studied reactions of participants to changes made to scenes to understand how the brain compiles the snapshots. While people were reviewing a picture they removed an object during a saccade and varied it between whether the saccade happened before the fixation or after the fixation. The results of the study indicated that people better detected the deletion when the deleted object was the target of the saccade, rather than when the object had just been fixated, implying the brain already knew the contents of the picture before the fixation occurred. Also, saccade target deletions were better detected than either saccade target type or token changes (e.g., changed a phone to a notebook).

Recent interest in the scanpath theory (e.g., Foulsham & Underwood, 2008) has begun to give credence again to the scanpath theory, by suggesting that the repeated viewing of the same pattern by people may be explained by the saliency of the objects, not top-down effects.

Mathematical Modeling of Vision

Vision research on attention, in general, has consisted of two approaches – the top-down approach which explains the processing of scenes via cognitive processes (e. g., Yarbus, 1967; Noton & Stark, 1971) and the bottom-up approach which explains viewing of scenes via automatic processes in reaction to the saliency of the scene. Mayer and Moreno (n.d.) define saliency as having a quality that thrusts itself into attention. Saliency applies to the objects in the scene itself (e.g., Parkhurst, Law, & Niebur, 2002). "With a few possible exceptions, both impact a visual episode" (Egeth & Yantis, 1997). Mathematical modeling of scan paths started with perhaps the easier of the two, the bottom-up approach and has progressed to models which include both bottom-up and top-down approaches (e.g., Cerf, Frady, & Koch, 2008), which, as theory would predict, come closest to predicting an actual scan path.

Saliency features in scenes include contrast, color, orientation, texture, and motion (Oliva, A. et al., 2003). The filter theory of selective attention (Broadbent, 1958 as cited in Duchowski, 2007, p. 6) has been the starting point for the development of biological models of vision (Itti, Koch, & Niebur, 1998). This computer model creates a three dimensional saliency map with a numeric value for saliency for every point on a picture. The Itti model (2008) which was implemented in C++ code, has been used by many studies, but generally adapted in some way or another for each study. For example, Cerf, Frady, and Koch (2008) added a facial recognition algorithm (Viola & Jones, 2001), which is widely used to improve prediction. A facial recognition study used the Itti model as a standard to compare the scanpaths of people with and without autism (Neuman, Spezio, Piven, & Adolphs, 2006).

More recently the Koch Lab at the California Institute of Technology has implemented the model again using the MATLAB language and its Image Processing Toolbox to create the Saliency Toolbox (Walther & Koch, 2006) which runs faster because the number of lines of code is significantly reduced from the C++ version, has a graphical user interface and will run on any operating system which supports MATLAB, including Windows. It creates areas of saliency which are associated with shapes of objects, rather than simple circles, as does the Itti model. This software takes a digital image as an input and generates areas of interest, as well as allowing for weights. The main difference is the Walther model finds the most salient object and point, then the next most salient point and object, and so on rather than producing a map which determines the saliency at every point. This radically reduces the computing resources required. Both models objectively generate Areas of Interest, based on saliency. Note the circles around parts of the balloons in *Figure* 1. These are examples of areas of interest.

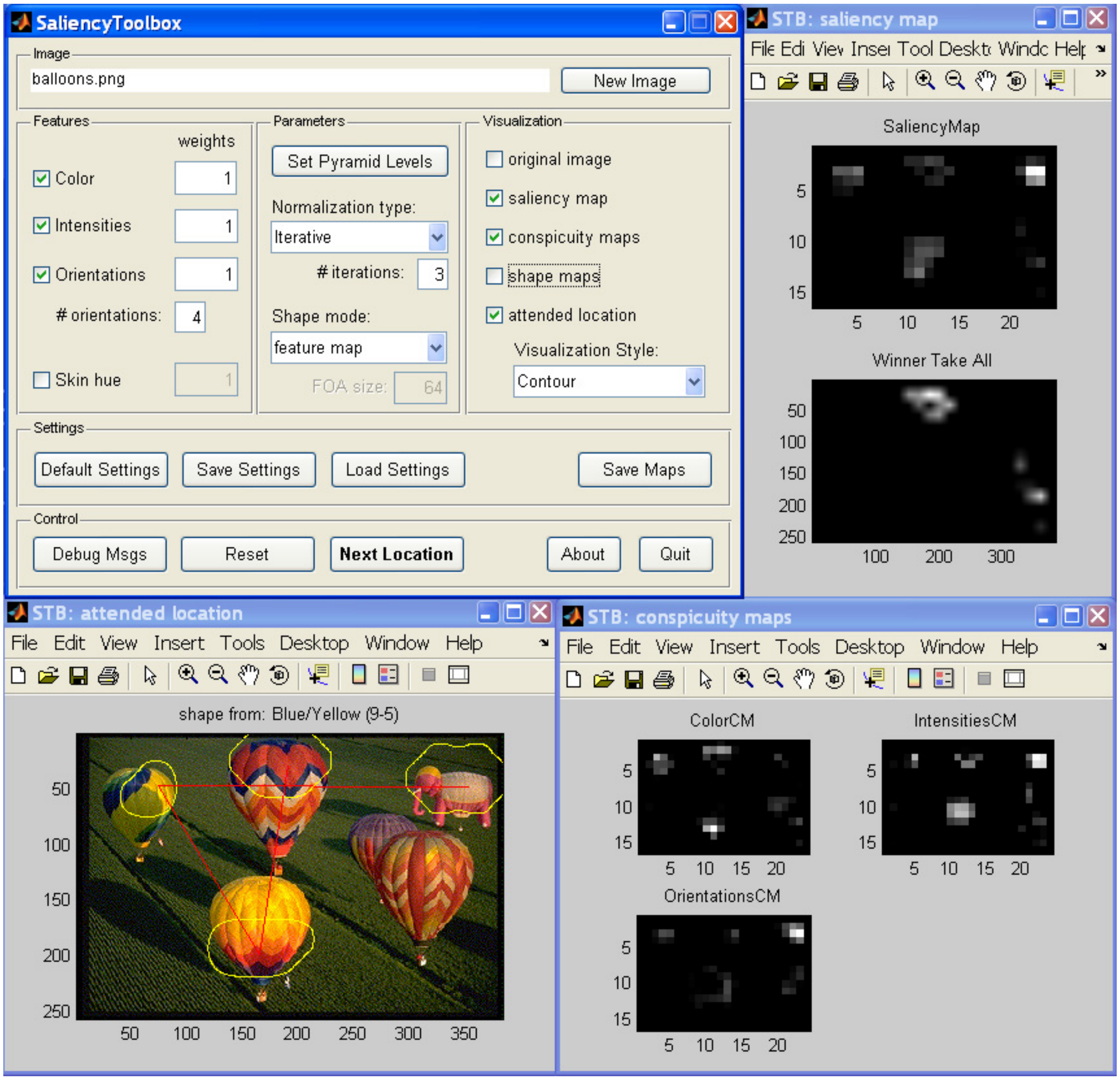

Figure 1. Saliency Toolbox 2.1 graphical user interface (Walther, 2007)

Specific Research Relevant to the Topic

The Top-Down Approach

Yarbus' eye-tracking apparatus required use of an anesthetic on both his patient's eyes in order to apply, via suction, a contact lens with a small mirror attached to it. He also tied back the patient's eye-lids. He said that no experiment should exceed a few minutes (p. 29). He noted that all the observers were well educated, cultured, and familiar with Repin's work and the epoch (Yarbus, 1967, p. 192). He made seven records of scan paths for each of his seven participants with one or two days apart, presumably for their eyes to recover, as they viewed the famous picture by Ilya Evimovich Repin, "The Unexpected Visitor." They were first requested to do a

> Free examination of the picture. Before the subsequent recording sessions, the subject was asked to: …estimate the material circumstances of the family in the picture; give the ages of the people; surmise what the family had been doing before the arrival of the "unexpected visitor"; remember the clothes worn by the people; remember the position of the people and objects in the room; estimate how long the "unexpected visitor" had been away from the family. (p. 174).

Figure 2. The Unexpected Visitor by Ilya Evimovich Repin

Yarbus' results include the diagrams of the seven scan paths produced by one of the participants.

EYE MOVEMENTS DURING PERCEPTION OF COMPLEX OBJECTS 173

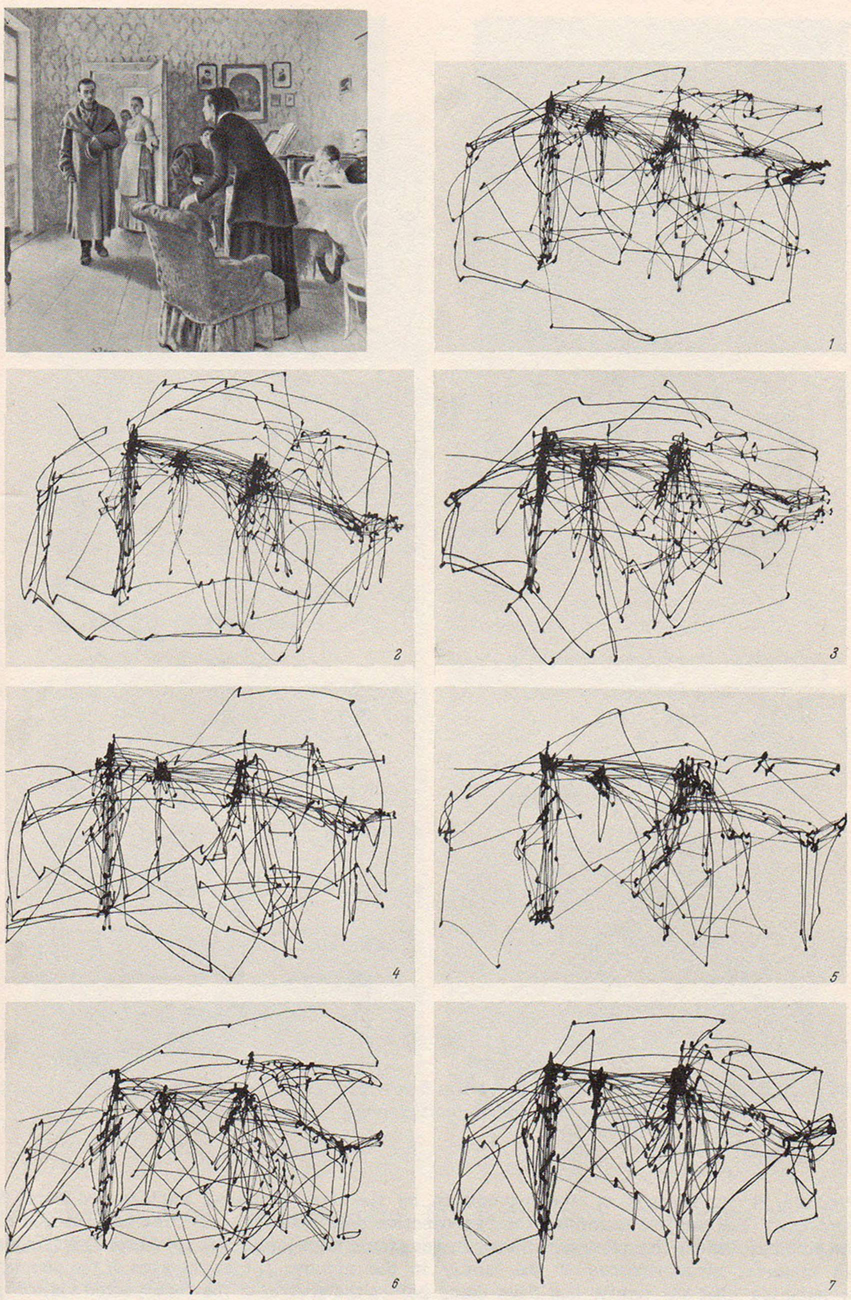

Fig. 108. Seven records of eye movements by the same subject, examining Repin's picture freely with both eyes. The records, arranged in chronological order, lasted 3 minutes. The interval between records was 1 or 2 days.

Figure 3. Yarbus (1967) eye movements by same subject, used with kind permission of Springer Science and Business Media

In addition, he analyzed the scan path of one of the participants by taking a picture every 5 seconds, by quickly removing the sheets of photosensitive paper, noting that all of the significant features were examined within 25 seconds and in subsequent cycles, the same features were examined again. He noted that the scanpaths for a single question across participants were similar and attributed that to the similarity in the backgrounds of the people in the study.

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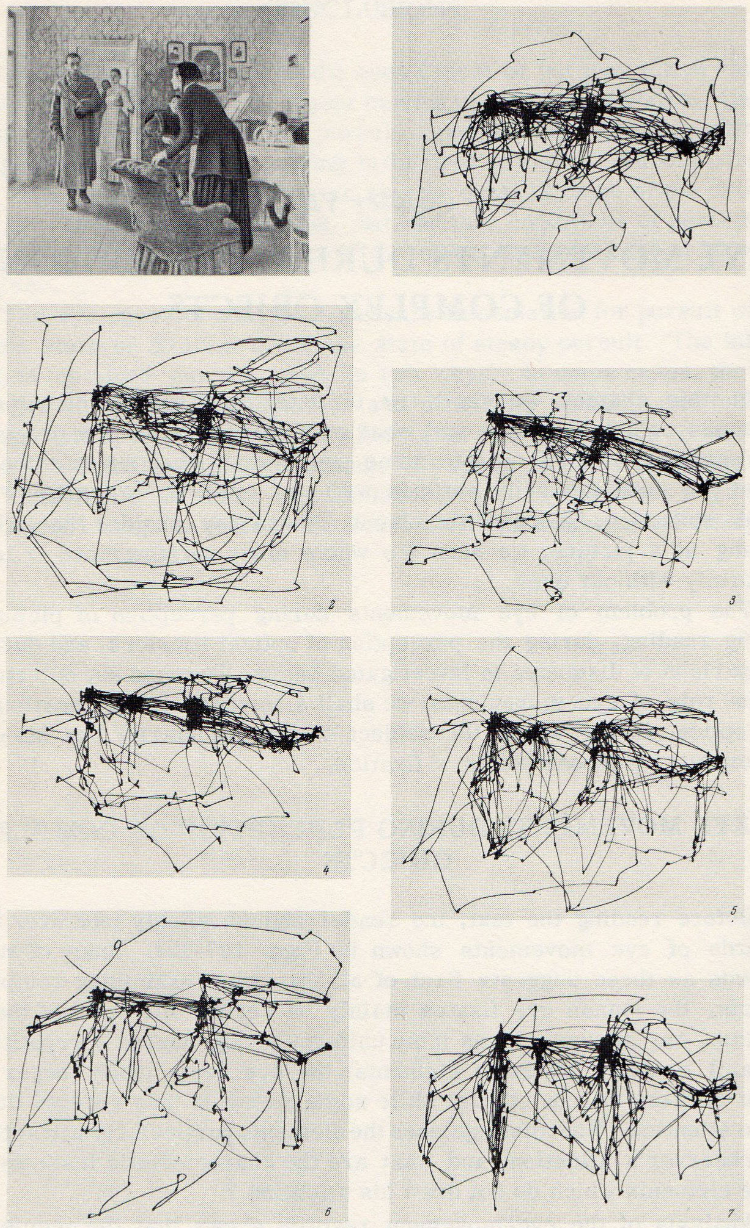


Fig. 107 Reproduction from I.E. Repin's picture "An Unexpected Visitor" and records of the eye movements of seven different subjects. Each subject examined the picture freely (without instruction) with both eyes for 3 minutes.

Figure 4. Yarbus (1967) eye movements by seven subjects, used with kind permission of Springer Science and Business Media.

Yarbus did not state whether or not he actually asked his participants to answer the question or demonstrate that they could remember a location. Neither did he share the age, gender, ethnicity, or occupation of his participants, or whether they were paid or blackmailed to participate. He did, however, say they were cultured and highly educated. He attributed the similarity of scan paths for the same question across people to their cultural similarity. Lipps and Pelz (2004), noting that 3 minutes was an extraordinarily large amount of time to look at a single picture and the likelihood that the apparatus was painful to wear, replicated the study with 20 participants, who viewed a large version of the picture for a self-paced time, using current, non-invasive eye-tracking technology. They achieved the same results; scan paths were definitely task dependent but the patterns were less dramatic than those produced by Yarbus. Yarbus spread the questions over a period of one to two days to allow his participants' eyes to recover, but it also may have "cleared their minds" for a new question, resulting in more distinct patterns.

Pieters and Wedel (2007) analyzed the seven goals by Yarbus and categorized them. They stated that Yarbus' thesis was that the informativeness of particular objects in a scene was dependent on the goal. Reviewing Yarbus' diagrams, it can be seen that when asked to estimate the ages of the people, there are fixations on people's faces, but when asked about economic circumstances the fixations are on the furniture. They hypothesized that attention is greatest for learning goals, intermediate for evaluation goals, and least for free-viewing.

Reviewing the questions, they were categorized as:

Question Type 1: Free Viewing

Question 1: Look around the picture.

Question Type 2: Evaluative

Question 2: Try to understand how rich or how poor the people are.

Question 3: How old are the people in the picture?

Question 4: What were the people doing before the unexpected visitor came?

Question 7: How long do you think the visitor was away?

Question Type 3: Learning

Question 5: Remember the clothing the people are wearing.

Question 6: Remember where the people and objects are in the room.

From their 1992 eye-tracking literature review on scene perception, Rayner and Pollatsek reported that the average fixation time for reading studies was 225 ms, for scene perception studies, 330 ms, and for visual search 275 ms. In addition, they noted that there was considerable variation in fixation lengths, 200 to 225 ms for some individuals, but others on the order of 400 to 425 ms. They agree that global information is fixated on in at least the first two fixations and useful information is extracted from the picture only if it is fixated on. We know from studies in the intellectual disabilities literature that people with intellectual disabilities take longer than people without intellectual disabilities to accomplish tasks, so the hypothesis was that people with intellectual disabilities will fixate longer than those without disabilities. However, the hypothesis of interest is whether people with and without intellectual disabilities differ in the way they allocate attention by measuring the proportion of total time spent on each of the seven questions to see if the two groups are different. Considering the two groups as different cultures we would expect differences.

Bottom-up Approach

An important example of a "bottom up" approach was the study by Parkhurst, Law, and Niebur (2002) that used a model (Itti, Koch, & Niebur, 1998) to demonstrate that the model predicted a scanpath much better than chance for the first few fixations. They defended its use by referencing six studies that used the model during the 1990s and stated "Indeed, converging evidence from neuro-physiological and neuro-anatomical studies suggest a plausible neural implementation of the two-stage model in the primate visual cortex" without a reference. Broadbent's model was actually a model of auditory attention (Duchowski, 2007), but the concepts of parallel channels (i.e., two ears) and filtering are incorporated in the standard model used by researchers in the field, based on a biologically plausible model, using color, intensity (i.e., contrast), and orientation and produces a three dimensional graph with "mountains" of saliency for the first pass and then chooses the most salient in local regions for subsequent analysis. Parkhurst, Law, and Nieber credited Egeth and Yantis (1997) for providing timings showing that top-down effects took more time to affect the scan path, so they expected prediction of only the first and second fixations. They had four participants, not identified by any disability, who were students at the university, and showed the students digitized scenes from three data bases (home interiors, natural landscapes, buildings and city scenes); the fourth type was fractals that were computer generated. Participants were told "look around the images." The screen displayed the fixation cross, the students were required to fixate by clicking on the cross and they viewed each picture in the database for 5 seconds. The results of the first round indicated some issues with sensitivity to high spatial frequency in the periphery, so the model was modified. The final results indicated the stimulus salience correlated much better than expected by chance and, as they had hypothesized, the best correlation occurred just after stimulus onset, specifically the first four fixations.

This study is of interest to this current study because it used three types of naturalistic scenes of different types, which were more representative of pictures that might be used in online instructional materials. Unfortunately, the paper did not reference the source of the pictures and a follow-up with the key authors was unsuccessful in locating the pictures.

Scanpath Analysis

Scan path analysis does not calculate time; only the order of fixations between areas of interest. There have been at least four methods of quantitatively determining the differences between scanpaths (West, Haake, Rozanski, & Karn, 2006). The string edit algorithm is the easiest. Consider a scan path is identified by the four Areas of Interest (AOI), with names A through D. Considering up to four fixations, assuming 16 people (i = 1 to 16) for each of two types, with and without intellectual disabilities, (j = 1, 2) reviewing the pictures (k = 1 to 30) researchers can compare Picture (i, 1, k) to Picture (i, 2, k) using string analysis for the comparison. String analysis (Privitera & Stark, 2000) is easiest to understand using a simple example. If the first scan path passed through ABCD and the second scan path passed through ABDC, then the similarity value would be 1, because each passed through the same AOIs. If the first one was ABCD and the second one was ABAB, then a series of operations would be applied to the first string to make it like the second string. The operations allowed are deletion, insertion, and substitution. In order to make the first string like the second, A would be substituted for C, and B would be substituted for D, for a cost of 2. The similarity would be calculated as (1 – 2/4) = .5. One of the limitations of this methodology is that someone has to determine, a priori, what the areas of interest actually are, so a path can be determined from one area to another. Mackworth and Morandi (1967) divided the picture into a grid, implicitly labeling each an AOI and calculated the percentage of amount of time spent in each cell of the grid. The only study in the Intellectual disabilities literature that used eye-tracking used this technique (Carlin, Soraci, & Strawbridge, et al., 2003). Because this method can possibly misrepresent a real area of interest which spans two cells in the grid, Antes (1974) used the density of eye-tracking data to identify areas of interest and chose to use 20 students from the psychology pool to rank the regions in terms of how informative they were, prior to doing his study. He used students from the same pool to do his study except for those who wore glasses (who were not supported by early eye-tracking equipment) and threw away the first fixation, assuming it was randomly determined.

Mathematical models of vision called saliency models were used to determine areas which represent high saliency and objectively identify the Areas of Interest for bottom up studies. Foulsom and Underwood (2008) compared the first five fixations of scanpaths of people looking at the same complex scenes twice, the second time randomly repeating the pictures, but adding a few new ones. They compared the scanpaths using three different methods, dividing up the scenes into a grid and using a string-edit approach, a distance approach which calculated the mean linear distance between a fixation in one scanpath with the closest one in the other scanpath (Manning, Ruddock, & Wooding, 1995) and third comparing the scanpaths to that generated by the Itti model. They found that the model predicted the scanpath of the new pictures better. They reiterated that the results were similar to those from previous studies (e.g., Parkhurst, et al.) showing that the model was a “reliable way of identifying areas likely to be fixated,” but cautioned that the model was not highly predictive of human scanpaths.

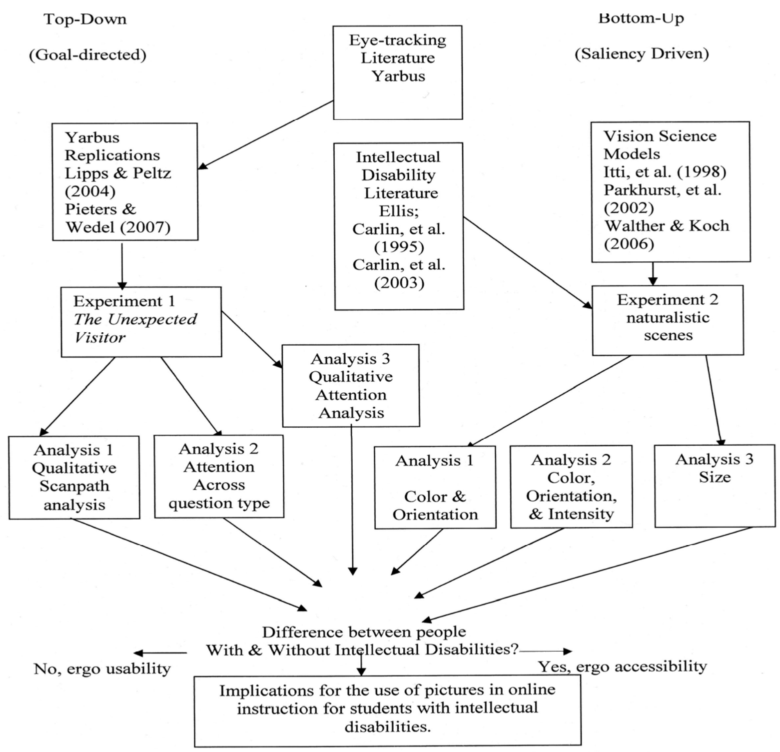


Figure 5. Conceptual framework for visual attention

The experimental design started with the two approaches to studying visual attention – the top-down or goal approach (Experiment 1) and the bottom-up or saliency driven approach (Experiment 2).

A review of the vision literature identified Yarbus (1967) and his classic study on the goal approach. Yarbus's study implied that cultural similarities or differences affected scan paths. There have been many cultural studies to support this (e.g., Qutub, 2008). Yarbus described his participants as cultured, well educated people who were very familiar with *The Unexpected Visitor*. People with and without intellectual disabilities could be viewed as having a cultural difference.

A review of the Intellectual disabilities literature pointed to two areas where people with and without intellectual disabilities were different. First, Ellis (Detterman, Gabriel, & Ruthsatz, 1982, p. 144) identified deficiencies in the area of VSTM, very short term memory. This is activated in the first few eye-fixations. Second, Carlin, Soraci, Goldman, and McIlvane (1995) found that people with intellectual disabilities recognized color and orientation in visual searches, but not form and size.

Recent literature in the vision field supported both attentive and preattentive areas and suggested the design of two experiments, each with three analyses, all of which used at least 16 participants with and at least 16 participants without intellectually disabilities. A qualitative component was also included to better understand differences between the two groups. An output of each study was the answer to the question: Are people with intellectual disabilities different from people without intellectual disabilities?

Experiment 1

Analysis 1, Qualitative Scanpath Analysis

Lipps and Peltz (2004) replicated the Yarbus (1967) study, allowing participants to reduce the time to view the picture. The first experiment was a replication of the Yarbus study with people able to choose, up to three minutes how much time they took to answer each question. By reviewing the scan paths, cooperating and independent reviewers decided whether they were different or the same for each person and determined whether the scan path diagrams represented the scanpaths of a person with or without intellectual disabilities.

Analysis 2, Attention Across Question type

Pieters and Wedel (2007) viewed the questions Yarbus asked in terms of three types and hypothesized different levels of effort for each type. By adding the time of all the fixations and allocating the time across the different types, we were able to determine whether there were differences between people with and without intellectual disabilities for both proportion and average time per question type.

Analysis 3, Qualitative Attention Analysis

After the student viewed *The Unexpected Visitor*, the researcher asked the same questions again and recorded student responses, providing a qualitative means of understanding differences. By analyzing the responses in terms of word volumes and recollection of key elements in the picture, differences between students with and without intellectual disabilities were identified.

Experiment 2

Analysis 1, Color and Orientation

Parkhurst, Law, and Niebur (2002) conducted a study using the Itti, Koch, and Niebur (1998) model of vision, that Itti (2000) implemented using C++, maintains, and makes available to researchers. This model is very large and requires a robust system, but does calculate saliency at every point on a digital picture. This was a feature used by Parkhurst, et al. (2002). Using a different model (Walther & Koch, 2006), Walther (2007) implemented a more computationally conservative approach using MATLAB on a Windows system. The model focuses on salient objects rather than points, but both models performed the same function in the sense that they used a digital picture as input and used a consistent set of rules to determine salient areas (Areas of Interest). The Walther and Koch (2006) model afforded the opportunity to test most of the results of Carlin, Soraci, Goldman, and McIlvane (1995), who concluded that color and orientation features are intact for people with intellectual disabilities, but not size and form. The model has supported three types of saliency: color, orientation (line), and intensity (contrast). This experiment used color, orientation, and size, but not form, which couldn't be demonstrated. Because the study concerned saliency, only the first four fixations were of interest. The pictures were displayed at a rate of one every five seconds, each being prefaced with a one second simple calibration screen followed by the picture for three seconds and followed with a one second blank screen which allows the separation of pictures and is consistent with the approach of the Potter (1999).

Analysis 2, Color, Orientation, and Contrast

Experiment 2 Analysis 2 was exactly the same as Experiment 2, Analysis 1, except the Walther and Koch model is configured to use all three saliency types (color, orientation, and contrast).

Analysis 3, Size

Experiment 2 Analysis 3 analyzed the maximum number of fixations common to all participants, collected for one of the images in the study – a mother and baby elephant to compare the saliency type of size for the two groups.

3. Methodology

This was a mixed method study with both qualitative and quantitative analyses. Primarily quantitative using both parametric and non-parametric statistics, the qualitative component involved both the researcher's observations of participant's responses during the interview and the comparison of scanpaths by multiple independent reviewers to determine whether scanpaths were similar or different. The research is supported by two technology components – a model of human vision and an eye-tracking system. The research questions addressed were:

1) Do individuals with and without intellectual disabilities exhibit goal-directed behavior when viewing an image of a complex scene?
2) Is there a difference between people with and without intellectual disabilities in viewing images of naturalistic scenes of different types?
3) Can the Walther (2007) model be used to study people with and without intellectual disabilities?

Participants and Setting

Planned participation was a minimum of 16 students with intellectual disabilities and a minimum of 16 students without intellectual disabilities.

Students with Intellectual Disabilities

The participants in this research were students in a four year post-secondary program for students with mild to moderate intellectual disabilities. The students were between 18 and 23 at the start of the program and were categorized as having mild to moderate intellectual disabilities. They varied in terms of their disabilities, including significant learning disabilities. In the fall, 2008 session they attended daily classes from 9:00 to 3:00 covering a wide range of academic subjects with emphasis on improving math, literacy, and life skills such as use of money and use of public transportation. Students had the option of living in a student residence. All students used Blackboard and the World Wide Web, although a few did not read. During the 2008-2009 year, there were 24 students in the program. This researcher was invited to present the research proposal and program at a parents' meeting in August, 2008 and students participated during the month of October, 2008. Twenty-three students volunteered to participate.

Participation in this study was voluntary, and required a Consent form signed by the authorized legal representative of the student, generally, the student's parent or legal guardian. In a few cases, the student was the authorized legal representative. In addition, there were two Assent forms available for use, one written at a 6th grade level and another simplified form requiring a lower reading level. In all cases, the assent and/or consent forms were signed at a meeting prior to the research session. In general, the simplified assent form was read to the student and the student signed the simplified assent form. Depending on the student, the sixth grade version was used to explain the consent process to the student and the student signed the 6th grade version. Although it had been planned to read the simplified assent form only to students who could not read, it was read to everybody to prevent any embarrassment. Both the students and the parents were provided with a copy of the forms (see Appendices J to O for copies of the forms approved by the George Mason University Human Subjects Board).

Students Without Intellectual Disabilities

George Mason students between 18 and 27 without identified intellectual disabilities comprised the control group. These students will be recruited by word of mouth on campus, using a prepared script as a Guideline (see Appendix O). They signed two consent forms and kept one of them.

All Students Participating in the Study

A gift of $10 was paid to all participants for one session which took under an hour. All participants were treated in accordance with the "Ethical Principles of Psychologists and Code of Conduct" (American Psychological Association, 1992). All participants were treated in accordance with the George Mason University policy on Research Subject Protection (Office of Research Subject Protections, 2008). For copies of the approved forms, see Appendices J to O.

Data Collection Procedures

Eye-Tracking System

The eye-tracking technology used was the Eye-Trac6000 system (Applied Science Laboratories, 2008). This system (ASL6000) places the optical components (60Hz), a camera, and near infrared light source on a chin rest which comfortably restricts movement of the participant's head. The system uses bright pupil technology to track the pupil and corneal reflections and is accurate for .5 to 1 degree of foveal angle, depending on the quality of the calibration. The other system components consist of a control unit, two lightweight LCD monitors, and a scan converter. The researcher added a 17 inch flat screen monitor placed 60 cm from the participant's left eye and two laptop computers, one for the stimulus (Dell Vostro 1500) and another to run the operating software (Dell Latitude D830 with built in RS 232 serial port). The addition of a large hard-sided photographer's carrying case to hold the basic system components, made the system portable. The researcher attended two days of onsite one-on-one training in Bedford, MA.

The ASL6000, like all eye-tracking technology, produced images of the scanpaths produced by the participants' eyes, optionally superimposed over the pictures they viewed. The data collected included, at a minimum, a record for each fixation, including the area of interest (defined by the researcher), the length of the fixation, and the coordinates of the fixation, which were adequate for this study. The system supported a large number of optional features, but default options were used in all cases. Reports and visual eye-tracking diagrams were produced by the system to facilitate data analysis (see Appendix X for all scanpath diagrams).

Eye-tracking Process

The general process for a research session was the following: The student was greeted at the door and provided a chair to store his or her gear. The "Do not disturb" sign was posted on the door. The student and researcher turned off their cell phones. The researcher assigned a number to the student and recorded it in a log which was stored in a locked desk and recorded the number on a sheet with the seven questions and space used to take notes.

The student sat in a chair and the researcher adjusted the chair and adjusted the chin rest until the student was comfortable. The researcher told the student to look at the five in the middle of the screen and that the first step was to get a good picture of their eye. The researcher viewed the LCD monitor and adjusted the camera. The researcher told the student that the calibration process was beginning and that the calibration took pictures of their eye. The researcher then told the student to look at each of the nine points on the calibration screen. This took a few minutes or more depending on the individual being tracked, but the time decreased over time after the camera was adjusted and the operator gained experience.

The researcher directed the student to the mouse, which was required for the first experiment and said to the participant, “You will be asked to answer questions. When you know the answer, click the mouse to go onto the next question.” The researcher initiated *The Unexpected Visitor* PowerPoint. If the student took a full three minutes on the first question, the researcher said, “Remember you can use the mouse to go to the next question.” This was done only once. After the PowerPoint ended, the student turned his or her chair around and the researcher asked the participant the same questions and recorded field notes on the sheet for that purpose. The researcher repeated the calibration process again prior to the initiation of the second PowerPoint presentation for the second experiment. At the end, the researcher thanked the student, answered any questions they had and paid the student for his or her participation. The student signed for receipt of the money. The whole process took as little as 20 minutes and as much as 50 minutes, depending on the student.

Experiment 1

Experimental Design

The research question addressed by this experiment is the following: Do individuals with and without intellectual disabilities exhibit goal-directed behavior when viewing an image of a complex scene?

With eye-tracking studies, goal-directed behavior is indicated by what people look at and how long they look at it. Both of these aspects were addressed in Experiment 1. Experiment 1 consisted of a replication of Yarbus' classic eye-tracking experiment (1967) with modifications suggested by a recent study (Lipps & Peltz, 2004), and an extension suggested by a very recent study (Pieters & Wedel, 2007). There were two groups – individuals with and without intellectual disabilities of similar chronological age, who were compared. In the qualitative component of the experiment, the seven scanpaths for each individual were analyzed to determine whether or not the scanpath varied depending on the goal. Ten raters, two cooperating raters and eight independent raters from a doctoral level research class used the Guidelines for Reviewing Scan Paths (see Appendix D) and the example from the original Yarbus study (*Figure* 3). They assessed whether the scanpaths were different or the same for each of 34 individuals and categorized whether they were produced by a person with or without intellectual disabilities. The Binomial test, a non-parametric statistic, was used to determine whether there were differences between the two groups and whether the determination of group type (with or without intellectual disabilities) was random or not. The field notes taken during the interview were transcribed and summarized by student and question for both the number of words used and major elements identified.

The quantitative component of the experiment used the average time in seconds the participant viewed the questions in each question type (Free viewing, evaluative, and learning), and the proportion of the overall time for each question type to test whether there was a difference between the two groups and whether that difference depended on the type of question (free viewing, evaluative, or learning). A 2 (group) x 3 (question type) ANOVA with repeated measures was used for the average time study and the proportion of time study.

The research project was planned to have two phases -- a pilot and a production phase. Replication of the Yarbus (1967) study was planned to confirm that the hardware and software configuration was performing correctly and, as well, establish a base line for the next experiment with students with intellectual disabilities. This approach was used. The camera was found to have been installed incorrectly and corrected. There were two additional minor modifications. The original plan was to display *The Unexpected Visitor* for up to three minutes and to require the participants to view it for 30 seconds. The plan was to have the student use the mouse to click to proceed to the next question. In testing of the experiment, the 30 seconds was found to be too long and students were clearly frustrated and distracted when they clicked the mouse and didn't get a response.

The minimum time was eliminated, making the conditions the same as those used by Lipps and Peltz (2004). The original study required each participant to view the picture for 3 minutes. Lipps and Peltz noted that the average time on the questions was about 1.5 minutes.

During the pilot period, the participants appeared to interpret the experiment as a memory test and were using the full three minutes for the questions, which was not the intent. In order to eliminate this behavior, the script was modified slightly during testing, which solved the problem. The script used was the following:

> Thank you for agreeing to participate in this project!
> You will be viewing a picture called the Unexpected Visitor. It was painted by Ilya Repin in 1884, so the picture is now around 125 years old. I will be giving you a task or question each time you see the picture. When you finish the task or know the answer to the question, click the mouse. This will take you to go to the next question. Please do not talk. At the end, you will tell me what you were thinking about. Thank you. Enjoy!

The language was simplified from Yarbus' original to accommodate participants with intellectual disabilities and the seven tasks were spoken and written on the PowerPoint slide prior to showing the picture for each task:

1. "Look around the picture."
2. "Try to understand how rich or how poor the people are."
3. "How old are the people in the picture?"
4. "What were the people doing before the unexpected visitor came?"
5. "Remember the clothing the people are wearing."
6. "Remember where the people and objects are in the room."
7. "How long do you think the visitor was away?"

At the last slide the participant heard the following:

"Thank you for participating in this project. It is OK to talk now!"

Data Sources

A 14 X 16 inch reproduction of *The Unexpected Visitor* was purchased from www.allposters.com and scanned into the computer with the maximum resolution supported by the scanner used. Because the flatbed on the Epson CX7400 scanner supports only an 8.5 X 11 inch page, a professional scanner was required, which was 600 dpi. Adobe Photoshop was be used to size the picture to fill the 17 inch flat screen and pictures were saved in format which were inserted into a PowerPoint presentation which controlled the display of the pictures and the recorded directions.

Data Analysis Procedures

Analysis 1, Comparing Scanpaths

The ASL6000 produced a scanpath for the eye movement for each person and question. A scanpath diagram, similar to those produced in Yarbus' original study, called the scanpath diagram was produced (see *Figure* 3). See *Figure* 6 for an example of a scanpath diagram for a person without intellectual disabilities and *Figure 7* for an example of a scanpath diagram for a person with intellectual disabilities. Creation of these diagrams entailed a detailed, multi-step process (see Appendix F). A single sheet of paper with seven scan paths was created for each participant in the study.

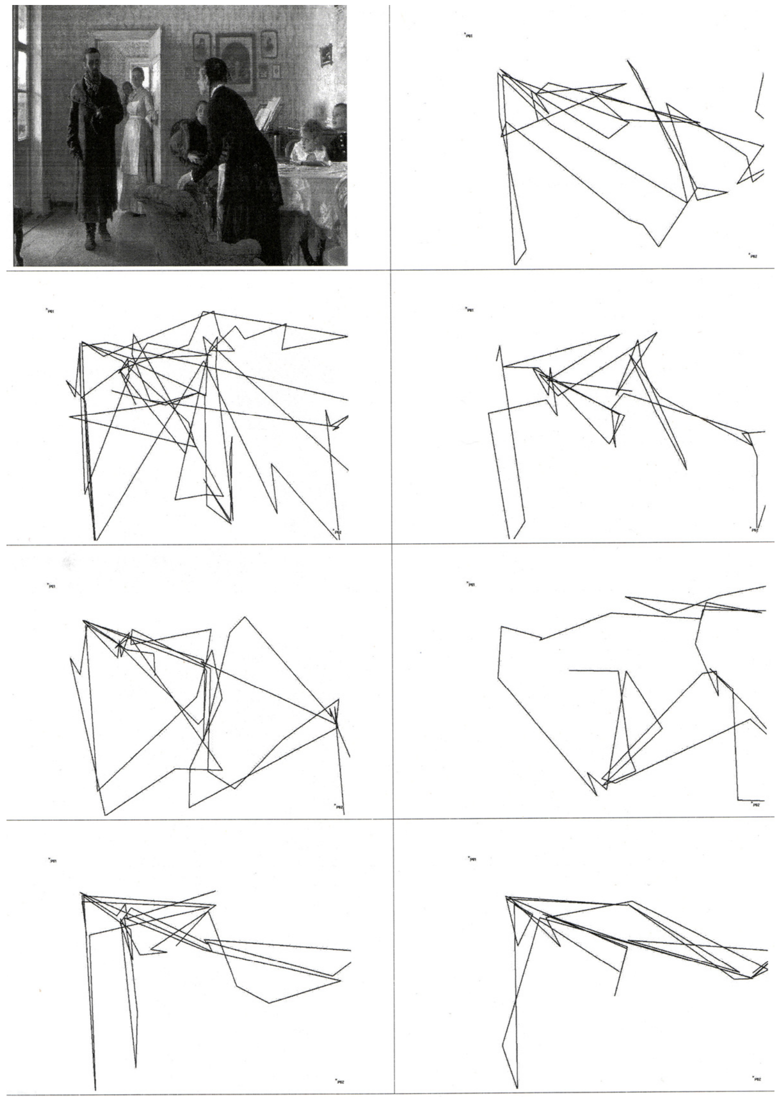


Figure 6. Scanpath diagram for person without intellectual disabilities

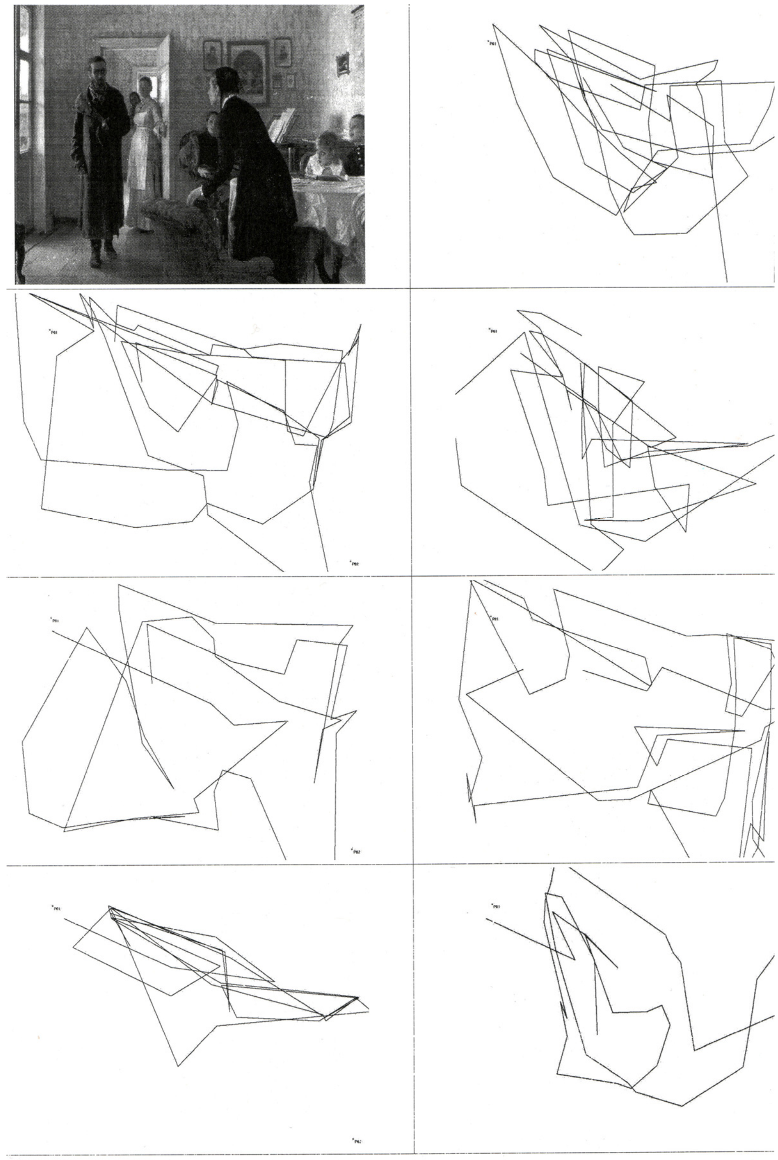


Figure 7. Scanpath diagram for person with intellectual disabilities.

Two cooperating raters (CR) and eight independent raters blind to the experimental condition (intellectual disabilities or not), independently evaluated the scanpaths. They used the same Guidelines for Reviewing Scan Paths (see Appendix D) and Figure 3, Yarbus' original scanpath diagram. They each made a decision as to whether the scanpaths were the same or different and whether the scanpath belonged to a person with or without intellectual disabilities. For the independent raters, the rule of six or more raters finding a difference was the criterion applied for goal-directedness. The cooperating raters compared their responses and negotiated a single response. Yarbus expected the diagrams to be mostly different (see Appendices Y and Z).

The research questions determined whether each group exhibited goal-directed behavior and whether there was a difference between the two groups (intellectual disabilities or not). These questions were answered by using the responses from the reviewers and the binomial test.

Analysis 2, Comparing Time Allocations

The total fixation time was calculated for the combination of participant and question. The average fixation time per question in each of the three question types (or categories of goals) – free viewing, evaluative, and learning was be calculated. A 2 (group) x 3 (question type) ANOVA with repeated measures for question type was used to determine whether there was a difference between students with and without intellectual disabilities for average fixation time and whether the difference depended on the question type. The same analysis was applied to the proportion of time.

Analysis 3, Comparing Interview Responses

Interview data was transcribed and categorized by person and question. Word counts were made for each person and question combination using the Word Count Tool in MS Word. Each of the 15 major elements of The Unexpected Visitor were identified and each participant's transcribed and categorized interview was assessed against those elements, producing a file arranged by persons with and without intellectual disabilities and identifying for each person whether he or she mentioned the element during the interview. These two sets of data were used for multiple inferential statistical tests which are addressed in more detail in the results section.

Experiment 2

Experimental Design

The Research questions addressed by this experiment were:

1) Is there a difference between people with and without intellectual disabilities in viewing images of naturalistic scenes of different types?
2) Can the Walther (2007) model be used to study people with and without intellectual disabilities?

This experiment was designed to replicate the results of research (Carlin, Soraci, Goldman, & McIlvane, 1995) who used traditional psychology laboratory experiments, but using a different approach. Their study indicated that color and line orientation is intact in people with intellectual disabilities, but not form and size. This research design was quasi-experimental and used vision models which were configured for combinations of color, orientation, and contrast. Size was studied by including an image of two elephants of different size. Form was not able to be accommodated within the framework of this study.

The methodology was modeled after the experiment performed by Parkhurst, Law, and Niebur (2002). It used the Walther and Koch (2006) MATLAB saliency model, rather then the Itti, Koch and Neibur (1998) C++ model. The 300 images used in the Parkhurst, et al. study were not available, nor were they used in a replication of that study (Peters, Iyer, Itti, & Koch, 2005), which used black and white digital photographs. There were only four participants in the original study, but the number of pictures displayed was very large, as the study focused on the predictive capability of the model, rather than the behavior of the participants.

In the present study, each participant was provided with the same instruction, "Look around each picture" and was exposed to thirty pictures at a rate of one every 5 seconds. The recorded script on the first slide played, "Hello, this experiment is called Quick Pics because you will see thirty pictures quickly. First look at the 5 in the middle of the screen, then look around the picture. Please do not talk. Enjoy it!" A calibration screen with one central point marked "5" was shown before each picture for one second, followed by the picture for three seconds, followed by a blank screen for one second, which is consistent with other research (Parkhurst, Law, & Niebur, 1999; Peters, Iyer, Itti, & Koch, 2005) and facilitated separation of the data between pictures. The last screen stated, "Thank you for your support."

The objective of the experiment was to determine if there were differences between the two groups of people and whether those differences depended on the type of image. Three analyses were applied to the data produced by the experiment, first using only color and orientation features for saliency and second, using color, orientation, and contrast, and third using one of the pictures for size. The 30 pictures and instructions were displayed using PowerPoint.

Data Sources

There were thirty pictures, ten of each of three types of complex scenes used previously (see Appendix T). The first type consisted of wide-angle natural scenes used in previous vision model testing (Walther & Koch, 2006; Itti, Koch, & Neibur, 1998), the second type consisted of close-up scenes used in GO Inquire, a fourth grade course on geomorphology (Bannan-Ritland, et al., 2006), and the third type consisted of ten home pages from the 2008 and 2007 Webby awards (Barbarian Group, 2008). This organization, which is sponsored by companies in the online industry, has a Web site which allows people to submit nominees and to vote for award winning sites. Each of the images was processed through the Saliency ToolBox 2.1 (Walther, 2007) software and six Areas of Interest were identified for each of two experimental analyses (saliency features of color and orientation and saliency features of color, orientation, and contrast.) Areas of interest for the two objects in the third (size) experiment were entered manually.

A PowerPoint presentation was used to display the pictures allowing 5 seconds between them. Each of the pictures was processed by the MATLAB and Simulink Student Version R007a from The MathWorks, Inc. and the Saliency Toolbox 2.1 (Walther, 2007) to determine the Areas of Interest for the first two analyses. For the saliency option of color and orientation a set of Areas of Interest was identified and a second set of Areas of Interest was generated for all three saliency types.

Stark, who studied eye-tracking for thirty years, said that when viewing a picture, a person usually looks at five or six salient points (Kreisler, 2000). Therefore six points times two experimental analyses multiplied by 30 images is equal to 360 areas of interest. These were configured using the ASL6000 software. Because research (Carlin, Soraci, Goldman, & McIlvane, 1995) indicated that color and orientation was intact for people with intellectual disabilities, the Walther and Koch (2006) model was configured first to analyze for only color and orientation. The Saliency Toolbox 2.1 (Walther, 2007) was run to locate the six most salient locations, one at a time, for each picture used in the study. The most salient location had a weight of 7, the next most salient location, 6, and so on until 1 which was not one of the salient regions and 0 which is not on the picture. The model was run again for the same picture, this time using the model configured for color, orientation, and contrast and the same weighting scheme was used. The final output consisted of two sets of 20 *Saliency Areas of Interest* for each image with up to 6 ordered saliency points, which were used to configure the ASL6000 software (see Appendix G – Experiment 2 Image Preparation).

The size experiment used a picture of a large mother element followed by a small baby element (one of the 30 used in the Experiment). Two areas of interest were established manually using software provided by the ASL6000 system.

Data Analysis Procedures

Analysis 1, Color and Orientation Saliency Features

The saliency models. The Itti model produced saliency values for every point on the picture when the picture was input to the model, but required an upgraded work station, a UNIX operating system and a very long time. For a single picture, the Walther model produced the coordinates of the point with the highest saliency score the first time the model was run; the second time it produced the next highest saliency score, the third time it is was run, it produced the next highest saliency score, etc. This saliency model was loaded onto a laptop with MATLAB and a Windows operating system, and ran very quickly. The issue was how to convert the information it provided into a number which could be used as a saliency value similar to the Itti model's saliency value.

Saliency value definition. Saliency Value was invented in order to use the Walther model in a similar way to the Itti model for the purpose of the second experiment. Two variables were assumed to affect the saliency value. They were: the fixation number and the saliency score of the area of interest where a participant's eye fixated (e.g., rests for at least 100 ms). The choice of using four fixations was made for two reasons. Research (Parkhurst, et al., 2002) found that the saliency value declined for the first four fixations. Bottom-up effects decline over time, so there was fairly good confidence that the first four fixations represented automatic responses. Also, existing algorithmic methods for comparing scanpaths cannot accommodate paths with more than four fixations, as matrices created by the calculations become too large to efficiently process (Foulsham & Underwood, 2008). The formula defined for saliency value multiplied the two variables together. This met several criteria. It ensured that order mattered for the scanpath. The saliency value for a first fixation landing on an area of interest with a high value was greater than the saliency value of a second, third, or fourth fixation landing on the same spot. In effect, the saliency score counted for more than the fixation number, as the highest saliency score is normally seven and the highest fixation value is five. It didn't penalize any person's saliency value if a person did not fixate on an area which was not salient. If a person made four valid fixations on areas which have no saliency score, then the Saliency value was 14, so meaningful saliency was measured by any saliency value over 14. All calculations for this experiment used *Saliency value*, which was a ranking, as the unit of measure. Saliency value was the product of *Fixation value* times *Saliency score* summed over the first four valid fixations for the viewing of a picture by an individual.

Fixation value definition. The fixation value was assigned as a whole number between 5 and 2, where the first fixation, the most important, had a value of 5, the second fixation had a fixation value of 4, the third fixation had a fixation value of 3, and the fourth fixation, which was least important had a fixation value of 2.

Saliency score definition. The six points (coordinates) were generated by running the Walther model six times for one picture. Each point was assigned decreasing saliency scores starting with 7 (most salient point, identified in first run), 6 (next most salient point, identified in second run) to 2 (least salient point, identified in sixth run). Each point was assigned to one of 20 cells in a 4 by 5 grid over the picture (i.e., non-overlapping Areas of Interest). If the person looked at the screen, but not in an Area of Interest, the saliency score was 1. If a person didn't look at the screen, the saliency score was 0.

Saliency value example. The saliency value for a person viewing a picture was the sum of the product of fixation value and saliency score across the four valid fixations. An example of a saliency value calculation might be (5*3) + (4*1) + (3*7) + (2*5) = 50. This would mean that the person's first fixation fell into an area of interest with a saliency score of 3, the second fixation did not fall into an area of interest, the third fell into the area of highest saliency, and the fourth fell into an area of interest with a saliency score of 5, giving a value for this person's view of a picture a saliency value of 50. If the person did not generate four valid fixations, then the fixation value was 0 for the absent fixations.

Valid fixation example. The PowerPoint presentations delivered a picture every 5 seconds. The picture was prefaced by an image with a "5" in a small circle in the middle of the screen. The participant was told to first look at the five, and then look at the picture. If the first fixation occurred in the middle of the screen, based on the coordinates of the fixation, it was assumed that the participant was still looking at the previous image, not the picture itself. That fixation was considered to be invalid and was ignored. This was called a centralized fixation (see Appendix P). In a few cases, there was more than one fixation ignored.

Using the eye-tracker, the ASL coordinates of each fixation were recorded. Only the first 4 fixations were considered, as these were considered to occur during the pre-attentional phase. Fixations less than 100 ms were ignored, as they are considered to be noise by most experimenters (Rayner & Pollatsek, 1992, p. 342), as the average fixation is around a third of a second for free viewing of a scene. Each of the first four fixations for the 30 images was assigned a saliency value using the results of the Saliency Toolbox 2.1 for the features of Orientation and Color. The saliency value was a ranking. Researchers (e.g., Yarbus, 1967) have observed that fixations appear to be highly variable. The study was conducted with two groups of people and three types of pictures. An ANOVA with repeated measures for three picture types was used to determine whether there was a difference between students with and without intellectual disabilities and confirmed with a non-parametric statistic, the Mann-Whitney *U* test, designed for use with ordinal data and two independent data sets.

Analysis 2, Color, Orientation, and Contrast Features

The same data analysis as used in Analysis 1, Color and Orientation was applied except the coding was completed against the saliency areas of interest for the features of Color, Orientation, and Contrast.

Analysis 3, Size Saliency Feature

Because the saliency models do not predict for the saliency feature of size, the method used by Grier (2004) was used to establish areas of interest. Two areas of interest were created, one around the mother elephant and another around the baby elephant, which were not overlapping. These were coded, using the saliency value calculation as described above. A Chi-square and Mann-Whitney *U* test were used, as it is designed for ordinal data and two independent data sets.

4. Results

This chapter presents the results of quantitative and qualitative analyses for the two experiments conducted to answer the three research questions. They were:

1) Do individuals with and without intellectual disabilities exhibit goal-directed behavior when viewing a picture of a complex scene?

2) Is there a difference between people with and without intellectual disabilities in viewing pictures of naturalistic scenes of different types?

3) Can the Walther (2007) model be used to study people with and without intellectual disabilities?

For the first experiment supporting the first research question, there were three analyses and 12 sub-tasks. For the second experiment, supporting the second research question, there were three analyses and four sub-tasks. The third research question was a single entity.

Participants

The study consisted of 43 participants, 23 with intellectual disabilities and 20 without intellectual disabilities (see Tables 1 and 2). Of the 23 students with intellectual disabilities, one could not be included in the study due to the physical limitations of the eye-tracking system, as the chin rest could not be moved to accommodate the student. Fourteen students were able to successfully complete both eye-tracking experiments. Three other students completed only the first experiment because more than 20% of their data was missing on the second experiment, possibly due to closing their eyes. Another three students completed only the second experiment because a complete set of scanpaths was not produced from the first experiment, yielding 17 cases to analyze. There were 22 students who participated in *The Unexpected Visitor* interview. Nineteen students were able to provide usable data to complete the interview. The three students who were not included did not mention any of the objects or people in the picture during the interview. Two of them had provided usable eye-tracking data by producing a valid scanpath.

Of the 20 students without intellectual disabilities, one could not be eye-tracked, due to scratches on his glasses. Of the remaining 19 students, all 19 completed the interview associated with *The Unexpected Visitor*. Fifteen students completed both experiments, two completed only the first experiment, and another two completed only the second experiment, again yielding 17 cases to analyze. For a detailed participant analysis, see Appendix W.

Table 1

Numbers of Participants With and Without Intellectual Disablities

Activity	With	Without	Total
Volunteered for Study	23	20	43
Qualified for eye-tracking	22	19	41
Experiment 1 (19 cases)			
Contributed to eye-tracking	20	19	39
Participated in Interview	22	19	41
Completed Interview	19	19	38
Experiment 2 (17 cases)			
Produced usable eye-tracking data			
Both experiments	14	15	39
First experiment only	3	2	5
Second experiment only	3	2	5
Total Participants	21	19	40

Table 2

Demographics for Participants With and Without Intellectual Disabilities

Category	With	Without
Men (count)	7	10
Women (count)	12	12
Mean age (months)	246	255
Standard deviation age	27	26
Minority status (count)	2	2
Total participants	21	19

Data Collection and Analysis

General Data Collection Process

After approval by the Human Subjects Review Board, data collection began with students without disabilities, who were recruited on the university campus using the Recruiting Script (see Appendix O). The study began, as planned, with a pilot study for the purpose of testing the equipment and operational procedures. A description of the issues encountered and changes made are included in Appendix Q of this document. With those changes, the pilot test period ended and actual collection of data for the experiment began. First, students without intellectual disabilities were eye-tracked and then students with intellectual disabilities were eye-tracked. Appendix P documents fixation level observations during data collection.

Conventions Used in the Analyses

SPSS 17.0 was used for repeated measure studies and SPSS 15.0 was used for all other studies. An alpha level of .05 was used in all statistical tests, unless otherwise noted.

According to Balkin and Erford (2008, p. 399), Cohen's (1988) system of classification for η^2 (eta squared) was .01 for a small effect size, .06 for a medium effect size, and .14 for large effect size. Balkin and Erford stated that this statistic overestimates practical significance in ANOVA. SPSS provides the partial eta-squared statistic ($p\eta^2$) which was used in this study and the same interpretation of the statistic was used: $p\eta^2 = .01$ is a small effect size, $p\eta^2 = .06$ is a medium effect size, and $p\eta^2 = .14$ is a large effect size. This classification will be used whenever ANOVA results are presented.

In Data Tables, the effect size (Cohen's *d*) was calculated for the two groups (X and Y) using the equation $ES = (Mean_X - Mean_Y) / [(SD_X + SD_Y) / 2]$. An effect size of 1.00 (either positive or negative) indicates a very large difference, an effect size above .67 indicates a large difference, over .33 indicates a moderate difference, over .20 indicates only a little difference, and an effect size zero or greater indicates little or no difference (Lloyd, Forness, & Kavale, 1998).

This study is exploratory in nature and the data analyzed is created by the experiments. With the exception of the average time data and the word count data, which are continuous (ratio scale) and are normally distributed according to the non-parametric

Kolmogorov-Smirnov Z test, and meet the homogeneity of variance assumption according to the Levene test, the remainder of the data in the study is assumed not to be normally distributed, so the appropriate statistical test is a non-parametric test. In general, if the data type was binomial, then the Binomial test was used and tested for the proportion of .50. If the data type was categorical or proportional, the Chi-Square test was used. If the data type was ordinal, the Mann-Whitney *U* test was used.

In some cases, however, two statistics, a non-parametric statistic and an ANOVA, a parametric test were both used. The use of an ANOVA with data which may not meet the underlying population assumptions of normality and homogeneity of variance is used in this study in these cases. Some researchers (e.g., Hinkle, Wiersma, & Jurs, 2003, p. 346) state that the statistic is robust to the underlying assumptions, as long as the samples used are of equal size, which is the case for all of the analyses in this study. Others caution that it comes at the cost of a reduction in power, i.e., an increased risk of Type II error (Scheffe, 1959, as cited in Beasley, 2008, p.440). Often both statistics yield the same or consistent results, but sometimes they do not. The reader, therefore, must exercise caution in reviewing and interpreting the study methodology and results under these conditions.

Data Validity

The present study is primarily quantitative and used data which was generated by the experiments. The validity of the present study depended primarily on the accuracy of the data. Several techniques were used to ensure the accuracy of the data and results.

Experiment 1. The primary source of data in this eye-tracking study was the equipment. Choice of the technology (hardware and software), the Applied Science Laboratories ASL6000, was partially based on the company's 30 year history of producing only test equipment. Results were reviewed by the researcher on a daily basis and analysis of the data produced proof to the manufacturer that something was wrong during the pilot test. The manufacturer sent two of their technical experts from Boston to physically review the operation who determined that the camera had been configured incorrectly, corrected it, and confirmed that the system was working correctly.

For the first experiment, eight independent raters from a research class, blind to whether they were looking at scanpaths belonging to people with or without intellectual disabilities, assessed the results of the scanpath diagrams produced (see Appendix D). A single person entered the data and it was double checked by the same person after a delay of several days. One researcher entered the timing data and it was read to another person who checked it.

Experiment 2. The second experiment required the creation of 2,040 saliency values, using a two step process. First a check for valid fixations using the results of the Fixation Adjustment Analysis was done (see Appendix P). Second, 10,200 calculations were performed. This was initially done manually. The second time, the data were created independently again and entered into the computer which did the calculations in a spreadsheet. Every inconsistency was checked and corrected by two people working together, so that the data entered into SPSS was accurate.

There were 360 areas of interest, each defined by four points in the ASL6000 (1,440 data points). The use of a 20 cell grid for the areas of interest reduced the complexity and increased the accuracy of the results, as there were only 20 possible sets of four coordinates and any deviation would immediately show up in a list of areas of interest. The same researcher created the numbers twice, but separated by at least a week in time, using the built-in capabilities of the ASL6000 to display the same data in another format, a way to identify inconsistencies. In addition, the naming convention used for the areas of interest included its saliency score and a short name for the picture, which reduced the complexity of calculation and opportunity for error. The use of multiple statistical tests – Mann-Whitney *U* test, and ANOVA with repeated measures also confirmed the reliability of the results.

In addition, the 17 participants with and the 17 participants without intellectual disabilities who were included in the second experiment were highly similar. Both groups contained 6 men and 11 women, the median age of both groups was 249 months, and the mean age for students with and without intellectual disabilities was 249 and 255 months respectively, only a difference of 6 months.

Experiment 1

The first experiment required each participant to view *The Unexpected Visitor* while the scanpath was collected in response to seven goals or questions (e.g., Remember the clothing the people are wearing. How old are the people?). The first experiment was divided into three analyses. They were Analysis 1: Qualitative scanpath analysis (7 sub-tasks), Analysis 2: Attention across question type (2 sub-tasks), and Analysis 3:

Qualitative Attention Analysis (3 sub-tasks).

Each individual participant in the study produced seven scanpaths. The ASL6000 EYENAL application processed the scanpath location data and the FIXPLOT application created the seven scanpaths online. They were further processed and printed on a scanpath page, similar to *Figure* 3 in this document, except that the scanpaths were displayed by column, not by row. The scanpath diagram consisted of a 4 X 2 table, with the first cell containing a picture of *The Unexpected Visitor* and the first through seventh scanpath filling the first, then second column. See Appendix F for a detailed description of the data processing for Experiment 1. See Appendix X for scanpath diagrams for all participants.

Eye-movement is goal-directed if the scanpath varies in response to a different question. Two cooperating raters and a research class consisting of eight individuals served as raters for the scanpaths. They were given copies of the scanpath diagram for each of the 34 cases and were asked to complete the Scan Path Analysis Coding Sheet (see Appendix E). These raters were blind to which page belonged to which group (with or without intellectual disabilities), and made two decisions. First, they categorized whether the individual's seven scanpaths together were different or the same. "Yes" means the scanpaths were different (goal-directed). "No" means the scanpaths were the same (not goal-directed). Next, they categorized whether the person who produced the scanpaths was a person with or without intellectual disabilities. Based on the literature regarding intellectual disabilities and vision, it was expected that a person with intellectual disabilities would view *The Unexpected Visitor* differently depending on the questions asked (i.e., be goal-directed). In addition, there would be differences between the two groups, consistent with the original study by Yarbus (1967), who attributed similarity of scanpaths between persons to their culture.

Table 3

Goal-Directed Behavior Counts Based on Raters' Judgments

	With ID		Without ID	
Rater Type	Yes	No	Yes	No
Cooperating raters	10	7	16	1
Independent raters				
R1	13	4	16	1
R2	12	5	12	5
R3	12	5	13	4
R4	8	9	8	9
R5	13	4	14	3
R6	14	3	17	0
R7	13	4	17	0
R8	5	12	9	8

Note. Although raters four and eight appear to be outliers, the decision was made to retain them in the dataset, as it was unlikely to alter the results and would yield more conservative estimates in the studies that followed; ID = intellectual disabilities.

Research Question 1

Do individuals with and without intellectual disabilities exhibit goal-directed behavior when viewing a picture of a complex scene?

The hypothesis stated a priori was that students with and students without intellectual disabilities would exhibit goal-directed behavior when viewing the image with different prompts. The decision as to whether the scanpaths were different or the same is a binary decision (i.e., two choices only) and independent, so the binomial distribution applies. As the number of decisions increases, the binomial distribution becomes more like the normal distribution and SPSS uses the standard normal distribution (z distribution). If 50% of the paths were different, or 50% of the paths were not different, this would be considered to be random behavior. If the proportion of scanpaths judged to be different is significantly different from 50%, then this would indicate goal-directed behavior.

Analysis 1, Comparing Scanpaths: Cooperating and Independent raters

The analysis of scanpaths was conducted under two rating conditions. The first condition employed two raters rating the scanpaths individually and then conferring with each other to reach agreement on each decision. The second condition employed eight individual raters who rated each set of scanpaths independently. Their results were collected based on the independent rating with no consultation among the raters. The difference is that the cooperating raters added another step, which was to negotiate one solution. Within this section, the results of the cooperating raters are covered in sub-task

1. Sub-tasks 2 through 6 are devoted to the results of the work of the independent raters. Finally, sub-task 7 summarizes the results of the two approaches.

Sub-task 1: Cooperating raters' results. Do students with intellectual disabilities exhibit goal-directed behavior? The two cooperating raters each independently made 68 decisions based on 34 scanpath diagrams. They determined whether the scanpaths were different or the same and determined the group membership for each person. There was initial agreement on 47 out of 68 decisions (69.1%) and they negotiated the remainder for 100% agreement. See Appendix Y for responses under the column labeled CR.

See Table 4 where the CR column is the data for this sub-task. The null hypothesis was that students with intellectual disabilities would exhibit random behavior, i.e., the proportion of those scanpath diagrams which were different (or the same) was .50. Using a *z* approximation to the binomial distribution, the hypothesis of a proportion equal to .50 (random) failed to be rejected, $p = .629$, therefore, goal-directed behavior was not observed, based on the judgments of two cooperating raters, for students with intellectual disabilities.

See Table 5 where the CR column is the data for this sub-task. The null hypothesis was that students without intellectual disabilities would exhibit random behavior, i.e., the proportion of those scanpath diagrams which were different (or the same) was .50. Using a *z* approximation to the binomial distribution, the hypothesis of a proportion equal to .50 (random) was rejected, $p = .000$, therefore, goal-directed behavior was not observed for students without intellectual disabilities, based on the judgments of two cooperating raters.

By combining Tables 4 and 5, we can answer the question as to whether there is goal-directed behavior for the group as a whole. The null hypothesis was that the decision as to whether the participants are goal-directed is a random one, so the binary test was used to see if the proportion was .50. Test results indicate that the group, as a whole, exhibits goal-directed behavior, $p = .003$. There is, therefore, a clear difference between the two groups with respect to goal-directed behavior as assessed by two cooperating raters. In addition, a Pearson Chi-Square was used, with a continuity correction, to compare the two groups. The groups were again determined to be statistically significantly different, $\chi^2(1) = 4.087$, $p = .043$.

Can the cooperating raters distinguish between students with and without disabilities by observing their scanpaths? The raters were asked to make a separate decision as to whether each scanpath diagram of the person they were analyzing belonged to a person with or a person without intellectual disabilities.

Each of the decisions on group membership was assessed as to whether it was correct or incorrect depending on the participant's number, which was coded in the original data set so that the status of the person as one with or without intellectual disabilities was available. See Appendix Z, Predicting Person Type for the data in the CR column. The decisions were scored 1 if the decision was correct and 0 if the decision was incorrect and it appears in Table 6 in the CR row. The null hypothesis was that cooperating raters' determination of group membership was a random decision, and compared to a chance assignment of 50%. The binomial test was applied and failed to reject the null hypothesis of random decision, $p = .229$, using a z approximation, indicating that the cooperating raters decisions regarding the group membership based on scanpaths alone failed to improve over random chance.

Sub-task 2: Goal-directed behavior with intellectual disabilities. Do students with intellectual disabilities exhibit goal-directed behavior? Each independent rater made one decision for the seven scanpaths as a whole for each of the 34 individuals as to whether the scanpaths were different or the same. See Appendix Y for responses. If the decision was that the scanpaths were different, the coding was 1, and if the decision was they were the same, then the coding was 0. Only the data for the participants with intellectual disabilities was used for this sub-task. The variables used were R1 though R8 in Table 4.

Table 4

Raters' Determination of Scanpaths for Participants With ID

Participant	CR	R1	R2	R3	R4	R5	R6	R7	R8	Total
154	1	1	0	1	0	1	1	1	0	5
169	0	1	0	0	0	0	1	0	0	2
168	0	0	0	1	1	1	1	1	0	5
165	1	0	1	1	1	1	1	1	1	7
164	0	1	0	1	1	1	1	1	0	6
160	1	1	0	0	0	0	0	0	0	1
155	1	1	1	1	1	1	1	1	0	7
157	0	1	1	0	0	1	1	0	0	4
149	1	1	1	1	0	1	0	1	0	5
159	1	0	1	0	0	0	0	1	0	2
151	1	0	1	0	0	0	1	0	0	2
152	0	1	1	1	1	1	1	1	1	8
153	0	1	1	1	1	1	1	1	1	8
150	1	1	1	1	1	1	1	1	0	7
148	1	1	1	1	0	1	1	1	1	7
158	1	1	1	0	1	1	1	1	1	7
147	1	1	1	1	0	1	1	1	0	6

Note. 1 = different; 0 = same; ID = intellectual disabilities; CR = cooperating raters; R1 to R8 = independent raters.

The null hypothesis was that students with intellectual disabilities would exhibit random behavior, i.e., the proportion of those scanpath diagrams which were different (or the same) was .50. Using a z approximation to the binomial distribution, the hypothesis of a proportion equal to .50 (random) was rejected, $p = .000$, therefore, students with intellectual disabilities exhibited goal-directed behavior, based on the judgments of eight independent raters.

Sub-task 3: Goal-directed behavior without intellectual disabilities. Do students without intellectual disabilities exhibit goal-directed behavior? The same analysis as the previous one was conducted except only the students without intellectual disabilities were used for sub-task 3. See Table 5 for the data used in the study. The columns R1 though R8 were used for this analysis.

Table 5

Raters' Determination of Scanpaths for Participants Without ID

Participant	CR	R1	R2	R3	R4	R5	R6	R7	R8	Total
136	1	1	1	1	1	1	1	1	1	8
127	1	1	0	1	1	1	1	1	0	6
135	1	1	0	1	0	1	1	1	0	5
141	1	1	1	1	1	1	1	1	1	8
128	1	1	0	1	0	1	1	1	0	5
140	0	1	0	0	0	0	1	1	0	3
129	1	0	0	1	1	1	1	1	1	6
130	1	1	1	1	1	1	1	1	1	8
138	1	1	1	1	0	1	1	1	0	6
124	1	1	1	1	1	1	1	1	1	8
125	1	1	1	1	1	1	1	1	1	8
137	1	1	1	0	0	1	1	1	0	5
142	1	1	1	0	0	0	1	1	0	4
133	1	1	1	1	0	1	1	1	1	7
139	1	1	1	1	1	1	1	1	1	8
126	1	1	1	1	0	0	1	1	0	5
134	1	1	1	0	0	1	1	1	1	6

Note. 1 = different; 0 = same; ID = intellectual disabilities; CR = cooperating raters; R1 to R8 = independent raters.

The null hypothesis was that students without intellectual disabilities exhibit random behavior, i.e., the proportion of those which were different (or the same) was .50. Using a *z* approximation to the binomial distribution, the hypothesis of a proportion equal to .50 (random) was rejected, $p = .000$, therefore, students without intellectual disabilities exhibit goal-directed behavior, based on the judgments of eight independent raters.

Sub-task 4: Comparison between groups for goal-directed behavior. Is there a difference between students with and without intellectual disabilities in terms of goal-directed behavior? There were the same number of participants (17) and raters (8) for both groups of students (with and without intellectual disabilities). Because both groups were determined to be goal-directed, the next step was to compare the two groups as to whether they were significantly different with respect to goal-directedness. The null hypothesis was that there was no difference between the two groups.

This was done by summing the times the scanpaths that were considered to be different (i.e., goal-directed) across all the independent raters for each person, creating a variable called total. If the total was 6 or more, then the participant was determined to be goal-directed. Anything less than 6 would entail the possibility of chance assignment and so would not be considered to represent goal-directedness. Comparing the Table 4 and Table 5, it was determined that 9 in the group with intellectual disabilities and 11 in the group without intellectual disabilities scored 6 or higher. Using a Chi-square statistic, $\chi^2(1) = .486$, $p = .728$, no statistically significant difference was observed and the groups do not have a different level of goal-directedness, based on the decisions of the eight independent raters.

Sub-task 5: Group membership (raters together). Can all the independent raters' decisions together distinguish between students with and without disabilities by observing their scanpaths? The independent raters were asked to make a separate decision as to whether the scanpath diagram of the person they were analyzing belonged to a person with or a person without intellectual disabilities.

Each of the decisions recorded in Tables 4 and 5 for the independent raters was assessed as to whether it was correct or incorrect depending on the participant number, which was coded in the original data set so that the group membership status of the person as one with or without intellectual disabilities was available. See Appendix Z, Predicting Person Type for the data. The decisions were converted scored 1 if the decision was correct and 0 if the decision was incorrect. A single variable was created by concatenating all the binary data from R1 to R8 which contained all of the correct or incorrect decisions made. The null hypothesis was that independent raters' determination of whether a set of scanpaths was created by a person with or without intellectual disabilities was a random decision, therefore was compared to a chance assignment of 50%.

Using a z approximation to the binomial distribution, the null hypothesis was rejected, $p = .018$. The conclusion was that by considering all of the independent raters together, decisions as to the determination of the person's group (with or without intellectual disabilities), were significantly more accurate than random chance.

Sub-task 6: Group membership decision by each rater. Considering each rater, can the independent rater's decisions distinguish between students with and without disabilities by observing their scanpath diagram? Each independent rater reviewed 34 scanpaths. The raters were blind to whether the scanpaths belonged to a person with or without intellectual disabilities. For each scanpath diagram, they were asked to determine whether it belonged to a person with or without intellectual disabilities. The data was assessed in terms of whether each rater was correct or incorrect in their decisions. This is the same data used in the previous sub-task, except that each rater was considered separately. The variables R1 through R8 were used, one for each rater, plus the grouping variable (with or without intellectual disabilities) for the analysis.

In this case, the null hypothesis was that each rater's determination of whether a scanpath diagram was created by a person with or without intellectual disabilities was a random decision, therefore compared to .50. Because the data is binomial (i.e., has only two possible outcomes, either 0 or 1) and the trials are independent of each other, the Binomial distribution, a non-parametric test, was used. Each person assessed 34 participants, which is considered to be a large number and with large numbers, the normal distribution approximates the binomial distribution. SPSS used a z approximation to the binomial distribution and the null hypothesis (that the decision was random) failed to be rejected for all but one of the raters (p = .024).

Table 6

Summary of Responses to Group Membership by Raters (N = 34)

Rater Type	Incorrect	Correct	*p*
CR	13	21	.229
R1	17	17	1.000
R2	15	19	.608
R3	15	19	.608
R4	10	24	.024
R5	14	20	.392
R6	15	19	.608
R7	15	19	.608
R8	16	18	.864

Note. Based on the *z* distribution. CR = cooperating raters; R1 to R8 = independent raters.

The *p* value is significant for only rater four. Recall that rater four was previously identified as an outlier and the decision was made not to remove him or her. The conclusion, therefore, was that the determination of whether a person has or does not have intellectual disabilities cannot be made reliably by inspection of scanpaths by single individuals. This analysis raises the possibility of inflated alpha level, but it does not impact the findings, as all but one of the raters found non-significant differences.

Sub-task 7: Summary of all rater results. How do cooperating and independent rater results compare with respect to their analysis of the scanpaths? The cooperating raters determined that overall the group was goal-directed, but considered separately, persons without intellectual disabilities were goal-directed, but persons with intellectual disabilities were not goal-directed. This contradicts the finding by the eight independent raters, whose decisions implied that both groups were goal-directed, but there was no statistically significant difference in their goal-directedness.

It was determined that a reasonable criterion for being goal-directed would be a score higher than 6 out of 8, as anything less would be subject to chance. The scores of each of the participants were calculated using this rule. The results were nine participants with intellectual disabilities were determined to be goal-directed and eleven participants without intellectual disabilities were determined to be goal-directed in each group, again reinforcing the decision of no difference between the groups.

The cooperating raters together correctly categorized 18 out of 34 decisions, as to whether the scanpath belonged to a person with or without intellectual disabilities. This number is not statistically significantly different from chance. Therefore, the cooperating rater approach is no better (or no worse) than the multiple rater approach and the conclusion is that the scanpaths produced by people with and without intellectual disabilities cannot be reliably differentiated.

This study is intended to be a replication and extension to the classic Yarbus study. Yarbus appears to have made his decision independently, which is closer to the decision-making approach of the eight independent raters, so the remainder of this study will use the results of the independent raters.

Analysis 2, Comparisons of time allocations

Pieters and Wedel (2007) analyzed the Yarbus' seven goals and categorized them into three categories of increasing complexity. They hypothesized that attention, as measured by fixation time, is greatest for learning goals, intermediate for evaluation goals, and least for free-viewing. Reviewing the questions, they would be categorized as:

Question Type 1: Free Viewing

Question 1: Look around the picture.

Question Type 2: Evaluative

Question 2: Try to understand how rich or how poor the people are.

Question 3: How old are the people in the picture?

Question 4: What were the people doing before the unexpected visitor came?

Question 7: How long do you think the visitor was away?

Question Type 3: Learning

Question 5: Remember the clothing the people are wearing.

Question 6: Remember where the people and objects are in the room.

The ASL6000 calculated the fixation time for each person for each of the seven questions, which were used to determine if there were differences between the two groups (with and without intellectual disabilities) with respect to conformance to the hypothesis of Pieters and Wedel. This was applied to both the actual average time per question per question type and for the proportion of time spent on the three different questions types of increasing complexity (free viewing, evaluative, and learning).

Sub-task 1: Average fixation time and question type. Is there a difference between students with and without intellectual disabilities for average fixation time and does that difference depend on question type? The null hypothesis was that no difference would be observed, given the data, between the average fixation times between students with and without intellectual disabilities and no dependence on question type.

First, the variables used for the analysis were the fixation times for each of the seven questions asked. This was produced by the ASL6000 system. Because the question types (free viewing, evaluative, and learning) consisted of different numbers of questions, the average required dividing the sum of the fixation times of the questions in the questions type divided by the number of questions in the question type. Question type 1 consists of Question 1. Question type 2 fixation time consists of Questions 2, 3, 4, and 7, and was divided by 4. Question type 3 fixation time consists of Question 5 and 6 and was divided by 2.

Table 7

Average Time in Seconds for Question in Question Type

	With ID		Without ID		Total		
Question Type	*M*	*SD*	*M*	*SD*	*M*	*SD*	*ES*
1 Free viewing	76.218	63.229	67.094	65.199	71.656	63.410	.01
2 Evaluative	43.482	47.791	27.502	35.336	35.491	42.173	.38
3 Learning	33.488	37.010	16.270	16.499	24.879	29.538	.64

The analysis used was a 2 (group) x 3 (question type) ANOVA with repeated measures on the question type. The variables used were the group (with or without intellectual disabilities) and the question type, which was the repeated measure. Mauchly's test indicated that the assumption of sphericity had been violated $\chi^2(2) = 29.766$, $p = .000$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity, $\varepsilon = .558$. The results show a statistically significant difference between the question types, $F(1.237, 39.575) = 15.822$, $p = .000$, $p\eta^2 = .331$. The effect size was large. No interaction effect was observed, given the data, between the question types and the groups, $F(1.237, 39.575) = .125$, $p = .779$, $p\eta^2 = .004$. No statistically significant difference between the groups was observed, given the data, $F(1, 32) = 1.230$, $p = .276$, $p\eta^2 = .037$.

There were three question types: Free Viewing, Evaluative Questions, and

Learning Questions. There was a statistically significant main effect for question type, $F(1.237, 39.575) = 15.822$, $p = .000$, $p\eta^2 = .331$. The effect size is large. No statistically significant interaction effect between group and question type was observed, given the data.

The average time for question type 1 (Free viewing) was largest, followed by the average time for question type 2 (Evaluative) and then question type 3 (Learning). This was essentially the reverse of the pattern hypothesized by Pieters and Wedel (2007).

The Tukey *post-hoc* tests show that there was a statistically significant difference between Question type 1 (Free viewing) and 2 (Evaluative), ($p = .001$), a statistically significant difference between Question types 1 and 3 (Free viewing and Learning), ($p = .000$), and also between question types 2 and 3 (Evaluative and Learning), ($p = .016$).

Specifically, the 95 percent confidence intervals showed that Question type 1 (free viewing) was higher than Question type 2 (evaluative) by at least 16.315 seconds and at most 56.013 seconds. Question type 1 (free viewing) was higher than question type 3 (learning) by at least 24.875 seconds and at most 68.678 seconds. Question type 2 (Evaluative) was higher than Question type 3 (Learning) by at least 2.091 and at most 19.134).

No statistically significant difference between people with and without intellectual disabilities for average fixation time was observed, given the data collected from these participants. The Participants with intellectual disabilities had longer average fixation times. All pairs of question types exhibited significant differences. Therefore, this test indicates no difference between people with and without intellectual disabilities

Sub-task 2: Proportion of fixation time and question type. Is there a difference between students with and without intellectual disabilities for the proportion of total fixation time applied to each question type?

The ASL6000 records the fixation time in response to each question for each participant. The total fixation time on each question type for each participant was calculated. This amount was divided by the total fixation time for all seven questions for that participant to create three variables, the proportion of time spent on each of the three question types by each individual.

The average fixation time variable was subjected to the Kolmogorov-Smirnov Z test. The two-tailed significance of the test was calculated for each of the three question types for people without intellectual disabilities, free viewing, $p = .055$, evaluative, $p = .071$, and learning, $p = .131$. A non-significant p value indicates that an assumption of normality can be made. The Levene's Test for Equality of Variances including the samples for people with and without intellectual disabilities for the free viewing question type indicated an assumption of homogeneity of variance can be used, $F(1, 32) = .002$, $p = .967$. For the evaluative question type, including the samples for people with and without intellectual disabilities, an assumption of homogeneity of variance can be used, $F(1, 36) = .851$, $p = .363$. For the learning question type, including the samples for people with and without intellectual disabilities, an assumption of heterogeneity of variance must be used, $F(1, 32) = 6.055$, $p = .019$.

Table 8

Proportion of Time for Question Type

	With ID		Without ID		Total		
Question Type	*M*	*SD*	*M*	*SD*	*M*	*SD*	*ES*
1 Free viewing	.329	.174	.276	.145	.300	.160	.33
2 Evaluative	.480	.135	.511	.105	.495	.120	-.26
3 Learning	.194	.085	.211	.097	.206	.091	-.19

A 2 (group) x 3 (question type) ANOVA with repeated measures for question type was used for the analysis. The variables used were the group (with or without intellectual disabilities) and the proportion of fixation time for each question type, which was the repeated measure. Mauchly's test indicated that the assumption of sphericity had been violated, $\chi^2(2) = 15.586$, $p = .000$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity, $\varepsilon = .717$. The results show a statistically significant difference between the question type proportions, $F(1.434, 31.073) = 31.073$, $p = .000$, $p\eta^2 = .493$. The effect size was large. No interaction effect was observed, given the data, between the question type proportions and the groups, $F(1.434, 45.873) = .633$, $p = .485$, $p\eta^2 = .019$. No statistically significant difference between the groups was observed, given the data, $F(1, 32) = .704$, $p = .408$, $p\eta^2 = .022$.

The Tukey *post-hoc* tests show that there was a statistically significant difference between proportions for Question type 1 (Free viewing) and 2 (Evaluative), (p = .000), a statistically significant difference between Question types 1 and 3 (Free viewing and Learning), (p = .020), and also between question types 2 and 3 (Evaluative and Learning), (p = .000). Specifically, the 95 percent confidence intervals showed that Question type 1 proportion (free viewing) scored lower than Question type 2 proportion (evaluative) by at least .102 and at most 5.290. Question type 1 proportion (free viewing) was higher than question type 3 (learning) by at least .016 and at most .178. Question type 2 (Evaluative) was higher than Question type 3 (Learning) by at least .243 and at most .342).

In addition, a Chi-square statistic was also applied to the same data to examine whether there was a difference between the groups for each of the three proportions. The results were: no difference between groups was observed for the free-viewing question type proportion, $\chi^2(31) = 32$, $p = .417$, for the evaluative question type proportion, $\chi^2(33) = 34$, $p = .419$, or for the learning question type proportion, $\chi^2(1) = 32$, $p = .467$, confirming no statistically significant difference was observed between the groups, given the data.

No statistically significant difference between people with and without intellectual disabilities for proportion of fixation time was observed, given the data. All pairs of question types exhibited statistically significant differences. This is the same result as the previous analysis of fixation time.

Analysis 3, Comparisons of Group Responses to Interview

Based on interviews conducted after viewing *The Unexpected Visitor experiment*, are there differences between students with and without intellectual disabilities?

Interviews with 19 participants with and without intellectual disabilities consisted of asking Yarbus' seven questions again (e.g., How old are the people in the picture? Remember the clothing the people were wearing). The researcher recorded field notes. The present study was not intended to be a memory test, but the interview was included to motivate students to look at the picture and to give them an opportunity to talk about what they observed. There were two approaches taken. First, the interviews were transcribed and the Microsoft Word tool for word count was used to count the words in the response for each question for each of the 38 participants. Second, major elements in the picture were identified and each person's interview was analyzed in terms of which of the major elements were mentioned.

Sub-task 1: Word volume. Is there a significant difference between students with and without intellectual disabilities for the number of words used in their responses to each question type?

Nineteen students from each group successfully completed an interview after viewing *The Unexpected Visitor*. The seven questions were asked again and field notes were recorded. The notes were transcribed. Using MS Word's tool for word count, the words were recorded for each person and question. The two variables were whether the participant was one with or without intellectual disabilities and the number of words used in response to each of the seven questions. The data was compiled into question types as defined above.

The number of words variable was subjected to the Kolmgorov-Smirnov Z test. The two-tailed significance of the test was calculated for each of the three question types, free viewing, $p = .606$, evaluative, $p = .575$, and learning, $p = .661$. A non-significant p value indicates an assumption of normality is allowed. The Levene's Test for Equality of Variances of the free viewing question type for samples of people with and without intellectual disabilities indicated that the assumption of homogeneity of variance should be used, $F(1, 36) = 3.088$, $p = .429$. The Levene's Test for Equality of Variances of the evaluative question type for the samples of people with and without intellectual disabilities indicated that the assumption of homogeneity of variance should be used, $F(1, 36) = 3.182$, $p = .083$. The Levene's Test for Equality of Variances of the learning question type for the samples of people with and without intellectual disabilities indicated that the assumption of homogeneity of variance should be used, $F(1, 36) = 3.088$, $p = .087$. In these cases, a non-significant p indicates the homogeneity of variance assumption holds.

Table 9

Average Word Count by Question Type

	With ID		Without ID		Total		
Question Type	*M*	*SD*	*M*	*SD*	*M*	*SD*	*ES*
1 Free viewing	11.368	6.962	16.368	5.479	13.868	6.679	-0.80
2 Evaluative	8.776	5.429	19.750	7.288	14.264	8.432	-1.73
3 Learning	14.184	10.976	37.079	15.778	25.632	17.729	-1.71

The analysis used was a 2 (group) x 3 (question type) ANOVA with repeated measures for question type. The variables used were the group (with or without intellectual disabilities) and the average word count per question type (free viewing, evaluative, and learning). Mauchly's test indicated that the assumption of sphericity had been violated, $\chi^2(2) = 14.232$, $p = .001$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity, $\varepsilon = .750$. The results show a statistically significant difference between the question types, $F(1.499, 53.969) = 35.296$, $p = .000$, $p\eta^2 = .495$. The effect size was large. There was a statistically significant interaction effect between the average word count for question type and the groups, $F(1.499, 53.969) = 16.412$, $p = .000$, $p\eta^2 = .313$. There was also a statistically significant difference between the groups, $F(1, 36) = 28.279$, $p = .000$, $p\eta^2 = .857$. Therefore, this test indicates a large statistically significant difference between the groups for word count and the difference increases as the difficulty of the question type increases.

The Tukey *post-hoc* tests show that there was a statistically significant difference between question types 1 (Free viewing) and 3 (Learning), (p = .000) and between Question types 2 and 3 (Evaluative and Learning), (p = .000). Specifically, the 95 percent confidence intervals showed that Question type 1 (free viewing) scored lower than Question type 3 (learning) by at least 15.553 and at most 7.974. Question type 2 (evaluative) was lower than question type 3 (learning) by at least 14.881 and at most 7.855.

Therefore, this test indicates a large statistically significant difference between the groups for word count and the difference increases as the difficulty of the question type increases.

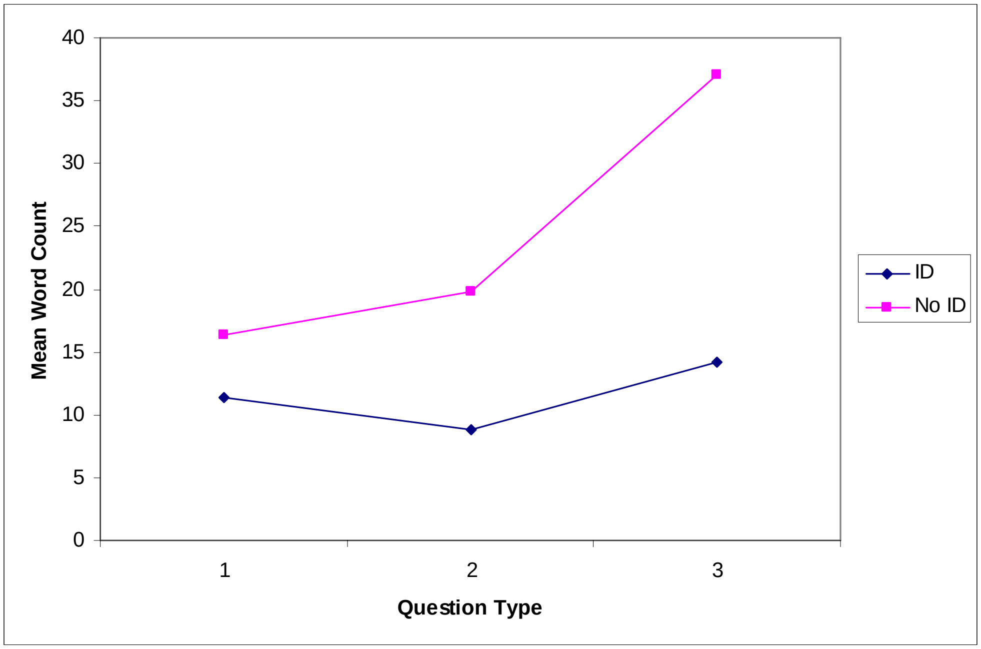


Figure 8. Interaction of word count and question type

Sub-task 2: Recall of major picture elements. Is there a difference between students with and without intellectual disabilities in terms of their reporting of the major elements in *The Unexpected Visitor*? The major elements of *The Unexpected Visitor* consisted of people and objects. The people were: the unexpected visitor, the old lady, the young boy, the young girl, the girl at the piano, the maid at the door, the person behind the maid. The objects were: pictures on the walls, the piano, the door, the window, chairs, chair legs, the table, and objects on the table. The participant's response to the questions was evaluated against each of the elements, in terms of whether the element was mentioned during course of the interview or not.

Table 10

Elements Reported By Participants With Intellectual Disabilities

Participant	Objects Count	People Count	Total Count
148	4	2	6
152	2	3	5
153	3	2	5
156	3	4	7
157	3	0	3
158	1	0	1
159	5	0	5
167	1	4	5
169	0	4	4
150	6	5	11
149	2	1	3
154	5	2	7
155	3	2	5
160	2	5	7
161	2	5	7
164	3	3	6
165	3	2	5
151	3	0	3
168	6	4	10

Table 11

Elements Reported By Participants Without Intellectual Disabilities

Participant	Objects Count	People Count	Total Count
124	5	6	11
125	6	7	13
126	7	7	14
127	4	7	11
128	6	7	13
129	4	7	11
130	7	7	14
131	3	6	9
133	7	7	14
134	5	7	12
135	4	5	9
136	4	5	9
137	5	7	12
138	5	4	9
139	7	6	13
140	4	5	9
141	6	7	13
142	6	6	12
144	3	1	4

The data was captured as binary data for each of the elements and each individual, but three variables were created by summing across the people elements (people), the object elements (objects) and all the elements (total). The Mann-Whitney *U* test, designed for ordinal data, independent samples and two groups was used. As a non-parametric test, there was no assumption of normality for the use of this test. The null hypothesis was the median number of all elements recalled (total) was the same for people with and without intellectual disabilities. The results indicated a statistically significant difference between the medians of the two groups, $p = .000$, without correction for ties and an exact significance. This represents a difference between the two groups for recall of all the elements together. A Pearson Chi-Square was also applied, $\chi^2(11) = 33$, $p = .001$, which yielded the same result.

Next, the Mann-Whitney *U* test was used to determine if there was a significant difference between the groups for median number of objects in the picture recalled. The test indicated a statistically significant difference between the two groups, $p = .000$, without correction for ties and an exact significance. Therefore, there is a statistically significant difference between the two groups for recall of objects, with the group without intellectual disabilities recalling more. A Pearson Chi-Square was also applied, $\chi^2(7) = 17.778$, $p = .013$, which yielded the same result.

Next, the Mann-Whitney *U* test was used to determine if there was a significant difference between the groups for median number of people in the picture recalled. The test indicated a statistically significant difference between the two groups, $p = .000$, without correction for ties and an exact significance. This indicates a statistically significant difference between the two groups for recall of people. A Pearson Chi-Square was also applied, $\chi^2(7) = 26.800$, $p = .000$, which yielded the same result.

Sub-task 3: Researcher's observations. The level of detail reported by individuals varied considerably. A main difference between the responses of the students without intellectual disabilities was to provide support for their answers. For example, in response to the question, "How long was the visitor away?" a response was, "Very long, for war, based on the expression, skin tone and facial hair." Another response was, "Six months to a year or longer, based on the reaction of the children in the room." The students with intellectual disabilities gave answers, such as "2 or 3 weeks," "30 years," "30 days," but, in general, no rationale for their answers. Four of the students with intellectual disabilities (seven instances overall) mentioned personal experiences in their answers. Some examples were: "A girl plays the piano; my mom plays the piano," "Old man. He is like my old father. That's why I remember." None of the students without intellectual disabilities did this. One student in each group mentioned a president (George Washington and Thomas Jefferson) in their responses. The students with intellectual disabilities mentioned seven objects that did not exist in the picture, e.g., a dog. There was no instance of this in the group without intellectual disabilities. In response to the question, "How rich or how poor do you think they are?" there were essentially four answers – rich, poor, both (e.g., "Some were very poor and some rich") or neither (e.g., "I don't know which"). Half of the students with intellectual disabilities thought the family was poor. More than half of the students without intellectual disabilities thought they were rich. See Appendices V and W for sample responses to all seven questions by students with and without intellectual disabilities.

Experiment 2

For Experiment 2, the participants were rapidly shown 30 pictures of three different types. The first ten were pictures used in previous vision science saliency studies, the second ten were pictures used in a geomorphology course for fourth grade students studying erosion, and the third ten were Webby award winning web sites (see Appendix T for all pictures). Use of different types of pictures and no randomization was the pattern used in previous saliency studies (e.g., Parkhurst, Law, & Niebur, 2002). Computer models of visual attention (e.g., Itti, Koch, & Niebur, 1998; Walther & Koch, 2006) used a picture as input and produced saliency points and two dimensional areas of interest, where people would be expected to look during the first second or two. The Walther model was configured for Analysis 1 to create saliency coordinates based on the saliency features of color and orientation (see Appendix G) and for Analysis 2 to create saliency points based on the saliency features of color, orientation, and contrast. The saliency points were used to assign ranked saliency scores to every point on each picture, so when someone fixated on a point in a picture, a saliency value could be calculated for that instance of picture viewing by a particular person. Analysis 3 of this experiment used one of the pictures, that of a mother and baby elephant, to determine the effect of the saliency feature of size.

Research Question 2

Is there a difference between people with and without intellectual disabilities in viewing pictures of natural scenes of different types?

Analysis 1, Color and Orientation

Considering saliency features of color and orientation, is there a difference between the two groups in viewing natural scenes of different types?

This analysis used two variables: saliency value for each of 30 pictures (10 pictures used in previous saliency studies, 10 pictures used in a fourth grade geomorphology course and 10 images of Webby award winning Web sites) and whether the person has or does not have intellectual disabilities. The data was created for the purposes of this study using the methods described previously: using eye-tracking equipment, the Walther saliency model (configured for color and orientation), and the saliency value calculation. Because the data were rankings and entail multiple viewings of pictures, two tests were used: a 2 (group) x 3 (picture type) ANOVA with repeated measures for picture type, confirmed with a Mann-Whitney *U* test.

Sub-task 1: Repeated measures ANOVA for picture types. Tables 12, 13, and 14 display the descriptive statistics for the three picture types for the saliency features of orientation and color. Each time a person looked at a picture, a saliency value was created. The means represent the mean saliency value across the 17 participants in each group. The total is the mean saliency value across all 34 participants.

Table 12

Picture Type 1 Saliency Values for Color and Orientation

	With ID		Without ID		Total		
Picture	*M*	*SD*	*M*	*SD*	*M*	*SD*	*ES*
1	23.65	10.897	37.29	7.490	30.47	11.521	-1.48
2	20.88	13.299	29.00	18.145	29.94	16.198	-0.52
3	19.65	23.283	14.00	00.000	16.82	16.464	0.49
4	26.71	19.566	30.59	12.263	28.65	16.199	-0.24
5	27.06	16.898	37.29	14.538	32.18	16.368	-0.65
6	38.76	17.402	41.88	13.209	40.32	15.295	-0.20
7	38.41	23.246	45.65	16.575	42.03	20.216	-0.36
8	16.76	10.383	19.82	9.139	18.29	9.756	-0.31
9	35.94	17.686	34.18	15.436	35.06	16.371	0.11
10	43.41	22.288	53.65	15.600	48.43	19.643	-0.54

Note. ID = intellectual disabilities.

Table 13

Picture Type 2 Saliency Values for Color and Orientation

	With ID		Without ID		Total		
Picture	*M*	*SD*	*M*	*SD*	*M*	*SD*	*ES*
11	21.59	12.395	19.59	8.711	20.59	10.598	.19
12	18.29	9.366	17.18	6.167	17.74	7.829	.14
13	37.88	28.677	60.29	27.039	49.09	29.708	-.80
14	48.59	33.403	49.41	18.066	49.00	29.708	-.03
15	31.35	44.180	44.18	20.531	37.76	24.695	-.40
16	24.88	16.324	27.29	9.873	26.09	13.340	-.18
17	24.24	12.983	23.88	10.653	24.06	11.695	.03
18	24.53	13.001	20.88	8.506	22.71	10.975	.34
19	51.06	35.790	48.94	23.464	50.00	29.819	.07
20	20.35	11.324	23.00	8.155	21.68	8.809	-.07

Note. ID = intellectual disabilities.

Table 14

Picture Type 3 Saliency Values for Color and Orientation

	With ID		Without ID		Total		
Picture	*M*	*SD*	*M*	*SD*	*M*	*SD*	*ES*
21	27.06	22.515	33.29	16.984	30.18	19.891	-0.32
22	17.71	9.668	20.35	12.811	19.03	11.256	-0.23
23	20.53	12.645	32.24	17.598	26.38	16.216	-0.77
24	42.41	28.178	31.12	15.095	36.76	22.985	0.52
25	23.88	13.499	23.06	9.134	23.47	11.357	0.07
26	20.53	11.533	22.94	7.110	21.74	9.513	-0.26
27	23.88	14.322	29.88	17.164	26.88	15.861	-0.38
28	20.59	12.047	19.06	8.407	19.82	10.259	-0.15
29	52.47	37.291	50.65	23.632	51.56	30.755	0.06
30	32.59	34.666	18.18	9.671	25.38	26.106	0.65

Note. ID = intellectual disabilities.

The analysis used was a 2 (group) x 3 (picture type) ANOVA with repeated measures for the three picture types. Mauchly's test for picture type indicated that the assumption of sphericity had been violated, $\chi^2(2) = 7.482$, $p = .024$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity, $\varepsilon = .823$. The results show a statistically significant difference between the picture types, *F*(1.647, 52.700) $= 4.507$, $p = .021$, $p\eta^2 = .123$. The effect size was moderate. No interaction effect was observed, given the data between the picture types and the groups, $F(1.647, 52.700) = 1.784$, $p = .183$, $p\eta^2 = .053$. No statistically significant difference between the groups was observed, given the data collected from these participants, $F(1, 32) = 2.888$, $p = .099$, $p\eta^2 = .083$. There were three picture types: Pictures used in previous saliency studies, pictures used in a Geomorphology course, and Webby award winning Web sites. No statistically significant difference between people with and without intellectual disabilities for saliency value was observed, in the data collected from these participants. Participants without intellectual disabilities had higher saliency values. Because the assumption of sphericity was violated in this analysis, no *post hoc* tests were applied, consistent with the advice of (Boik, 1981, as cited in Field, 2005, p. 441) who demonstrated that they were not reliable for repeated measures and recommends not using them.

Sub-task 2: Mann-Whitney U test. The Mann-Whitney *U* test is a non-parametric statistic used to compare independent data sets when the data is ordinal. The saliency value for each of the thirty pictures is available, but because the interest is to compare picture types, the saliency values for the first ten pictures (from previous saliency studies) were summed to create Picture type 1; the next ten pictures (from the Geomorphology course) were summed to create Picture type 2; the next ten pictures (Webby award winning Web sites) were summed to create Picture type 3. The variables used by this study are group (with and without intellectual disabilities) and Picture type.

Table 15

Saliency Values for Picture Types for Color and Orientation

	With ID		Without ID	
Picture Type	*M* Rank	Sum of Ranks	*M* Rank	Sum of Ranks
1 Previously used	12.35	210.00	22.65	385.00
2 Geomorphology	15.76	268.00	19.24	327.00
3 Webby Web sites	18.12	308.00	16.88	287.00

Note. ID = Intellectual disabilities.

The Mann-Whitney *U* analysis sorts the data by order and assigns a rank to each number. The ranks are compared between the two groups (with and without intellectual disabilities) and summed to determine if a difference exists. This particular analysis did not correct for ties. There was a statistically significant difference between people with and without intellectual disabilities for picture type 1, $p = .002$, but no difference was observed, given the data for picture type 2, $p = .322$ or picture type 3, $p = .734$.

Analysis 2, Color, Orientation, and Contrast

Considering saliency features of color, orientation, and contrast, is there a difference between the two groups in viewing natural scenes of different types?

The same analysis was applied to Analysis 2 as for Analysis 1, except that a different set of data was used, as the Walther model creates a different set of coordinates for the features of color, orientation, and contrast and hence a different data table for saliency for each picture and person combination which was used.

Sub-task 1: ANOVA with repeated measures for picture types. Tables 16, 17, and 18 represent the three picture types for the saliency features of color, orientation, and contrast.

Table 16

Picture Type 1 Saliency Values for Color, Orientation, and Contrast

	With ID		Without ID		Total		
Picture	*M*	*SD*	*M*	*SD*	*M*	*SD*	*ES*
1	26.71	15.719	30.65	7.185	28.68	12.200	-0.34
2	24.18	15.380	27.76	14.902	25.97	15.022	-0.24
3	39.29	30.828	42.35	9.676	40.82	22.552	-0.15
4	22.53	19.226	30.53	14.612	26.53	17.298	-0.47
5	41.82	24.608	31.47	17.154	36.65	21.538	-0.50
6	37.41	25.288	44.76	20.179	41.09	22.835	-0.32
7	52.00	35.260	61.35	22.291	56.68	29.432	-0.32
8	20.06	16.600	30.35	23.476	25.21	20.691	-0.51
9	81.35	45.170	56.82	26.787	69.09	38.628	-0.68
10	59.47	31.849	63.35	21.814	61.41	29.952	-0.14

Note. ID = intellectual disabilities.

Table 17

Picture Type 2 Saliency Values for Color, Orientation, and Contrast

	With ID		Without ID		Total		
Picture	*M*	*SD*	*M*	*SD*	*M*	*SD*	*ES*
11	16.24	5.562	17.24	4.764	16.74	5.125	-0.19
12	18.88	10.355	19.06	10.201	18.97	10.122	-0.02
13	53.71	26.253	46.06	17.065	49.88	22.350	0.35
14	22.29	15.571	20.82	10.273	21.56	13.115	0.11
15	29.59	17.432	39.00	12.369	34.29	15.631	-0.63
16	47.47	24.401	43.47	19.226	45.47	21.726	0.18
17	24.29	14.653	21.65	8.746	22.97	11.940	0.23
18	26.12	14.615	20.12	7.729	23.12	11.908	.054
19	24.59	13.309	23.41	10.689	24.00	11.901	0.10
20	33.24	29.197	38.29	24.776	35.76	26.787	-0.19

Note. ID = intellectual disabilities.

Table 18

Picture Type 3 Saliency Values for Color, Orientation, and Contrast

	With ID		Without ID		Total		
Picture	*M*	*SD*	*M*	*SD*	*M*	*SD*	*ES*
21	21.47	15.042	21.53	9.220	21.50	12.285	0.00
22	20.71	10.264	23.88	12.175	22.29	11.205	0.28
23	36.88	22.702	31.76	14.087	34.32	18.784	0.28
24	23.00	12.258	21.76	12.647	22.38	12.280	0.10
25	38.12	33.232	77.65	31.771	57.88	37.780	-1.22
26	24.06	17.163	25.41	12.500	24.74	14.800	-0.09
27	29.65	16.534	29.06	12.023	29.35	14.238	0.04
28	25.94	14.614	14.41	2.425	20.18	11.859	1.35
29	57.71	29.212	61.59	17.472	59.65	23.783	-0.17
30	26.35	25.778	14.65	5.442	20.50	19.283	0.75

Note. ID = intellectual disabilities.

The purpose of this study was to examine the difference between the groups for saliency value for picture types. A 2 (group) x 3 (picture type) ANOVA with repeated measures for picture type was used. Mauchly's test for picture type indicated that the assumption of sphericity had not been violated, $\chi^2(2) = 5.137$, $p = .077$, therefore no correction was required. The results show a statistically significant difference between the picture types, $F(2, 64) = 45.978$, $p = .000$, $p\eta^2 = .590$. The effect size was large. No interaction effect was observed, given the data between the picture types and the groups, $F(2, 64) = .525$, $p = .594$, $p\eta^2 = .016$. No statistically significant difference between the groups was observed, given the data, $F(1, 32) = .209$, $p = .650$, $p\eta^2 = .007$.

There were three picture types: Pictures used in previous saliency studies, pictures used in a Geomorphology course, and Webby award winning Web sites. No statistically significant difference between people with and without intellectual disabilities for saliency value was observed, given the data.

Sub-task 2: Mann-Whitney U test. The Mann-Whitney *U* test is a non-parametric statistic used to compare independent data sets when the data is ordinal. The saliency value for each of the thirty pictures is available, but because the interest is to compare picture types, the sum of the saliency values for the first ten pictures (from previous saliency studies) were summed to create Picture type 1; the next ten pictures (from the Geomorphology course) were summed to create Picture type 2; the next ten pictures (Webby award winning Web sites) were summed to create Picture type 3. The variables used by this study are group (with and without intellectual disabilities) and Picture type.

Table 19

Saliency Values by Picture Type for Color, Orientation, and Contrast

	With ID		Without ID	
Picture Type	*M* Rank	Sum of Ranks	*M* Rank	Sum of Ranks
1 Previously used	16.62	282.50	18.38	312.50
2 Geomorphology	18.74	318.50	16.26	276.50
3 Webby Web sites	16.50	280.50	18.50	314.50

Note. ID = intellectual disabilities.

There was no difference observed between people with and without intellectual disabilities for picture type 1, $p = .610$, picture type 2, $p = .474$, or picture type 3, $p = .563$.

Analysis 3, Size

Considering the saliency feature of size, is there a difference between the two groups?

The two previous saliency feature analyses used the Walther (Walther & Koch, 2006) saliency model for color, orientation, and contrast. The saliency feature of size is not supported by the Saliency Toolbox 2.1 (Walther, 2007), so another approach was used to study size, modeled after another saliency study (Grier, 2004) which created areas of interest around the objects that were being studied.

One of the 30 pictures used in the previous analysis was analyzed again using a different set of areas of interest. This picture showed two elephants – a large mother elephant and a small baby elephant. Rather than having the model generate saliency points, two areas of interest, one around the large mother elephant and another around the baby elephant were established using the ASL6000 configuration capability.

The maximum number of fixations that were made across the 34 people in the study was 1 fixation. It had been expected that there would be more than four fixations for each person, but this didn't occur.

Table 20

Frequency of Viewing of Areas of Interest for the Size Experiment

Areas of Interest	With ID	Without ID	Total
Mother elephant	14	17	31
Baby elephant	0	0	0
Neither	3	0	3

Note. ID = intellectual disabilities.

Using the equation described in the methodology section for calculating saliency, these results would be interpreted in the following way: There is one fixation, so the fixation value would be 2. The saliency score would be 3 (big elephant), 2 (small elephant), and 1 (no salient point) because there were 2 areas of interest. Because there is only one fixation, there would be no summation involved; the saliency value for participants who looked at the elephant would be 3 x 2 = 6; for the participants who did not look at a salient region, it would be 2 * 1 = 2.

Sub-task 1: Mann-Whitney U test. The Mann-Whitney *U* test for ordinal data and independent data sets was used to compare the two groups as they looked at the picture with a large elephant and a small elephant. The variables used were the saliency value obtained from looking at the picture (6 for mother, and 2 for neither) and whether the person did or did not have intellectual disabilities. No difference was observed, given the data between the two groups, $p = .394$, using an exact significance test, which did not correct for ties.

Sub-task 2: Chi-square test. Using a Chi-square statistic, $\chi^2(1) = 3.290$, $p = .070$, no statistically significant difference was observed, therefore, given the data, no difference was observed between the two groups for the saliency feature of size.

Research Question 3

The third major research question in the present study was: Can the Walther (2007) model be used to study people with and without intellectual disabilities?

Using an approach similar to Foulsham and Underwood (2008), the fixations that occurred in highly salient regions (areas of interest) versus other regions were analyzed. They found, using the Itti and Koch model (2000) that 10.4% of the area on a picture was identified as salient regions, but 20% of their fixations landed in salient regions. Based on probability theory, if the model produced purely random results, then they would expect that the 10.4% of the fixations would land in highly salient regions (areas of interest), so this would mean that the model predicted better than chance with an improvement of 9.6%. They adjusted their data for first fixations on the center of the previous screen; their areas of interest were non-contiguous. The Itti model had previously been shown to estimate better than chance (Parkhurst, Law & Niebur, 2002).

This present study used a 20 cell grid for areas of interest. Each cell represented 5% of the area of the picture. These cells were contiguous, but not overlapping. The boundaries of the cells were on whole numbers on the ASL6000 grid on the screen. The saliency points produced by the Walther model had to be converted to the ASL6000 coordinates and the translation formula always yielded numbers with three digits to the right of the decimal, so there was no ambiguity as to which area of interest they belonged in. This was equivalent functionally to non-contiguous areas of interest. The average number of areas of interest per picture was 5.167 for both Analyses 1 and 2 in

Experiment 2, so if fixations landed on more than 25.8% of the pictures we would say that the Walther model predicted better than chance under the conditions of this experiment.

Because the Foulsham and Underwood study was a study using people without known disabilities, a large sample of 150 picture viewings by the first five participants without intellectual disabilities was used. These viewings were done within a day of the hardware and software being validated by the manufacturer. We were able to determine whether the results from the Walther model were near those of the Foulsham and Underwood study. We eliminated fixations that were on the center from the “5” in the middle of the screen. The results for Analysis 1 (color and orientation) were 34.8% of the fixations were on areas of interest. The areas of interest represented 25.8% of the screen, so the difference is 9.0% over a random fixation allocation, which implied that the Walther model predicted saliency regions better than chance. For Analysis 2 (color, orientation, and contrast), using the same participants, but a different set of areas of interest, the areas of interest represent 32.4% of the screen, yielding a difference of 6.6%, instead of 9.6%, but again indicating that the model predicted better than chance. For participants with intellectual disabilities, the value was 30.3%, which was 4.5% over a random allocation. In these three cases, the model estimated better than chance, as the values are higher than 25.8%.

5. Discussion

The purpose of this chapter is to summarize and comment on the results of the study reported in this dissertation. This study used two groups of people, those with and without intellectual disabilities. The objective was to determine if there were statistically significant differences between the groups in order to make a recommendation of usability or accessibility for Web design. This study includes attentive and pre-attentive aspects of attention. The first experiment replicated the classic attentive eye-tracking study by Yarbus (1967). He demonstrated that people will look at different areas of a picture when they are presented with different questions and called this goal-directed behavior. Yarbus' original seven questions were combined to create three question types (Pieters & Wedel, 2007). Two extensions were added to the study, an interview with the participants yielding word volumes and recollection of picture elements and decisions by raters on goal-directed behavior.

The pre-attentive experiment used a saliency model (Walther & Koch, 2006) which used a digital picture as input and produced coordinates of points on the picture with high saliency. This model is more efficient and runs on MATLAB, rather than the leading model (Itti, Koch, & Niebur, 1998) which is implemented in C++ and UNIX. Participants were exposed to 30 pictures, three types of 10 pictures each. Three sets of saliency features were used: color and orientation, color, orientation, and contrast, and size. Saliency values were calculated and used to compare the groups. The major results are displayed in Table 21. This chapter discusses the topics of Replication of *The Unexpected Visitor* study, Web Accessibility and Usability, Individuals with and without Intellectual Disabilities Research, Implication for the Design of Educational Materials, Implication for Future Research, and Conclusion. See Appendix H and Appendix J for detailed lists of assumptions and limitations.

Table 21

Summary of Differences Between People With and Without ID

Experiments	Differences
Attentive Experiments	
Goal-Directed Behavior	No SSD
Average Fixation Time per Question per Question Type	No SSD
Proportion of Time Allocated to Question Type	No SSD
Word Volume	SSD
Recall of *The Unexpected Visitor* Elements	SSD
Pre-Attentive Experiments	
Attention to Saliency Features for Color and Orientation	No SSD
Attention to Salient Features for Color, Orientation, and Contrast	No SSD
Attention to Size	No SSD

Note. SSD = statistically significant differences; ID = intellectual disabilities.

Replication of Unexpected Visitor Study

Goal-Directed Behavior

Yarbus (1967) built an early eye-tracking system using a contact lens, a stalk, and a very small mirror. He tied back the eye-lids of his participants, who could tolerate the equipment for only three minutes at a time. They viewed *The Unexpected Visitor* seven times, each time responding to a different goal or question for three minutes, but separated by a few days, presumably, for their eyes to heal. He recorded the scanpaths of his participants. The present study replicated Yarbus' study with non-invasive modern eye-tracking equipment, and allowed each participant to choose how long he or she looked at the picture each time it was displayed. Yarbus noticed different scanpath patterns for each of the questions for a single participant and called this "goal-directed" behavior. He also noticed that the seven scanpaths were similar across participants, which he attributed to their being all of similar educational and cultural background.

This replication of the Yarbus (1967) experiment, based on the decisions of eight independent raters, confirms that goal-directed behavior is characteristic of both students with and without intellectual disabilities, as hypothesized. Yarbus' study did not detail how he determined whether the scanpaths of his participants were all the same or different. A search of the literature failed to yield a methodology to do this; it presumed that they were so different that he made the decision himself. This study found participants in both groups (with and without intellectual disabilities) are both goal-directed, but not statistically significantly different, based on eight independent raters' decisions. However, two cooperating raters found the two groups to be different in terms of goal-directedness, indicating that the determination of whether a scanpath is goal-directed or not is dependent on the method used to make the decision. We know from statistical analysis that the raters' decisions were not random. It is assumed that when a rater made a decision as to whether the scanpaths were the same or different, the rater was using some rule to do that and used the same rule for all of the 34 participants. The two cooperating raters did the same thing initially. Because there were differences in opinion between the two raters, they were not using the same rule. By negotiating a decision for the cases which were different, they effectively applied at least three rules to their decisions, the original two and the negotiated one(s). Under these conditions one would not expect the independent raters and the cooperating raters together to come to the same conclusion. In addition, the cooperating raters are considered to be experts in the field, whereas the independent raters, students in a doctoral level class, would not, in general, be considered experts.

This study provides a framework for analyzing scanpath data in the future, including samples of scanpaths which were deemed to be the same and scanpaths which were deemed to be different. In addition, the present study adds an interview which was administered subsequent to the viewing of *The Unexpected Visitor* and compares responses between participants both for word count and recollection of significant elements in the picture, also something that has not been reported in the literature with respect to this classic eye-study.

Yarbus (1967) recognized that people who were culturally similar had similar eye-tracking patterns. This has been the basis for many cross-cultural eye-tracking studies (e.g., Qutub, 2008). Considering people with and without intellectual disabilities as people from different cultures, based on their scanpaths, the eight independent raters together found no differences between the two groups, and so the conclusion is that they are from the same culture. This study found that individuals, even cooperating pairs, cannot reliably determine group membership for people with and without intellectual disabilities.

High Level Cognitive Goals Hypothesis

Pieters and Wedel (2008) hypothesized that Yarbus' questions were divided into three different types (free viewing, evaluative, and learning) and that the average time spent on the three types should increase, as the questions become more difficult. Participants should choose to spend the least time on free viewing, the most time on learning, and an intermediate time on evaluative questions. This current study does not observe a statistically significant difference between students with and without intellectual disabilities for average time for question type, given the data. The present study finds the average time decreased from free viewing, to evaluative to learning for both groups; this is the opposite allocation from that hypothesized by Pieters and Wedel.

Why would there be a different result between the present study and that of Pieters and Wedel (2007)? One possible response to that question is that the conditions of the two experiments were so different that similar results would be surprising. Pieters and Wedel used the same three types of questions as a framework for an eye-tracking study of a large sample of existing advertising data. They failed to find a statistically significant difference between the evaluative and the learning groups. However, the average times are reversed on the present study (i.e. free viewing was the longest, not the shortest average time).

The Pieters and Wedel hypothesis (2007) was a useful framework for the present study to compare two groups of people, but their 200 participants were told to look at a set of 17 randomized full page food and cooking ads from a popular magazine as they would look at them at home or in a waiting room. The average time spent on an advertisement was four seconds. Using the framework of this study for top-down and bottom-up attentional processes, this would imply that viewing was controlled by a bottom-up automatic response to saliency in the ads, yet they were applying a framework for a top-down cognitive process. They categorized looking at the headline in an ad as free viewing and acknowledged that it was subject to a saliency response. The other two types, which were not statistically different, included reading of text describing the product which was more complex and would therefore take longer.

The average time spent on each viewing (question or goal) of *The Unexpected Visitor* for this current study was 46 seconds for the students with intellectual disabilities and 30 seconds for participants without intellectual disabilities. The average time spent on each question from the replication of Yarbus' study (Lipps & Peltz, 2004) was 1.5 minutes.

The participants in the Lipps and Peltz study used head mounted eye-tracking gear which enabled them to move freely, providing a more realistic (and perhaps more fun) environment than did this current study. Whether or not free head or fixed head viewing has an impact on the outcome is actually a relatively important and empirical issue, which could be pursued in future research. This concerns technical and operational issues, not cognitive issues, but whether technically the head mounted equipment affects the recording of the scanpaths, as participants will move their head rather than their eyes and whether the algorithms built into the eye-tracking system produces different scan paths under those conditions. For a study, such as this one, comparing two groups of people, it may not matter, but might affect cross-study comparisons.

Under the Pieters and Wedel hypothesis (2007), Yarbus' seven questions were grouped into question types which changed the order of the questions somewhat. In addition, under the hypothesis, the expectation was that the average time would increase, as the difficulty of the questions increases, but it decreases. Grouping the questions may, in part, overcome an issue raised for this experiment that the average time decreases due to a fatigue effect for both groups. However, it is more likely that the students viewed longer at the beginning because of the uncertainty about what they would be asked at the end of the experiment. Once they had an overall view of the picture, once they learned how to use the mouse, realized that they were looking at the identical picture each time a question was asked, they reduced the time on each question, as there was little incremental information to be gathered.

The researcher sensed that the responses being given by the students to the questions, because they were retrospective, were based on knowing all the questions, not specific to the question asked in the interview. For example, most of the students with intellectual disabilities when asked what they were thinking on the free-viewing question, gave a list of the people or objects they observed, such as "the objects, the clothing, and the visitor." The study should be restructured, so that the interview takes place after each question, rather than waiting until the end. *The Unexpected Visitor* painting itself may be the cause of the longer time than expected for participants without intellectual disabilities. Another approach might be to use other images as well as *The Unexpected Visitor* under the same conditions.

Web Accessibility and Usability

Web Accessibility

The Rehabilitation Act prohibited discrimination against "handicapped" students in federally funded programs in the US (Section 504). Section 508 of the law was amended in 1998 to require public federal Web sites to conform to a set of Web Accessibility standards to enable use of the Web by people with disabilities. The US Access Board maintains the standards, which are design rules. For example, every time a non-text element (e.g., a photograph) is displayed on a Web site, a description of that element must be available for the reader. Depending on the browser, a description of the image will display as the mouse is passed over the image and the text can be read by a screen-reader. Section 508 standards have been adopted by many state governments and applied to educational technology and Web sites. The World Wide Web Consortium (W3C, 2008a), a volunteer international organization has established a similar set of accessibility guidelines. In the fall of 2006, the Access Board convened a group of accessibility experts, the Technology and Electronic and Information Technology Advisory Committee (TEITAC, 2007), to review the Section 508 standards. TEITAC noted that the current standards focus primarily on disabilities related to sight and hearing and raised the issue of insufficient support for people with cognitive disabilities (TEITAC, 2007).

Usability Versus Accessibility

The overriding objective of this study was to add experimental research to the area of accessibility for people with cognitive disabilities. Specifically, this study was intended to answer the question of usability versus accessibility (Mariger, 2006) for people with intellectual disabilities, based on how they viewed images. Accessibility generally involves standards or guidelines that enable Web sites to work with assistive technology, whereas usability involves design principles that make a Web site easy to use. This study was designed to be general, in the sense that it included a "top-down" experiment, replication of the classic eye-tracking study (Yarbus, 1967) and a "bottom-up" experiment using a modern saliency model, so that it could be replicated with participants with other cognitive disabilities. There is already a rule in the Section 508 accessibility standards that requires any Web site with a feature that is timed to allow the user of the Web site to change the timing to accommodate the fact that it takes people with intellectual disabilities longer to perform most tasks (see Appendix A, item p).

This study concludes that usability is the correct approach for the design of Web sites, based on the second experiment, which studied immediate responses to Web sites and other images and found no difference between people with and people without intellectual disabilities. The study used very recent technology in vision science as the basis for the conclusion. The creation and testing of computer saliency models of visual attention (e.g., Itti, Koch, & Niebur, 1998; Walther & Koch, 2006) has been a leading edge in the field of vision research. These models use, as input, a digital picture and produce two dimensional "Areas of Interest," where people would be expected to look during the first few seconds they look at a picture. The Walther model (Walther & Koch) is a new saliency model compared to the Itti model (Itti, Koch, & Niebur) and this current study was exploratory in the sense that it was one of very few that have used a saliency model, as a standard against which to compare two groups. For example, Neuman, Spezio, Piven, and Adolphs (2006) used the Itti model to study facial recognition by people with and without autism. The Walther model can create "Areas of Interest" which are irregular and follow the boundaries of an object; the Itti model uses circular areas of interest around points identified as salient. This study used the Walther model in an "Itti" fashion, with rectangular shaped areas of interest (supported by the Applied Science Laboratories' EyeTrac 6000 system) because it was hypothesized that the Walther model could achieve the same functionality as the Itti model.

Considering the two models, the Walther model appeared to be the more parsimonious choice. The Itti model provided a saliency value on an equal interval scale for every point on a picture, making it very slow to run. It also required a UNIX operating system, which needed an advanced workstation, was complex and difficult to learn. The Walther model was written in MATLAB, had a graphical user interface, ran on any operating system which was supported by MATLAB and was much faster. It produced coordinates for one salient point each time it is ran, so the first point had the highest saliency score, the second point, the second highest, etc. Saliency score was an ordinal ranking for the Walther model, rather than a value on an equal interval scale in the Itti model. A picture was viewed as a 4 X 5 grid and the saliency scores were assigned to cells, depending on their coordinates. The results were compared to another similar study (Foulsham & Underwood, 2008) which used the Itti model and people without known disabilities and they were very close, confirming the Walther model could be exchanged for the Itti model under the conditions of this experiment.

An equation was created to determine a saliency value for each person's viewing of each picture. Using three types of pictures, 10 used in previous saliency model studies, 10 used in a fourth grade online geomorphology course, and 10 award-winning Webby Web sites, the study indicated no statistically significant difference between people with and without intellectual disabilities for viewing Web sites and pictures from the geomorphology course. There were differences between the groups for some of the pictures which had been designed and tuned to people without known disabilities, which would be expected. This was strong support for the recommendation of usability as opposed to creating standards to accommodate for differences in bottom up viewing of images.

Individuals With and Without Intellectual Disabilities Research

Attentive Processes

The present study fails to observe a difference in average time and proportion of time for question type between individuals with and without intellectual disabilities while viewing *The Unexpected Visitor,* which would not be expected based on the meta-analysis review of studies of individuals with and without intellectual disabilities.

Research indicates that students with intellectual disabilities take longer on virtually all tasks than their CA matched participants (Kavale & Forness, 1992).

This experiment was a simple task in that the participants are required only to look at a picture in response to simple questions. It should take a short time to do. The students with disabilities took longer because of their disabilities. The students without intellectual disabilities took longer because they thought they were taking a memory test and applied strategies. The result was similar times for both groups.

One participant without intellectual disabilities, when asked what she was thinking when she was asked to "Look around the picture" stated, "This is an experiment. What should I pay attention to? I was counting stuff." Use of strategies, such as this, extend the time for analysis. The extremely detailed responses to the interview provided by the students without intellectual disabilities suggested they thought it was a memory test and needed more time to memorize the picture elements. The result was similar average and proportional fixation times between the two groups for question types. Recalling that Yarbus' participants were described as highly educated and cultured, a possible extension to this study might be to recruit a group of high IQ students of the same age to see if they take longer than the other two groups of students.

Pre-Attentive Processes

The second experiment in the present study showed 30 pictures. Each picture was prefaced by an image with the number 5 in a circle in the middle of the screen and followed by a blank screen. In order to determine whether the person was looking at the actual picture or the image with the number 5 on the screen, a fixation analysis was done (see Appendix P). If the first fixation fell in the middle of the screen, it was called an early centralized fixation. For each person and each picture, early centralized fixations were recorded for each person and each picture and early centralized fixations were specifically excluded in the calculation of saliency value. Early centralized fixations were not counted as valid fixations in the present study, which was also considered by Foulsham and Underwood (2008), who ignored the first fixation. One of the surprises of this study was the importance and use of the fixation analysis, as it was so prevalent, it added a step to the saliency value calculation.

More than twice the number of early centralized fixations was observed for participants with intellectual disabilities during this current study. Although some of this can be attributed to the manual operation that was used to start and end data collection for each picture, it would not explain it all. It is more likely that the operational procedures improved over time, as the experimenter became more adept at starting and ending the data collection for each picture. The students without intellectual disabilities were eye-tracked first, when operations would have been less regular, but the number of centralized fixations for participants without intellectual disabilities was less than half of those for students with intellectual disabilities.

Carlin, Soraci, Strawbridge, et al. (2003) conducted a study using participants with and without intellectual disabilities and eye-tracking technology, making it similar to this one. They found that students with intellectual disabilities stay in the center of the screen longer than those who do not have intellectual disabilities. This current study has observed the same pattern. This may be reflective of the theory of Ellis (Detterman, Gabriel, & Ruthsatz, 1982) who suspected a deficit in Very Short Term Memory for people with intellectual disabilities.

Merrill (2005) stated that two studies reported a delay in pre-attentional processes of 100 ms for people with intellectual disabilities, which may also explain the delay. The 100 ms time is based on laboratory studies and may be larger in more realistic environments. This should be considered in the design of future eye-tracking studies for students with intellectual disabilities. It also occurs with people without intellectual disabilities, as Foulsham and Underwood (2008) and this current study discovered. Use of standard software which automatically separates the data for each picture should be used in the future to eliminate the early centralized fixations due to operational irregularities and an analysis of fixation times for the remaining fixations will enable further characterization of this effect.

This present study demonstrated more differences in the first experiment, a study on attention, than it did on the second experiment, a study of automatic response to saliency features in an image. This is consistent with the statement of Merrill (2005) that studies of adolescents and young adults of the same chronological age (CA) that involve *attentive* processes show more differences between people with and without intellectual disabilities than do studies which involve *pre-attentive* processes. This study is also consistent with the research of Roscos-Ewoldensen, et al. (2006) who saw no difference in picture viewing between the groups. Therefore, the present results suggest that differences in performance that are noted between groups arise at later stages of perceptual processing rather than in early stages.

Size Saliency Feature

The present study, using the Walther model (Walther & Koch, 2006) for the saliency features of color and orientation finds no statistically significant difference between the two groups of people, consistent with the Carlin et al. (1995) study. It also shows a statistically significant difference between the three types of pictures (pictures previously used in saliency studies, pictures from a fourth grade Geomorphology class, and award winning Webby Web sites). This current study does not find a difference between people with and without intellectual disabilities for the saliency feature of size, which was the result of Carlin et al. The Carlin et al. (1995) study concluded that individuals with and without intellectual disabilities showed no difference for orientation and color, but did show a difference for size. This current study has supported the first result, but failed to provide support for the size result. The Carlin et al. study was conducted in the laboratory using simple forms and colors and involved a serial search activity. The present study does not find support for the size result, possibly due to the nature of the experiment (free viewing versus search task) and the use of images of naturalistic scenes. In addition, the participants in the Carlin et al. study are identified as having been tested and enrolled in a special education facility in Atlanta and being a mean age of 27.57, which is not the profile of the participants in this study, who have a mean age of 20.5 years and either live at home or in a regular student dormitory at the university. It also may be due to the limited number of fixations (1) and the pictures (1) used in this analysis, which may not be representative of the population.

Implication for the Design of Educational Materials

Attention

The qualitative portion of the first experiment, the interview, makes very clear the significant differences between individuals with and without intellectual disabilities. Although it was not possible for raters in this study to distinguish differences in the scanpaths of the two groups, there are statistically significant differences between people with and without intellectual disabilities for the number of words used to describe the images and the recollection of key features in *The Unexpected Visitor*. The interview, an extension to the classic study, provides insight into the characteristic behaviors of the students with intellectual disabilities. First, the number of words used in response to the questions was significantly different between the two groups, but, as well, the difference increased as the questions became more complex, consistent with the hypothesis of Pieters and Wedel (2007). Many of these participants have difficulty communicating and also have memory problems (Kavale & Forness, 1992), so as the questions become more complex, they say less. The second interesting outcome was the use of guessing, a strategy used by people with intellectual disabilities when they don't know the answer to the question. Recollection of key elements by both groups yielded an interesting result, in that people with intellectual disabilities remember more objects than people, but people without intellectual disabilities remember more people than objects. Reviewing the data regarding recollection of key elements, leads to the observation that the groups are more similar when elements recalled have a lower incidence (e.g., the chair legs) versus elements with high incidence (e.g., the little boy).

The Unexpected Visitor is a picture which has 15 significant elements, instead of two or three as do the pictures in picture groups 1 and 2 in Experiment 2. It is laden with ambiguity, including different expressions on the faces of different people. (Any Web site which displayed a human face, which is highly salient, was precluded from Experiment 2.) It uses different cues to support both sides of any of the questions asked. The painting's age and cultural differences add another layer of complexity to the picture. It has been fascinating to the people who study eye-tracking for over forty years, but the antithesis of a picture which should be used in instructional materials for students with intellectual disabilities. Simpler images with controlled areas of saliency would be preferable to use in instruction, as this study has demonstrated that students with intellectual disabilities respond to saliency, as predicted by the model, better than chance.

Pre-Attention

There is no doubt that the design of a web page or images used in instructional or educational material matters. This study further supports that understanding. Under Experiment 2, both analyses yield statistically significant differences between the picture types. Because the present study is intended to add insight into the debate on usability or accessibility for Web accessibility, the Webby award winning Web sites are of special interest. Under the color and orientation study, a statistically significant difference between the groups was observed, given the data for picture type one (previous saliency studies), but no difference for the second (geomorphology) and third (award winning Webby Web sites). For the color, orientation, and contrast study, no statistically significant difference was observed, given the data, between the groups for all of the three picture types. In both studies, there was no difference observed between the groups for the Webby award winning Web sites, which strongly supports the position of Usability as opposed to Accessibility defined earlier in this chapter.

Figures 9 and 10 show saliency values by picture type for the groups for the two saliency feature sets (color and orientation and color, orientation, and contrast). Picture type 1 was used in developing saliency models and tested with people with no known disabilities, so would be expected to have higher values for saliency overall as the model was developed, tested and tuned using the same pictures. This prediction is true in both feature sets, as illustrated in *Figure* 9 and *Figure* 10. Saliency values should either stay the same or increase between Color and Orientation and Color, Orientation, and Contrast as another saliency feature is accounted for. This is true for picture types 1 and 3, but not for 2.

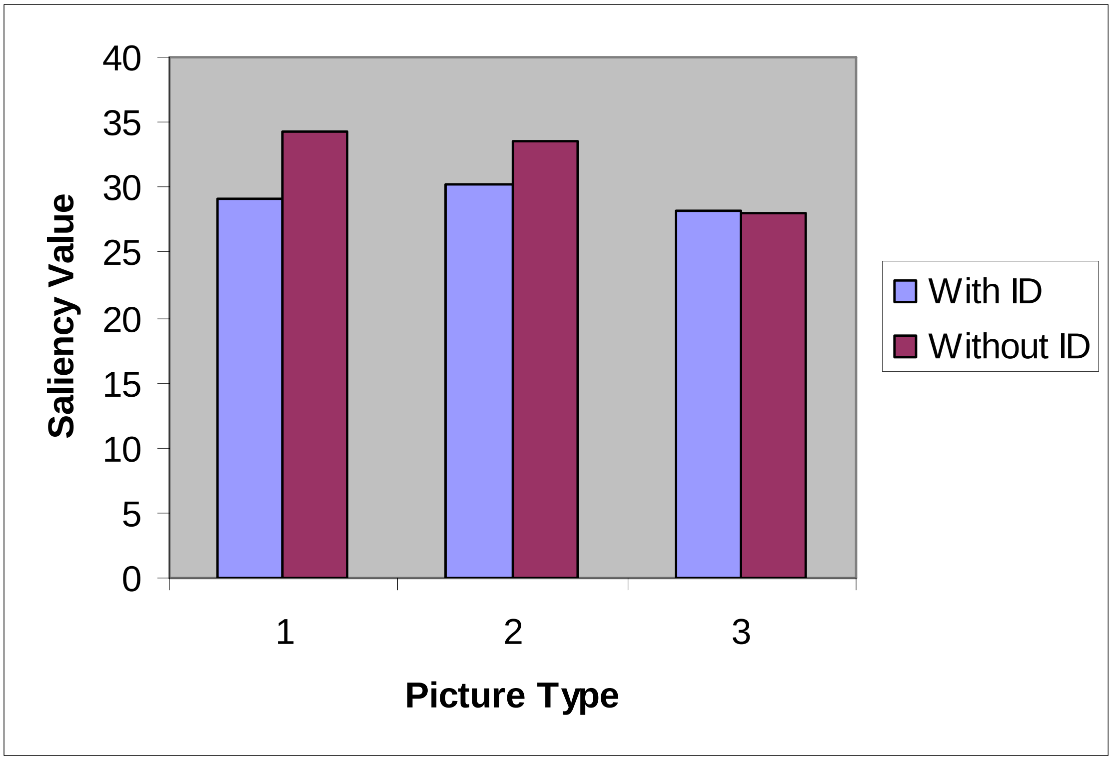


Figure 9. Color and orientation comparisons

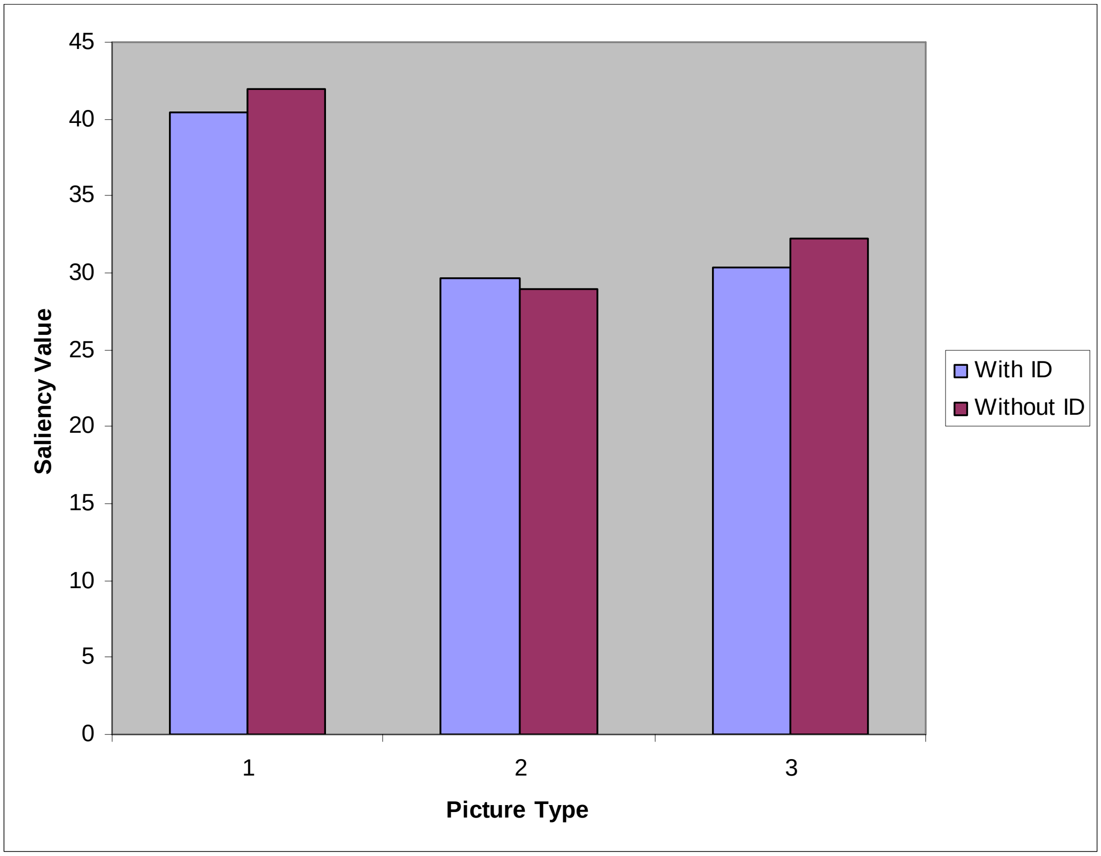


Figure 10. Color, orientation, and contrast comparisons

However, examination of the 95% confidence levels around the means of both Color and Orientation for Picture type 2 and Color, Orientation, and Contrast for Picture 2, indicate that an increase between the two is clearly possible, as the values are within the limits for the mean. This may indicate that reliable means may require a larger sample size.

The implication to designers of images for instructional materials is that both groups respond to saliency, as measured by this experiment, and saliency can be increased. Increased use of color, orientation, and contrast in the design of instructional materials for students with intellectual disabilities would also help all students. This could be done manually by use of a photo-editing tool, but researchers (Su, Durand, & Agarwal, 2004) were developing a saliency model to modify pictures to increase saliency in pictures. Although it is generally accepted that color perception is culturally determined, a Turkish study of color choice (Ece & Celik, 2008) determined that students with mild intellectual disabilities, ages 10 to 12, preferred the colors of red, orange, and yellow, rather than the colors of blue, green, and purple. Specifically, students with ADHD, ADD, and learning disabilities chose red, while students with Down's syndrome chose orange and students with autism chose blue. Participants with intellectual disabilities are also sensitive to line orientation, so exaggerate differences in line orientation to attract the attention of students with intellectual disabilities. For example, a picture of a picket fence is an example of orientation, as the pickets are lined up vertically, but a picture of the same fence with a broken picket would attract attention.

Examination of the mean scores for each of the pictures used in this study as well as examination of the pictures themselves (see Appendix T) reveals a pattern of winners and losers in terms of saliency response. For example, picture number 29, Milk, is very salient and picture 30, the Peace Corps site, is not. Future research might look at each of the pictures and the compare response to saliency by the two groups in order to look for patterns of similarities or differences, which could be applied to educational materials.

Implications for Future Research

Extension to the replication of the Yarbus (1967) study and demonstration that both students with and without intellectual disabilities exhibit goal-directed behavior should pave the way for more research using eye-tracking technology to study people with intellectual disabilities. While we were able to determine that goal-directed behavior was not different for people with and without intellectual disabilities, it would be useful to have an instrument and a scale to provide a number which measures goal-directedness, as measured by independent raters. In one situation, goal-directed behavior was not observed for people with intellectual disabilities, indicating that determination of goal-directedness is dependent on the decision-making method used.

The present study also created a process for analyzing data produced by Yarbus' study, which appears not to have been done before. Yarbus gave examples of scanpaths which demonstrated goal-directed behavior, but never gave examples of scanpaths which didn't represent goal-directed behavior. There are now cases where no differences between scanpaths were found that may be useful for training researchers in the future.

Cases were found where the ASL6000 system indicated that it had recorded a scanpath, but no scanpath was produced. This might be due to a very long fixation on the same spot by some of the students with intellectual disabilities or very close fixations. The present study is not focused at the fixation level, but in a few cases, the students with intellectual disabilities did not fixate on a picture. This may be because they are slow to move to the picture, skipping one or it could be that they don't look in the same location long enough for it to be counted as a fixation by the system. The disability literature mentions a time delay of 100 ms (Merrill, 2005) which would not explain a 5 second delay. In a few cases, multiple fixations for the same area of interest were made sequentially, which may also mean that students with intellectual disabilities may fixate longer than average or move incrementally to another feature in the same area of interest. This is another area which could be pursued.

The literature review indicated that there were efforts ongoing to change a picture to draw the attention of students with intellectual disabilities (e.g., Carlin et al., 2003), but use of multiple types of pictures is not common practice in the field of intellectual disabilities research as it is in eye-tracking research. The present study failed to find a difference between people with and without intellectual disabilities in three cases, color and orientation, color and orientation and contrast, and size. There might be a different response to people with intellectual disabilities with respect to contrast, as it would be expected that the first picture type in the orientation, color, and contrast situation, tuned for people without intellectual disabilities, was no different than for people with intellectual disabilities. Research comparing people with and without intellectual disabilities using available black and white pictures might yield some insight into why this happens. Also cartoons might be used as another type of picture. Pictures which use color and orientation in different ways might be a way to provide better guidelines for the design of instructional materials.

The present study was designed to be general in the sense that both “top down” and “bottom up” experiments were included. The participants in the present study were young adults with and without intellectual disabilities. It could be replicated with young adults with ADHD, Asberger's Syndrome or other disabilities.

Conclusion

The present study combines the research practices of vision science research (e.g., use of saliency models, use of multiple image types, extensive use of eye-tracking technology) and the research practices of special education (e.g., use of participants with and without disabilities, use of independent raters). It demonstrates that study results are sensitive to the image types used and that "bottom up" response in the first few seconds to the saliency features of all three pictures used in the study, in the most natural situation (color, orientation, and contrast), support the position of usability, rather than accessibility.

The present study provides two extensions to Alfred Yarbus' classic top-down eye-tracking study. They are: use of cooperating and independent raters to evaluate the scanpaths and an interview to both motivate participants and to understand the differences between the perceptions of the different groups. The scanpath analysis failed to deny that the two groups of students were the same culturally. However, the large differences between the two groups for the number of words used to describe the painting and the recollection of key elements in *The Unexpected Visitor,* reinforces use of simple pictures with few elements or use of cueing techniques (e.g., Carlin, Soraci, & Strawbridge, et al, 2005) in educational materials for students with intellectual disabilities. Use of pictures, rather than words can be a better way to communicate to people with intellectual disabilities. A good example is the disAbility Navigator (ARC, 2008), an accessible web site which uses pictures for icons in addition to words, (www.disabilitynavigator.org). It is being jointly developed by Fairfax County, Virginia, the ARC (2008) of northern Virginia, and the Helen A. Kellar Institute of Human disAbilities.

The present study offers a methodology to enable researchers to use the operationally simpler Walther model (Walther & Koch, 2006) instead of the Itti model (Itti, Koch & Nieber, 1998). The present study uses the Walther model as a method to compare two groups of participants, using inferential statistics, rather than using another approach to comparing scanpaths such as string editing. Lastly, the present study replicates the Yarbus (1967) classic eye-tracking study, providing examples of scanpath diagrams which are not goal-directed according to eight independent raters. While the results of this study are reasonable, in the end, the better contribution to the literature may be the methodology.

Appendix A

Section 508 Web Accessibility Standards

(Retrieved from http://www.access-board.gov/sec508/508standards.txt)

1194.22 Web-based intranet and internet information and applications.

(a) A text equivalent for every non-text element shall be provided (e.g., via "alt", "longdesc", or in element content).

(b) Equivalent alternatives for any multimedia presentation shall be synchronized with the presentation.

(c) Web pages shall be designed so that all information conveyed with color is also Available without color, for example from context or markup.

(d) Documents shall be organized so they are readable without requiring an associated Style sheet.

(e) Redundant text links shall be provided for each active region of a server-side image map.

(f) Client-side image maps shall be provided instead of server-side image maps except where the regions cannot be defined with an available geometric shape.

(g) Row and column headers shall be identified for data tables.

(h) Markup shall be used to associate data cells and header cells for data tables that have two or more logical levels of row or column headers.

(i) Frames shall be titled with text that facilitates frame identification and navigation.

(j) Pages shall be designed to avoid causing the screen to flicker with a frequency greater than 2 Hz and lower than 55 Hz.

(k) A text-only page, with equivalent information or functionality, shall be provided to Make a Web site comply with the provisions of this part, when compliance cannot be accomplished in any other way. The content of the text-only page shall be updated whenever the primary page changes.

(l) When pages utilize scripting languages to display content, or to create interface elements, the information provided by the script shall be identified with functional text that can be read by assistive technology.

(m) When a web page requires that an applet, plug-in or other application be present on the client system to interpret page content, the page must provide a link to a plug-in or applet that complies with □1194.21(a) through (l).

(n) When electronic forms are designed to be completed on-line, the form shall allow people using assistive technology to access the information, field elements, and functionality required for completion and submission of the form, including all directions and cues.

(o) A method shall be provided that permits users to skip repetitive navigation links.

(p) When a timed response is required, the user shall be alerted and given sufficient time to indicate more time is required.

Appendix B

Web of Science Search

Search	Term 1	Term 2	Responses	Relevant
1	Intellectual disability	Eye tracking	0	0
2	Mental retardation	Eye tracking	3	1
3	Visual Perception	Eye tracking	208	11
4	Visual attention	Mental Retardation	86	3
5	Visual Attention	Intellectual disability	16	0

The search terms visual attention AND eye tracking AND mental retardation yielded only 1 paper, which I had already identified as the closest to my topic, because it deals with naturalistic scenes

Appendix C
Ancestor Search for Eye Tracking Literature

	First Level Sources	Resources Discovered
1.1	Dissertations Abstracts using "eye movement"	1,250 abstracts (hand searched)
1.2	Dissertation Abstracts using "eye-tracking"	55 abstracts (hand searched)
1.3	Google Scholar "Unexpected Visitor"	√Peltz & Lipp, Yarbus Revisited.
1.4	Personal Library of Accessibility Books	√ Koyani, et al. (2004), √ Thatcher, et al. (2006)
1.5	Brigham, The Eye's Have it (UVA)	Brigham. et al. 2001
1.6	Eye-Tracking Methodology (2007). Duchowski, A. (Scene Perception) Clemson	Rayner(1998). √Rayner & Pallatsek(1998). Henderson & Hollingsworth (1998). √ Yarbus (1967).
1.7	Eye-Tracking Methodology (2007). Duchowski, A. (Computational Models)	√ Itti, et al. (1998).
1.8	Eye-Tracking Methodology (2007). Duchowski, A. (Computational Models)	√ Hornof & Cavender (2005). EyeDraw
1.9	Eye-Tracking Methodology (2007). Duchowski, A. (Empirical Guidelines) Berkley	√ Privatera & Stark (2000) ACM – ETRA SIGCHI (for very current research)
1.10	Using Semantic content as cures for better scanpath prediction, Cerf, Frady, & Koch (2008) California Institute of Technology	√Oliva A, et al. (2003). √Itti, Koch & Neiber (1998). (citations = 857) Viola & Jones, 2001a (cited by 1555). Viola & Jones, 2001b, (Face detection algorithm).
1.11	Henderson & Ferreira (2004)	Henderson, Human Gaze Control during real scene perception (2003).
1.12	Recent Dissertations Database search on "eye-tracking"	Russell – established a correlation between eye-tracking and usability while looking at web sites. Grier – studied Faraday's model

1.13	Benjafield (2007) Cognition	
	Second Level sources – e.g., 2.1a - 2 means second level, 1 means it came from 1.1, Dissertation Abstracts Searching for "eye movement"	Third level source/result from second level – duplications indicate an important article.
2.1a	Filippi & Tyron (1995) – study of reading disabled versus not reading-disabled students doing non-reading activities. – found significant differences between eye-tracking patterns.	Abstract – not available under Google Scholar, so presumed to be unpublished.
2.1b	Kotval & Goldberg (1998) EYE MOVEMENT BASED EVALUATION OF HUMAN-COMPUTER INTERFACES (USABILITY, SCANPATH MEASURES**)**	Abstract – multiple books/papers by the pair; Established eye-tracking technology as a legitimate way of studying Web Usability
2.9a	Privitera & Stark	√ Itti, Koch & Neiber (1998), √Mannan, Ruddock, & Wooding (1998) Spatial Vision 10,3,165-188 p. 116 √ Mannan, Ruddick & Wooding 1995 9(3) 363-386 also 10 (3) p. 165-188 √ Noton & Stark
2.9b	West, et al., eyePatterns:Software for Indentifying Patterns and Simularities Across Fixation Sequences.	√ Noton & Stark √ Privitera & Stark √ Yarbus (1967) Ellis & Stark (1986)
2.10	Oliva A., et al. (2003).	√ Itti, Koch & Neiber (1998), which is the saliency model used for which a URL exists but which isn't available online. Google search indicates that the new site is: ilab.usc.edu/bu
2.11	Henderson, Human Gaze Control during real world scene perception (2003)	√ Oliva A. et al. (2003) Liversedge, & Findlay (2000) √ Parkhurst, D., et al. (2002) √ Li, Z. Saliency map in visual

		cortex √Thorpe. (1996). Nature. 381, 520-522. Speed of Processing in human visual system √ Henderson & Hollingsworth (2003) Eye-movements and Visual Memory: Detecting changes to saccade targets in scenes. √ H & H Global Transsaccatic change blindness during scene perception (2003) √ Potter, MC, Fleeting Memories, 13-46 MIT Press; also √ H&H (2003) Eye-Movements during scene viewing: An overview 1998 in Chapter 12 Underwood.
2	Henderson & Hollingsworth (2003a)	√Antes (1974)
2.12	Grier;	√Faraday (2002); Tufte
	Third level sources – e.g, 3.2.11 means it came from 2.11	
3.2.11	Parkhurst, D, et al. (2002) (John's Hopkins)	Ellis. S. R. (1986), Statistical Dependency in Visual Scanning. √Egeth & Yantis (1997). Posner, 1980, Orienting of Attention, Quarterly Journal of Experimental Psychology 32, 3-25. (Too old for library) Treisman & Gelade (1980) √Mannan, Ruddock, & Wooding (1998) Spatial Vision 10,3,165-188 p. 116 √ Mannan, Ruddick & Wooding 1995 9(3) 363-386 also 10 (3) p. 165-188 √Antes (1974) Mackworth & Morandi (1967). (Couldn't access through GMU library).

Appendix D
Guidelines for Reviewing Scan Paths

We are trying to replicate a classic eye-tracking study done by Alfred Yarbus in 1967 with participants with and without intellectual disabilities. On the screen, you see the image that his participants viewed and a copy of the scan paths from a single participant who was asked a different question at each block. The picture has been removed from the scan path at each block because he wanted to know if people adjusted their scanpath when told to look for different things (e.g., How rich or how poor are the people? or How long has the visitor been away?). In the example before you, Yarbus determined that the scan paths all represented different patterns.

The questions in our study are: "Do people adjust their scan paths according to different instructions?" and "Are the scan paths of people with and with out ID noticeably different?" After you have looked at the scan paths from the original study, I will remove this image because we do not want you to compare the scan paths we obtained with his earlier images. Then I will pass out the images from our participants and give you the rest of the instructions.

Distribute the scan paths in sealed envelopes so that the people do not open them before they receive instructions. Then say:

You have been given copies of scan paths of people's eyes as they look at the picture "The Unexpected Visitor" by Ilya Repin. Thirty-four students looked at the pictures, half were students with intellectual disabilities and half were students without intellectual disabilities. Note that the participant number is on the upper right hand corner of each page. Record your answers on the Coding Sheet. Please put your initials on the top of the coding sheet.

Please look at each picture and make a decision as to whether the scanpaths in the 7 diagrams for each individual are the same or different from each other. That is, does it appear to you that the individual is changing visual behavior in some way from block to block? After you answer that question, decide whether you think the diagrams were made by a person with or without intellectual disabilities. We are requiring a response to a both questions, so the option so the response "I can't tell is not available."

You need make two decisions for each of the participants. If you want to separate them to determine which belong to ID or non-ID groups, it’s OK, but the coding sheet needs to be filled out.

Appendix E

Scan Path Analysis Coding Sheet

Participant Number	**The 7 Diagrams are: (Circle one)**		**The person is: (Circle one)**	
1	The Same	Different	ID	non-ID
2	The Same	Different	ID	non-ID
3	The Same	Different	ID	non-ID
4	The Same	Different	ID	non-ID
5	The Same	Different	ID	non-ID
6	The Same	Different	ID	non-ID
7	The Same	Different	ID	non-ID
8	The Same	Different	ID	non-ID
9	The Same	Different	ID	non-ID
10	The Same	Different	ID	non-ID
11	The Same	Different	ID	non-ID
12	The Same	Different	ID	non-ID
13	The Same	Different	ID	non-ID
14	The Same	Different	ID	non-ID
15	The Same	Different	ID	non-ID
16	The Same	Different	ID	non-ID
17	The Same	Different	ID	non-ID
18	The Same	Different	ID	non-ID
19	The Same	Different	ID	non-ID
20	The Same	Different	ID	non-ID
21	The Same	Different	ID	non-ID
22	The Same	Different	ID	non-ID
23	The Same	Different	ID	non-ID
24	The Same	Different	ID	non-ID
25	The Same	Different	ID	non-ID
26	The Same	Different	ID	non-ID
27	The Same	Different	ID	non-ID
28	The Same	Different	ID	non-ID
29	The Same	Different	ID	non-ID
30	The Same	Different	ID	non-ID
31	The Same	Different	ID	non-ID
32	The Same	Different	ID	non-ID
33	The Same	Different	ID	non-ID
34	The Same	Different	ID	non-ID

Appendix F
Data Analysis for Experiment 1, Analysis 1

The ASL600 Eye-tracking system produces a raw data file with an .eyd extension. The names of the files were constructed including the numbers assigned to the participants, but not the names. The manual start and stop capability of the ASL6000 software was used, which allowed the operator to start and stop recording of the data and created a unique segment in the raw data. It produced the raw eye gaze data for each question into a separate segment, which was be easily processed by subsequent steps.

The following steps were performed in order to produce the scan path diagrams for Experiment 1, Analysis 1:

1. Create a folder with a name including the participant's number (e.g. Person130) to hold the files and the scan path diagrams, preferably on another drive.
2. The Unexpected visitor was converted to a .jpg file with dimensions 640 X 452 using Faststone Image Viewer maintain the same aspect ratio as the original.
3. The Eyenal program was run, choosing the Make new fixation file alternative. Default settings will be used by responding OK to default settings. The number of the person who is being analyzed will be included in the name of the fixation file (e.g., EX111.fix). The fixation file has a .fix extension.
4. This assumes that check target points has already been done. The coordinates of number 1 and number 9 will be saved.
5. A Screen shot of the Calibration screen was taken using the Prnt Screen key, followed by Programs>Accessories>Paint>edit>paste and save as a .bmp file name including the word calibration.
6. A copy of this screen shot was made with another name (e.g., testcalibration)
7. FixPlot requires the entire ASL6000 system to be up and running, so must be done in the lab. FixPlot was run and the coordinates for 1 and 9 will be entered in V1 and V2. The default box will be checked; the scene plane box will be checked to ensure it is set at 0.
8. Using the calibration screen, the first point will be clicked and a small label P1 will be observed. The ninth point will be clicked and the label P2 will appear.
9. The bitmap for the calibration copy created in step 7 above will be opened. The "use default on attachment coordinates" will be chosen.
10. The Properties>Other options was chosen and the option to suppress the background is checked.
11. The Append-Fix-AOI command will be used to open the fixation file.
12. Right clicking on the screen will give a list of sequences and enable turning them on and off. The segment for scan path of interest is chosen.
13. Using the command Save as image, for each segment, the file was saved in the folder created in the first step with the participant's number and the segment number and saved as a .bmp file, completing the processing required in the lab
14. The next few steps are the post processing to produce the paper diagrams.

15. In order to reduce the file size, the files were be saved as a .jpg file using Faststone Image viewer and all files will retain the same names.
16. The Unexpected Visitor picture (from step 2) will be copied to the folder with the same name as the other images except that it will use a zero segment.
17. Highlight all files in the folder.
18. Select the tool FinePrint, all files in the folder will be highlighted and select 8 images per page, which prints an image similar to that in Yarbus's book (*Figure* 3 in this document).
23. Each page was scanned using an EPSON CX7400 scanner to create a .pdf file.

Appendix G – Experiment 2 Image Preparation

Preparation for Experiment 2 depended on the type of image being used for the stimulus. There were ten of each of three types of images – images used in previous vision studies (Walther, 2007; Itti, Koch, & Neibur, 1998) which are generally wide angle views of naturalistic scenes, close-up images used in a geomorphology course (Bannan-Ritland, et al., 2006), and Web sites which were selected from the 2007 and 2008 Webby Awards (Barbarian Group, 2008).

Web Sites

The Webby award winning Web site was searched for Winning Web sites which did not have people's faces, did not have moving components, and were able to be copied using Windows ScrnPrint function without error. The files were be run through Programs>Accessories>Paint>edit>paste and saved as .bmp files with a descriptive name. The resulting file were edited by Photo Shop to remove the windows headers and saved as both .bmp and .png formats and reduced in size to no more than 12 inches in one direction. The Saliency Tool Box 2.1 program was run six times as a test to ensure that the Web site had six saliency points. If not, then the web site will be rejected as a candidate. The Saliency Tool box had a size limitation which was be exceeded by the Web sites used, so the size is reduced by the Tool box. The option of interlaced or not was offered and it was declined.

Natural Images used in Landscapes

These naturalistic landscapes came from two sources. The landscapes from the Itti model were provided as .ppm files which are accepted by the Saliency ToolBox, but were not accepted by Photoshop or Paint. For this reason, these images were entered into Saliency ToolBox and the original image will be saved as a .bmp file, which also includes the scale markers added by the Saliency ToolBox. The pictures used in the Walther study were provided as .png which was accepted by the Saliency Toolbox, Photoshop, and Paint. They were, where possible, increased in size to make with one dimension eight inches.

Geomorphology Images

These images were provided in .jpg format, and were converted to .png format for entry into the Saliency ToolBox and were accepted by both Photoshop and Paint. They were adjusted to a 6X8 inch size for display.

1. The pictures were loaded into PowerPoint and were retained in a file that was used to run the PowerPoint. The pictures were stretched in each of four directions to cover the PowerPoint screen. When this was completed, the PowerPoint was saved and run set at full screen and each of the screens was captured with a

standard procedure recommended by the ASL Documentation for FIXPLOT (p. 4). The steps were use Prntscreen on the keyboard, programs>accessories>paint> Edit>paste. Then use File and save as filename. The file name convention included the slide number (01 to 30) followed by a PP indicating it was created from the PowerPoint, a short abbreviation to identify the picture (e.g, ball for balloon) and the extension .bpm (as was the calibration screen). These files (including the Calibration screen) were placed on both the stimulus and the system laptop.

2. Each of these was also run through the Saliency Tool Box six times to determine the Walther coordinates that were used for the saliency points for the first six areas of interest. Because of the requirement to use pictures which were already used in saliency studies, some of these files did not have six saliency points, so in a few cases, there were fewer than six saliency points.

3. The areas of interest were created as files with the extension .aoi in the ASL6000 Eyenal program with the naming scheme ensuring a name no longer than 10 characters:
    a. Image Number (1-30)
    b. Short Image description (4 or less)
    c. Saliency score (7-2)

    An example would be 01_ball_7. The names were stored in Excel with a sheet for each of the two main analyses (Orientation and color, Orientation, color, and contrast). The areas of interest for the size experiment were created using the capabilities of the ASL system to determine the actual ASL coordinates of points on the screen and these were used for the size experiment.

4. A spreadsheet was used to maintain the file names, the area of interest names and coordinates before and after translation.

5. Those six saliency regions were entered into the ASL6000 system via the Eyenal Analysis program, using the above naming scheme. This program allows the operator to define a rectangle which includes the object of interest, by defining the right, left, top, and bottom coordinates of the rectangle in the ASL6000 coordinate system. Overlapping areas of interest are not allowed, as they confound the interpretation of the fixations and the reports produced by the ASL6000 system. It was determined that a grid of 4X5 or 20 cells would be ideal (since it would allow the possibility of future scanpath comparisons and each cell represented a convenient 5%) and it was created and the coordinates of each cell determined. The ASL coordinate range is 240 X 260, so each area of interest was 60 X 52. A method way of converting those saliency points to the ASL6000 coordinates using a formula provided by ASL which required 2 points to be known in each coordinate system was used to convert the coordinates to the ASL coordinates. Each coordinate was then assigned to one of the 20 cells, which were assigned the

letters A though T. If multiple coordinates for a single picture fell in the same cell, the second area of interest was eliminated and the value added to the first occurrence. This reduced the number of areas of interest for some pictures, but preserved the saliency information provided by the model and maintained a consistent total saliency score across each picture. The areas of interest were entered for each picture, for each of the experimental analyses into the ASL6000 AOI process, using a special naming technique for the file. The folder PICS1 contained the area of interest files for the first experimental Analysis; the folder PICS2 for the second experimental Analysis, and PICS5 for the third experimental Analysis. Each folder contained the area of interest files, one file for each picture. They are named using a special format (e.g., pics1_00007.aoi, which contains 6 areas of interest), so that the Eyenal software can quickly analyze the files.

6. Scoring for this experiment was a ranking which was the product of the saliency score and the fixation value. This is a two step process. The results of the Fixation Sequence Report from the ASL EYENAL program were used as the basis for scoring.

First, recall the participants were directed to first look at the 5 in the middle of the screen. It was possible that the first fixation occurred on the 5, not on the picture. For this reason, the coordinates of the square surrounding the 5 were determined. The horizontal coordinates were 124.863 to 135.101, the vertical coordinates were 113.028 to 126.127. If both came within the range, then it was determined that the viewer was looking at the five. The first fixation was checked against those coordinates. If the first fixation was found to be in the box, the second fixation was checked, and so on to determine for each the picture where the first fixation on the picture occurred.

7. The Fixation adjustments were used. See Appendix P.

8. Second, this study looked at the first fixation in an image from a person followed by the second through fourth fixations and calculates a Saliency score for each. The score was the product of the saliency score and the fixation value. The saliency score was calculated using this rule: (7 if highest saliency from model, 6 next highest, down to 2 for the 6 generations run in the experiment, plus 1, if there is no area of interest and not identified by the model and 0, if the fixation is not recorded). The fixation value runs from 5 (first fixation) down to 2 for the fourth fixation. In the case of the third (size) Analysis using the elephant picture, the maximum number of fixations that applied was one, so only the first fixation was considered. There were two situations, the large elephant was first, or no salient area was identified in the picture.

Appendix H

Detailed Assumptions of the Study

The following are the detailed assumptions of the study, prior to beginning the research.

1) The participants for the study will be LIFE (Welcome to Mason Life, 2007) students. Should there be insufficient students volunteering, the Northern Virginia ARC organization (ARC, 2008) will be available.
2) Individuals with intellectual disabilities who use the World Wide Web will be able to perform the two experiments in this study.
3) The study will be able to be conducted within a one hour session.
4) The Applied Science Laboratories 6000 EyeStart system consisting of bright pupil eye tracking of the left eye, 60 Hz optics attached to chinrest, control unit with three channels of digital output, two seven inch LCD monitors, cables and analysis software will support the requirements of the experiments described in this proposal. This system is supposed by a Dell Vostro 1500 and a Dell Latitude D830 system with a built-in RS-232 serial port. The system does not support video, play-back features, or head movement by the participant.
5) Portability of the system is supported by a rugged, waterproof case on wheels designed for transporting photographic equipment and configured to hold system components via foam inserts, use of lap-top computers, and use of two seven inch LCD monitors on a stand instead of two 9 inch monitors. The case (33 pounds) plus the equipment weighs less than 50 pounds. The 17 inch monitor and two laptop computers will be carried separately.
6) Support to the eye-tracking system is provided remotely for a year by Applied Science Laboratories.
7) The system supports auto calibration, although a special training session in Bedford, MA is required.
8) Nancy Bazar was adequately trained by attending a full day on site training session on May 16, 2008.
9) The MATLAB and Saliency Toolbox 2.1 work according to specification.
10)The study includes a minimum of 32 participants – 16 with and 16 without intellectual disabilities.
11) eyePatterns, ScanPath software is being developed by Rochester Institute of Technology. They have said (April 18, 2008) it will be available as open source software for release at the end of the summer, 2008, so it may be able to be used with this project.

Appendix I

Detailed Limitations of the Study

The following limitations of the study were known prior to beginning the research.

1) With the exception of the Unexpected Visitor, the scenes in this study did not include human faces, as facial recognition, in itself, has become a field in its own right.
2) The study, a replication of Carlin et al. (1995) did not include results related to one of the variables they studied, form, as this is not supported by the saliency models or the structure of this study.
3) Due to attention spans of participants with intellectual disabilities, a eye-tracking session was limited to one hour.
4) No search of eye-tracking literature in the advertising field, instructional technology, and the Congressional Record was attempted.
5) Literature review was an on-going effort.
6) The ASL6000 EyeStart system supports rectangular Areas of Interest which may be overlapping, so the Areas of Interest were near squares which were all sized the same and which did not overlap for any picture.
7) The ASL6000 EyeStarter system supports only static images, but does support the requirements of this study. It does not support “heat maps.”
8) Starting and stopping of recording for each image was done manually, rather than using special purpose software such as E-Prime from Psychology Tools, Inc. ($995.00) which interfaces with the ASL6000 system.
9) APA flaws exist.
10) Thirty-two participants was a minimal number; the study could be improved with more participants.
11) Stimuli were presented via PowerPoint presentations, rather than software designed for the purpose; this may cause timing delays.

Appendix J

Human Subjects Authorization

GEORGE MASON UNIVERSITY | Office of Research Subject Protections
Research 1 Building
4400 University Drive, MS 4C6, Fairfax, Virginia 22030
Phone: 703-993-4121; Fax: 703-993-9590

TO: Rick Brigham, College of Education and Human Development

FROM: Sandra M. Sanford, RN, MSN, CIP SMS
Director, Office of Research Subject Protections

PROTOCOL NO.: 5921 Research Category: Doctoral Dissertation

TITLE: Web Usability or Accessibility: Comparisons between people with and without intellectual disabilities in viewing complex natural scenes using eye-tracking technology

DATE: August 1, 2008

Cc: Nancy Bazar

At its convened meeting on July 23, 2008, the George Mason University Human Subjects Review Board (HSRB) reviewed and approved the above-cited protocol.

Please note the following:

1. Copies of the final approved consent documents are attached. You must use these copies with the HSRB stamp of approval for your research. Please keep copies of the signed consent forms used for this research for three years after the completion of the research.
2. **Any modification to your research (including the protocol, consent, advertisements, instruments, etc.) must be submitted to the Office of Research Subject Protections for review and approval prior to implementation.**
3. Any adverse events or unanticipated problems involving risks to subjects including problems involving confidentiality of the data identifying the participants must be reported to Office of Research Subject Protections and reviewed by the HSRB.

The anniversary date of this study is July 22, 2009. **You may not collect data beyond that date without GMU HSRB approval.** A continuing review form must be completed and submitted to the Office of Research Subject Protections 30 days prior to the anniversary date or upon completion of the project. A copy of the continuing review form is attached. In addition, prior to that date, the Office of Research Subject Protections will send you a reminder regarding continuing review procedures.

If you have any questions, please do not hesitate to contact me at 703-993-4015.

Appendix K

Informed Consent

Accessibility or Usability: Comparisons between people with and without Intellectual Disabilities in viewing complex naturalistic scenes using Eye-tracking technology

INFORMED CONSENT FORM

RESEARCH PROCEDURES
This research is being conducted to better understand how people view real-life pictures and Web sites in order to design better Web sites for people with disabilities. The study is open to people between the ages of 18 and 27. If you agree to participate (or you agree to allow your adult child with intellectual disability to participate), you (or your adult child) will be asked to attend a one hour session at George Mason University campus in Fairfax, VA to view pictures which appear on a computer screen which records eye movements.

RISKS
There are no foreseeable risks for participating in this research.

BENEFITS
There is no benefit to you (or your adult child) as a participant, other than to further research into the design of Web sites for people with and without disabilities. In addition, the study may benefit other researchers who are studying the same area.

CONFIDENTIALITY
The data in this study will be confidential. Each person will be assigned a code number and which will be kept with the consent and/or assent form stored in a locked drawer, with access by only the lead researcher. All data files and results of the study will include only the number assigned, not your name.

PARTICIPATION
Your participation (or that of your adult child) is voluntary, and you may withdraw from the study at any time and for any reason before the completion of the session. If you (or your adult child) decide not to participate or if you (or your adult child) withdraw from the study, there is no penalty or loss of benefits to which you (or your adult child) are otherwise entitled. At the completion of the session, you (or your adult child) will receive $10 and will sign a form stating you received the money. There are no costs to you or any other party.

CONTACT
This research is being conducted by Nancy Bazar, Department of Education of George Mason University. She may be reached at 301-910-9357 for questions or to report a research-related problem. Her faculty advisor is Dr. Rick Brigham at George Mason University who may be reached at 703-993-1667. You may contact the George Mason University Office of Research Subject Protections at 703-993-4121 if you have questions or comments regarding your rights as a participant in the research. This research has been reviewed according to George Mason University procedures governing your participation (or participation of your adult child) in this research.

CONSENT
I have read this form and agree to participate in this study or agree to have my adult child participate.

____
Name of Legally Authorized Representative

____
Date of Signature

Version: July 23, 2008

Appendix L
Supplementary Information

Supplementary Information

Name of Person Signing Consent Form ___________________________

Telephone Number ____

Name of Study Participant ___________________________________

Gender of Participant_________

Birth Date (MM/DD/YY)_________

Internet or Web User? ________

Wear Hard Contact Lenses?_______

Version: June 17, 2007

Appendix M
Assent Form (Short)

Assent Form

My parent (or guardian) knows about this Picture Viewing study which will take less than one hour and says it's OK for me to be in the study, if I want to. I do want to be in the study, but I know that I can stop being in the study any time I want to. I know that Nancy Bazar and her teacher, Dr. Brigham, and Dr. Graff can talk about the study with my parent (or guardian), but will not talk about it with anyone else who is not working on the study unless I and my parent (or guardian) say it is OK. I also know that my name will not be on any of the reports. I can call Nancy Bazar (301) 910-9357 or Dr. Brigham (301) 993-1667 any time I have any questions.

____

Signature of Adult Child
Date

☐ I have solicited the assent of the adult child.

____

Signature of Person Obtaining Assent/Consent
Date

Appendix N

Assent Form (Long)

ASSENT FORM

RESEARCH PROCEDURES

The reason for this study is to learn how people look at pictures, so we can help teachers make better Web sites for students to learn. If you want to be in the study, you will sit for about one hour looking at pictures. You will sit in a chair in front of a computer screen. You will rest your chin on a chin rest which has a small camera attached to it. There is a head rest to help you keep your head still, so the camera can keep track of where your eyes move. It will all take about one hour to finish.

RISKS AND BENEFITS

You will not lose any of your rights by being in the study. The things I find out may help teachers make better Web sites with pictures.

CONFIDENTIALITY

Your name will not be on any of the reports that I produce. All of the information about your eye movements will just show as numbers.

PARTICIPATION

You don't have to do this study if you don't want to. If you change your mind after we start and want to stop that is OK. I will not get mad and nothing will happen to you. There will be a ten dollar gift for completing the study.

CONTACT

My name is Nancy Bazar, and I am studying to get a PhD in Education at George Mason University. You can call me at this cell phone number (301-910-9357) if you have any questions about this study. You can also call my teacher, Dr. Brigham, at George Mason University, at this phone number 703-993-1667. The George Mason University Office of Research Subject Protections knows all about my research and said that it was OK for me to do it. You can call them at 703-993-4121 if you have any questions about being a part of this research.

CONSENT

I have read this form and I agree to be part of this study.

Name____

Date______________________

Version: June 18, 2008

Appendix O
Recruiting Script

Recruiting Script

Hi! My name is Nancy Bazar and I am a graduate student studying how people look at pictures using eye-tracking technology for the purpose of improving Web site design for learning. I am looking for people on campus between the ages of 18 and 27, who use the Internet and who do not wear hard contact lenses to participate in the study. Do you meet those qualifications?

The testing is done on campus as soon as possible. It will take one hour and basically, you sit in front of a computer screen with a chin rest with an attached camera, looking at a computer monitor viewing pictures. The eye-tracking technology keeps track of where you look on the picture.

You will need to sign a consent form and I will give you $10 at the completion of the study.

Do you have any questions?

If you have any friends that meet the qualifications, I would appreciate you telling them about this study.

My cell phone number is 1-301-910-9357.

Appendix P
Fixation Analysis
Adjustments

The following Fixation adjustments were identified and used as the first step in every saliency value calculation.

For Experiment 2, the Quick Pictures Experiment, three images were displayed for each picture – an image with a number 5 in the middle, the picture, and then a blank screen. The participant was told to look at the five in the middle of the screen then to look around the picture. The horizontal coordinates that comprise the box around the 5 were124.863 – 135.101, the vertical coordinates were 113.028 – 126.127. If a fixation occurred within these boundaries, it was assumed the participant was looking at the five in the middle of the screen. These numbers are the same for the two experiments. These numbers were confirmed by one person, but on two occasions separated by at least a week.

1. Person 124
    - No adjustment required
2. Person 125
    - Skip 1st fixation for 11, 14
3. Person 126
    - No alterations required
4. Person 127
    - Skip 1st fixation for 10, 13, 14, 15, & 16
5. Person 128
    - Skip fixation 24
6. Person 129
    - Skip 17(2), 18, 21
7. Person 130
    - No adjustment required
8. Person 131
    - Skip fixations 26(2)
9. Person 133
    - No adjustment required
10. Person 134
    - No adjustment required
11. Person 136
    - Skip 1st fixation for 12, 20
12. Person 137
    - Skip 1st fixation for 3, 19, 25
13. Person 138

- Skip 1st fixation for 19

14. Person 139
    - No alterations required
15. Person 141
    - No alterations required
16. Person 142
    - Ignore 1st fixations for 2(3), 3(2), 4(2), 5(2), 6(1), 7(2), 8(2), 9,10,11,12(2), 13,14,15,17,18,21(2), 22,24,25,29
17. Person 144
    - No alterations
18. Person 147
    - Skip 1st fixation for 8,9,12
19. Person 149
    - No alterations
20. Person 150
    - Ignore the first segment, as it was spurious, but the numbers below represent the recorded segment number.
    - Ignore the 1st Fixation for 2,3,4,5,7,8,9,10,13,14(2),15,17,19,20,21(2),23(2),24,25,26(2),27,28,31
21. Person 151
    - Skip 1st fixation for 2(2),3,4,9,12,18,23
22. Person 152
    - Skip 1st fixation for 2,3,4,5,8,9,29
23. Person 153
    - Skip 1st fixation for 7,8,9,10, 11(3),18
24. Person 154
    - Skip 1st fixation for 1,2,3,4,5,6,7,9,12,13,14,15,16,17,18,20,21,22,23,24,27,28
25. Person 157
    - No alterations required
26. Person 159
    - Skip 1st fixation for 12, 22(2), 23, 27
27. Person 160
    - No alterations required
28. Person 161
    - Skip 1st fixation for 27
29. Person 164
    - No alterations required
30. Person 165
    - No alterations required
31. Person 166
    - No alterations required

32. Person 167
    - Skip 1st fixation for 1,17, 20(2).
33. Person 168
    - Skip 1st fixation for 1,2(2),3,4,5,7,8,9,10,11,12,13,14,20,23,24,25,26,27,30
34. Person 169
    - No alterations required

Observations

Cases were noticed where the ASL6000 system indicated that it had recorded a scanpath, but no scanpath was produced. This might be due to a very long fixation on the same spot by some of the students with intellectual disabilities. The present study is not focused at the fixation level, but in a few cases, the students with intellectual disabilities did not fixate on a picture. This occurred in both experiments. This may be because participants are slow to move to the picture, skipping one or it could be that they don't look in the same location long enough for it to be counted as a fixation by the system. The disability literature mentions a time delay of 100 ms (Merrill, 2005) which would not explain a 5 second delay. In a few cases, multiple fixations for the same area of interest were made sequentially, which may also mean that students with intellectual disabilities may fixate longer than average or move incrementally to another feature in the same area of interest. A very short scanpath was created in one instance.

Appendix Q
Review of Pilot Study

This section will serve as a short case study for those considering use of eye-tracking for the first time. As eye-tracking began, a number of problems were identified with the proposed operational process. The ASL6000 has multiple alternatives for collecting data and separating the data of one image from another. The best way is to use an automated connection between third party software. I knew one laptop required a serial port, but did not realize both laptops required parallel ports to automate the process and replacing the laptops would have entailed an additional cost of over $3,000. In addition, software which manages the automated interface (e.g., E-Prime from Psychology Tools, Inc. is an additional $995). The ASL6000 allows a single character to be entered into the data as the data is being collected, but, after eye-tracking a few people, it was determined that the feature was not supported in the ASL6000 software version which was being used and I did not want to upgrade the software in the middle of the experiment. It also had the disadvantage that a problem in separating the picture data would not be discovered until off-line analysis was being done. The third approach, which was difficult to do, was to manually turn the recording on and off between pictures. This had the advantage of enabling the operator to know immediately if 30 pictures had been collected correctly and permitted a re-run, if there were more or less pictures. It also separated each picture into a sequence file, which was supported by the software to very easily produce the reports needed. This manual process was practiced and eventually mastered using a two handed process – using the right hand to position the cursor over the start and stop buttons and the left hand to left click at the same time. Occasionally, static would interrupt the process, requiring a re-run. The re-runs of the second experiment were not considered to be an issue, as only the first four fixations were used, which were automatic responses, according to the pre-attentional phase concept underlying the study. There were two false starts with the first experiment, one when a participant used the mouse just at the moment the first picture displayed causing the first question to be skipped, and another time when the mouse wasn't plugged in, both of which were quickly identified and the experiment re-initiated.

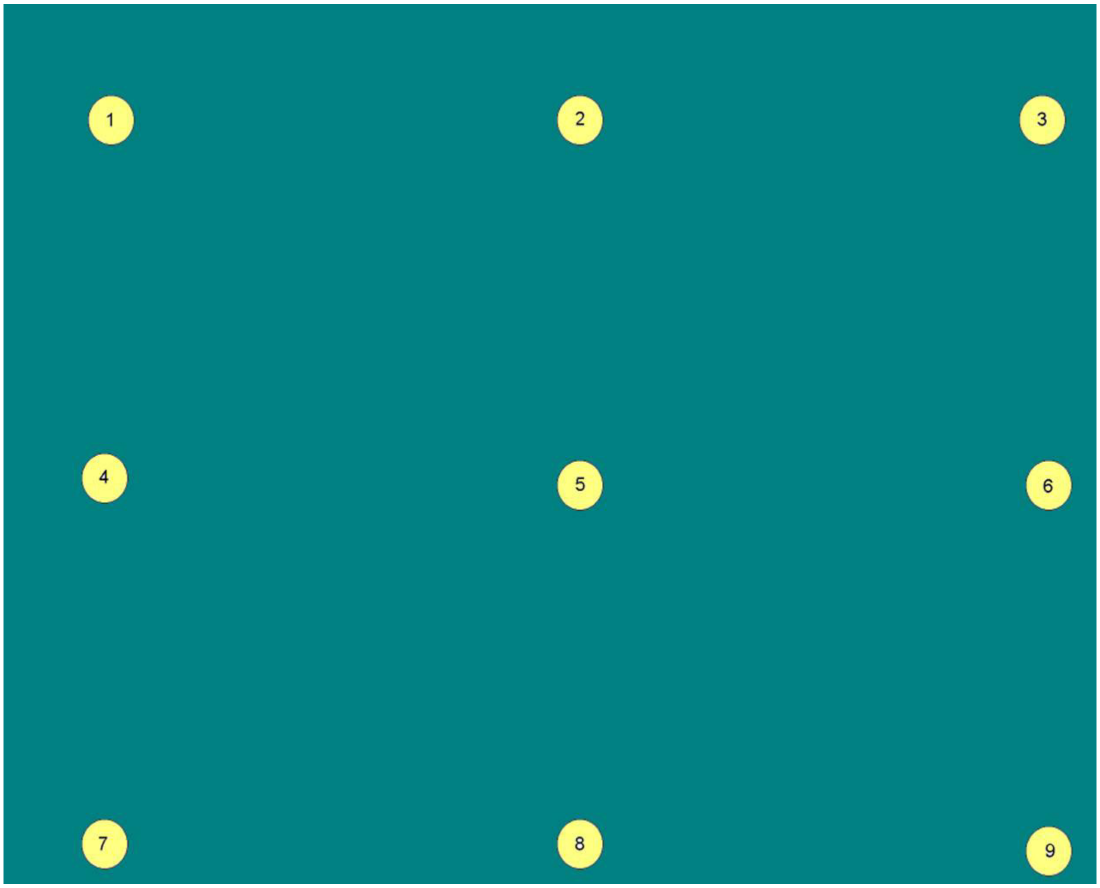
There was a second problem identified during the initial data collection. The calibration process was taking up to 45 minutes to do when it should have taken a few minutes. The output from each recording session was produced and analyzed by this researcher. Although improper calibration procedures, exceptional characteristics of the participants (e.g., people over 50 are difficult to track due to physical eye changes) or head movement by a participant can be blamed for incorrect data, there were two cases, where the participants were the text-book and near text-book calibration candidates, yet the horizontal and vertical coordinates produced were very large negative numbers. The data was sent to the Science Laboratory (ASL) for analysis and ASL determined that the calibration was marginally acceptable for the first one and not acceptable for the second one. ASL responded by sending two senior technical people to visit the lab to physically inspect the equipment and determined that the camera had been installed upside down, probably because of the way we packed it in the new hard-sided shipping case. When the camera was repositioned, calibration was simple and fast.

At that point, a third issue which had been apparent during early testing was resolved. The initial collection of data for the first experiment was done with a minimum of 30 seconds applied to the viewing of each of the screens for *The Unexpected Visitor*. This constraint was causing frustration and distraction on the part of the some of the participants who tried to move to the next screen prior to the thirty second minimum. It was decided to drop the minimum. Also, it was observed that students were not using the mouse, when they could have, so they were taking three minutes for each question, possibly interpreting the experiment as a memory test. Even the students without intellectual disabilities did not use the mouse, so the researcher directed the student's hand to the mouse prior to the beginning of the PowerPoint to ensure they would remember to use the mouse. In addition, if the student took a full three minutes for the first question, or exhibited some level of frustration, they were reminded once that they could use the mouse. With the above changes, the pilot test period ended and actual collection of data for the experiment began.

There were 41 participants reported in this study. There were two who volunteered, but could not be included due to scratches on the eye glasses for one and another person was physically unable to sit in the position required by the technology. In addition, there were 14 students who participated in the pilot study, which served to train this first-time eye-tracking researcher and debug the hardware and software. In total, there were 55 participants involved in order to produce 34 cases, which is a factor of 1.6, as opposed to the 1.2 which was planned.

There were some issues I anticipated, but did not come to fruition. I was concerned about use of the frame which held the students' head still. This absolutely was not an issue. While the creation of the configuration for this test was very time consuming, but likely no different for any eye-tracking system, it yielded an efficient production of the final reports and graphs. It was clear to me that the designers of the software had designed the data entry features well. They also added a feature to hit one button and automatically turn the recording off and on, which I'll use for the next study.

Appendix R
Sample Calibration Screen



Appendix S
Sample Slides From Experiment 1

The Unexpected Visitor
Ilya Repin (1884)

Look around the picture

Try to understand how rich or how
poor the people are.

And so on…

Thank You for Participating in
this project
It's OK to talk now!

Appendix T
All Pictures From Experiment 2

Picture Type 1 – Used in Previous Saliency Studies

Picture 1 – Balloons

Picture 2 - Alps

Picture 3 – Fog

Picture 4 - Chengill

Picture 5 – Coast

Picture 6 - Cow

Picture Type 1 – Used in Previous Saliency Studies (Continued)

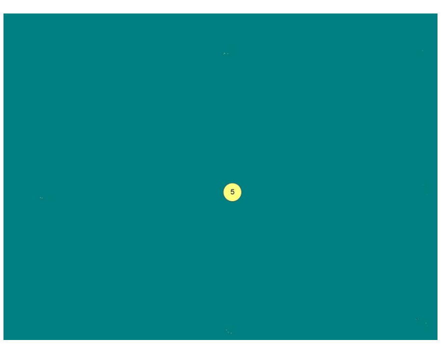
Picture 7 – Sailboats

Picture 8 - Elephants

Picture 9 – Planes

Picture 10 - Helicopters

Between the Pictures



Picture Type 2 – Geomorphology Course

Picture 11 – Sidewalk

Picture 12 - Dirt

Picture 13 – Heater

Picture 14 - Tree

Picture 15 – Manhole

Picture 16 - Grassy

Picture type 2 Geomorphology Course (Continued)

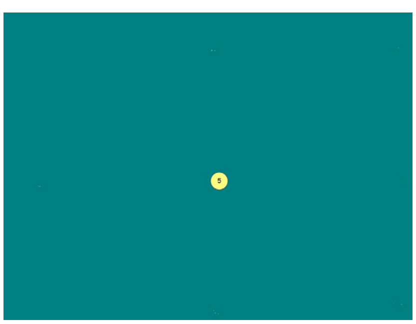
Picture 17 – Grate

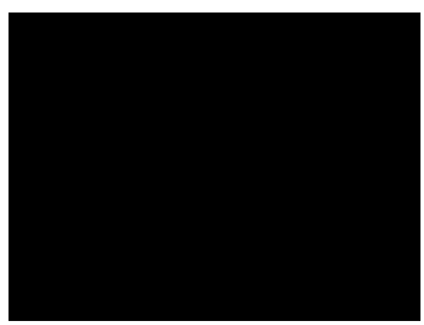
Picture 18 – Play

Picture 19 – Ballgame

Picture 20 - Multi

In Between the Pictures



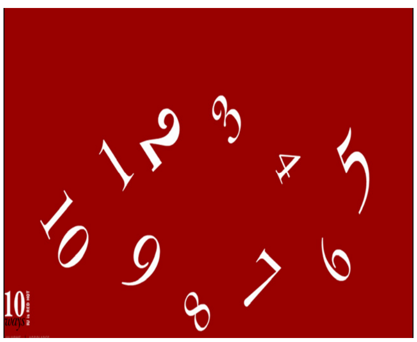


Picture Type 3 – Award winning Webby Websites

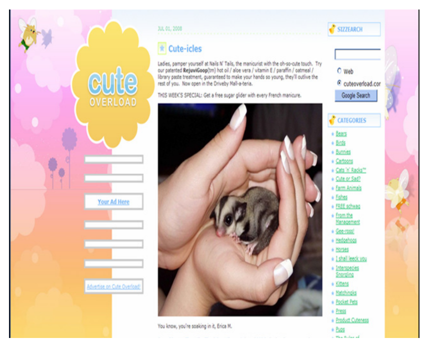
Picture 21 – Bank

Picture 22 - Bear

Picture 23 – Iowa

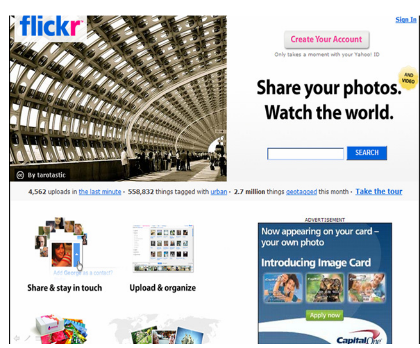


Picture 24 - Mouse



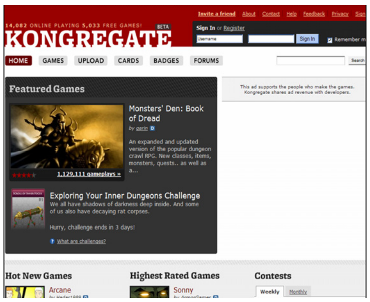
Picture 25 – Zoom

Picture 26 - Zoom

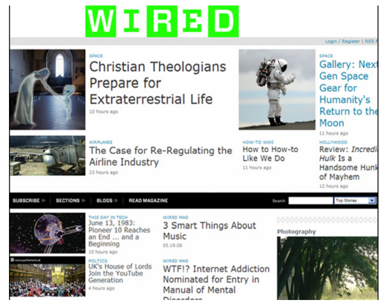


Picture Type 3 - Award Winning Webby Sites (Continued)

Picture 27 – Kong



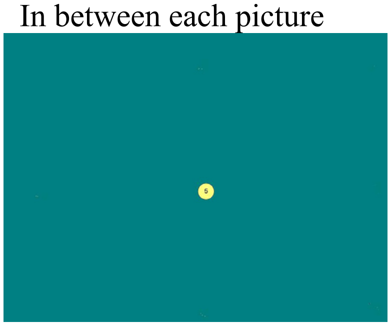
Picture 28 - Wired

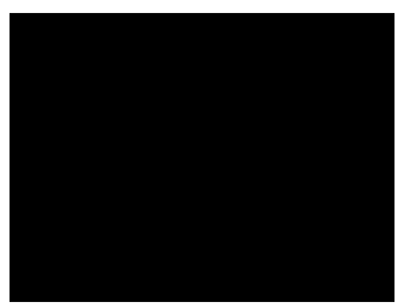


Picture 29 – Milk

Picture 30 - Peace

In between each picture





Appendix U
Detailed Participant Analysis

Detailed analysis for students without intellectual disabilities

Participant Number	Gender	Race	Age (Months)	Reported Disability
124	F	Caucasian	221	N/A
125	F	Caucasian	222	N/A
126	F	Caucasian	249	N/A
127	F	Caucasian	248	N/A
128	M	Caucasian	217	N/A
129	F	Caucasian	254	N/A
130	M	Caucasian	225	N/A
131	F	Caucasian	219	N/A
133	F	Caucasian	250	N/A
134	M	Caucasian	268	N/A
135	F	Caucasian	220	N/A
136	M	Caucasian	317	N/A
137	F	Caucasian	275	N/A
138	F	Caucasian	219	N/A
139	M	Caucasian	231	N/A
140	M	Caucasian	226	N/A
141	F	African American	276	N/A
142	F	African American	259	N/A
144	M	Caucasian	286	N/A

Detailed Analysis for Participants With Intellectual Disabilities

Number	Gender	Race	Age (Months)	Reported Disability
169	M	Caucasian	274	Pervasive developmental disorder
167	M	Caucasian	309	Down syndrome
168	F	Caucasian	256	Opsi myoclonus
166	M	Caucasian	236	Multiple disabilities
151	F	Caucasian	262	Down syndrome
165	F	Caucasian	310	Intellectual disabilities
164	F	Caucasian	240	Multiple disabilities
161	F	Caucasian	244	Down syndrome
160	F	Caucasian	231	Down syndrome
159	M	Caucasian	232	Mild intellectual disabilities
158	M	Caucasian	249	Mild intellectual disabilities
157	M	Caucasian	244	Down syndrome
156	M	Caucasian	232	Developmentally delayed
155	F	Caucasian	277	Down syndrome
154	F	African American	244	Borderline intellectual disabilities
153	M	Caucasian	244	Intellectual disabilities
147	F	Caucasian	232	Mild intellectual disabilities
149	F	Caucasian	312	Down syndrome
150	F	Caucasian	234	Intellectual disabilities
148	M	Caucasian	240	Down syndrome
152	M	African American	251	Intellectual disabilities

Appendix V
Sample Responses From Students With Intellectual Disabilities

Participant	1	2	3
Questions			
Look around the picture.	The guy had a raggy jacket.	The objects, the clothing, the visitor	Picture of the house, family, and kids. Older daughter. Middle son and younger.
Try to understand how rich or how poor the people are.	They didn't have money. No food.	They didn't have money.	One person rich – lady is rich. Mother and kids were poor. There was unexpected guest-poor. People were afraid. They looked scared.
How old are the people in the picture?	9-10, 20-25, could be 100.	I don't know.	Daughter – 1st child 17, middle son was 12, the daughter was 8.
What were the people doing before the unexpected visitor came?	Grandma stood up and was walking over to the man.	They were surprised.	They were trying to have dinner.
Remember the clothing the people are wearing.	Grandma was wearing black dress. Son wearing grey/brown pants and shirt.	Coat, shirt, shoes, a dress.	Not like regular clothes. No jeans from a mall, just clothes poor people wear.
Remember where the people and objects are in the room.	Pictures on the wall. Cups on the table. Piano	Pictures table book.	They were in the dining room. They didn't have a father and the father wasn't in the picture.
How long do you think the visitor was away?	2 or 3 weeks.	10 months.	Not sure. I don't know if he left. Same picture. Just one picture.

Appendix W

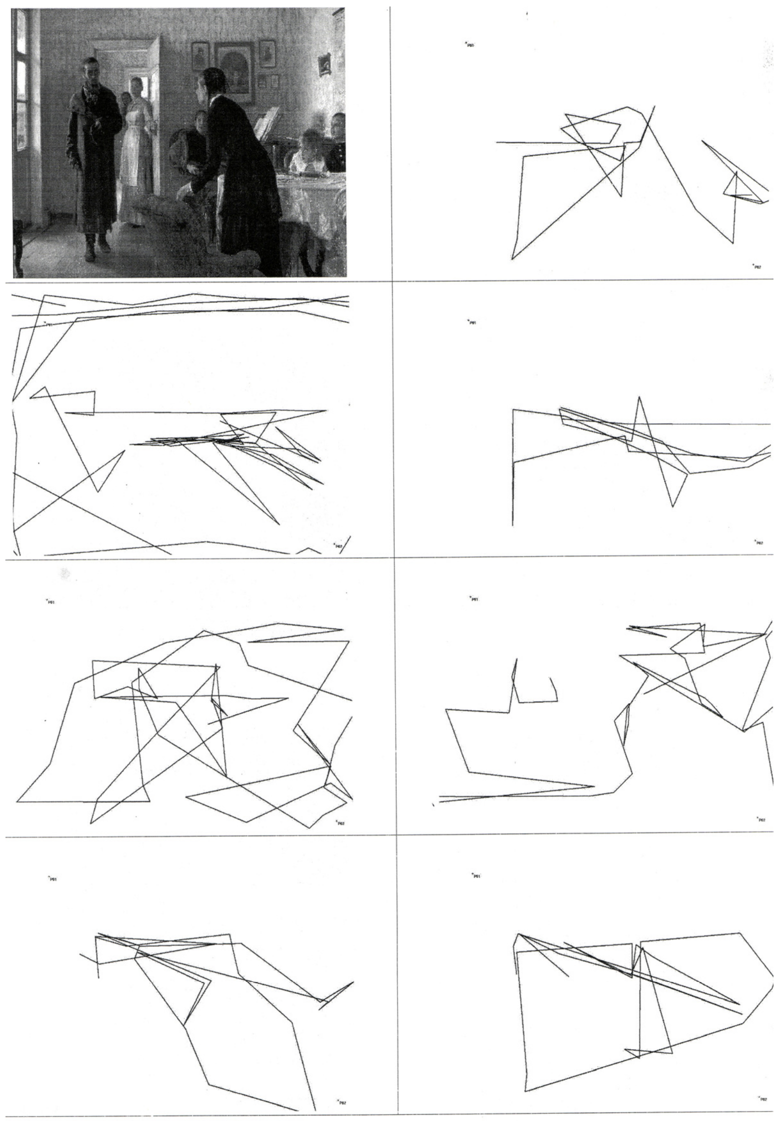
Sample Responses From Students Without Intellectual Disabilities

Participant	1	2	3
Questions			
Look around the picture.	Looking at how they were interacting and facial expressions on the kids	People looked Russian. Color and woman's thing on head, ornate chair leg.	Trying to take it all in. Get a broad sense of what was happening. Not worrying about details.
Try to understand how rich or how poor the people are.	Relatively wealthy because they had a maid.	Piano, maid, chair leg ornate, little boy had buttons down coat, so well off.	Middle to lower class difficult to tell in nice clothes and others dressed in older clothes.
How old are the people in the picture?	Kids under 10, adults mid 30s-early 40s.	Woman in middle. Rather old gentleman, rather old children – oldest 12-13, maid in 30s, another house worker – late 20s, 30s.	Varies from kid (10) to 40s.
What were they doing before the unexpected visitor came?	They were having a school lesson; there were books on the table.	Being home schooled – practicing at piano, studying at table, old lady tutoring, maid showed man to room.	I couldn't tell.
Rember the clothing the people are wearing.	Girl sitting at piano had a blanket wrapped around. Kids seemed overly dressed up for being as young as they are.	Woman wearing lots of backing in mourning, children well-dressed – shirt with button, little girl lacy. Woman at piano full, gentleman wore trench coat; maid blue dress and apron.	Little boy wearing button-down shirt, Another looked like wearing a blanket.
Rember where the people and objects are in the room.	Two girls in the doorway. The guy in the middle of the	Foreground – old woman, lower left corner, another	Piano in the back on the right hand side. Table in the

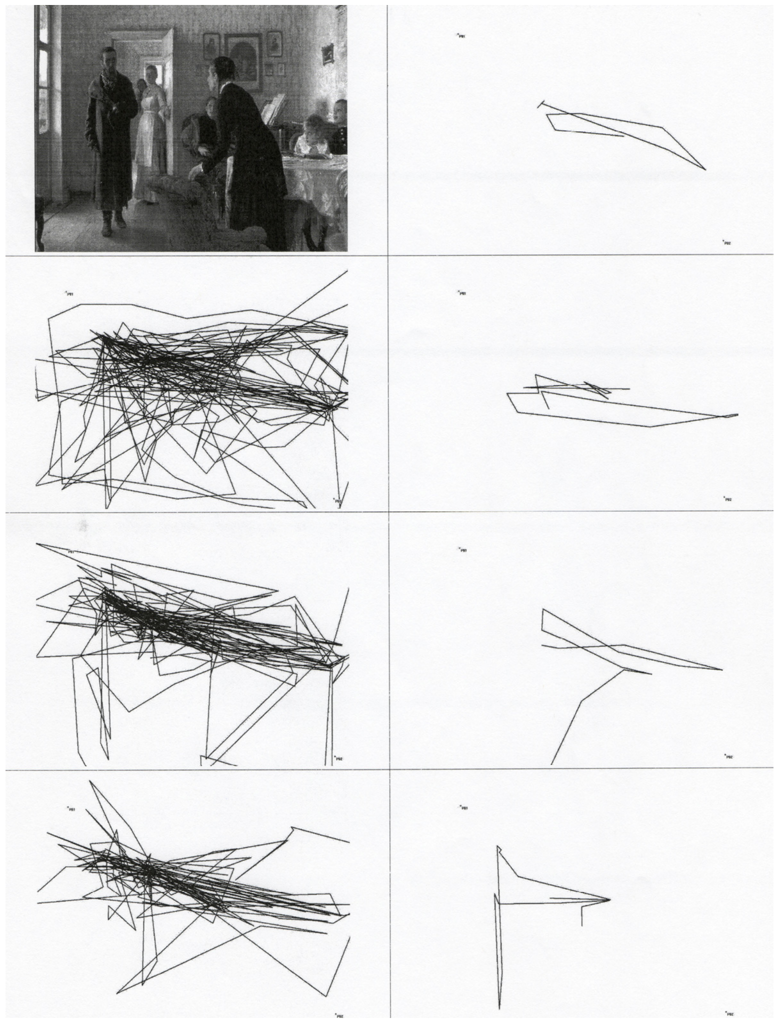
	room. The kids were at the table. The girl sitting next to the piano. Another girl who was teacher in the process of standing up next to the far left window and small part of green chair.	chair, children with books in corner, someone playing piano, Man standing in front of windows; maid in front of door and the woman peaking in at door.	foreground in right hand side, three people standing on left hand side, one person standing; one kneeling, door open on left hand side, table in foreground on left hand side that you only see leg on.
How long do you think the visitor was away?	Long time. The kids didn't seem to recognize him, more so the little girl.	Long enough for them to think he was dead. The kids looked like he hadn't seen in awhile. Little girl maybe didn't know him. The woman getting out of chair and maid looked astonished.	A fairly long time based on the woman's reaction, I don't have a time table.

Appendix X
All Complete Scanpath Diagrams
Participants without Intellectual Disabilities

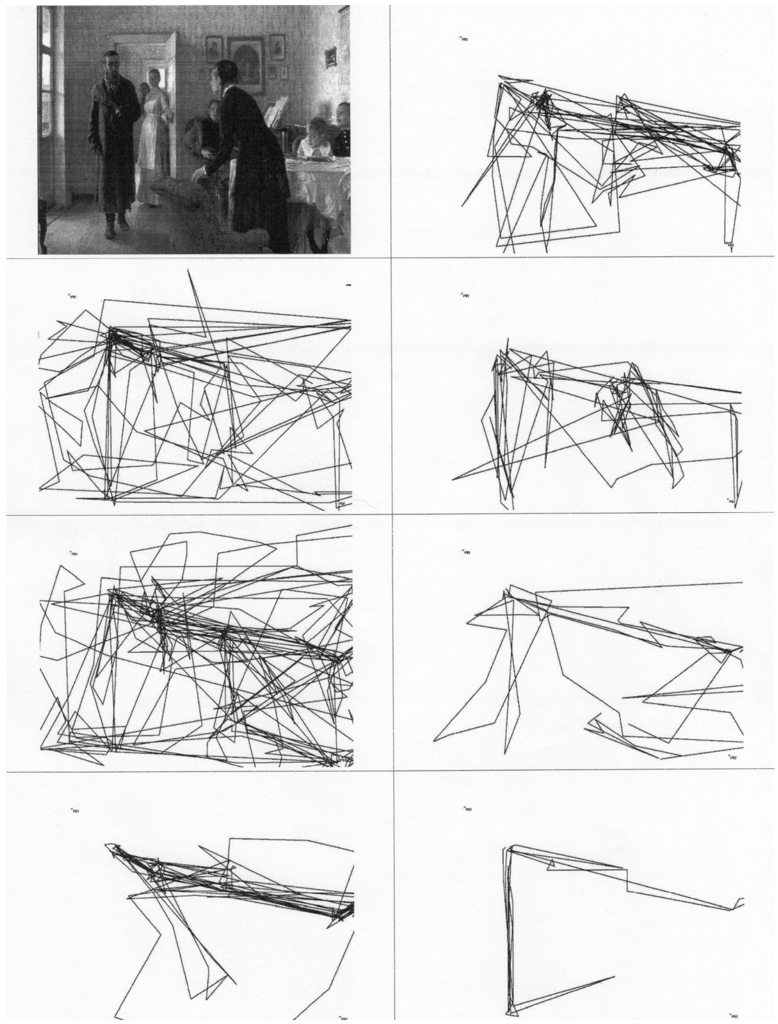
Participant 124



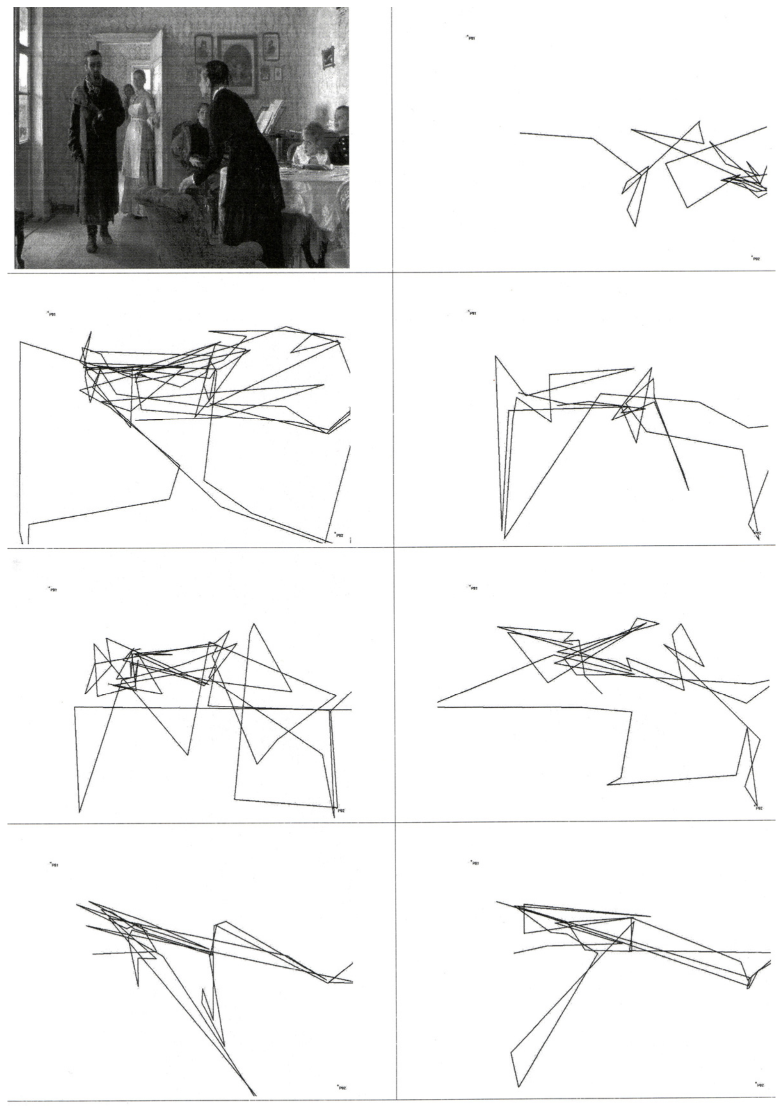
Participant 125



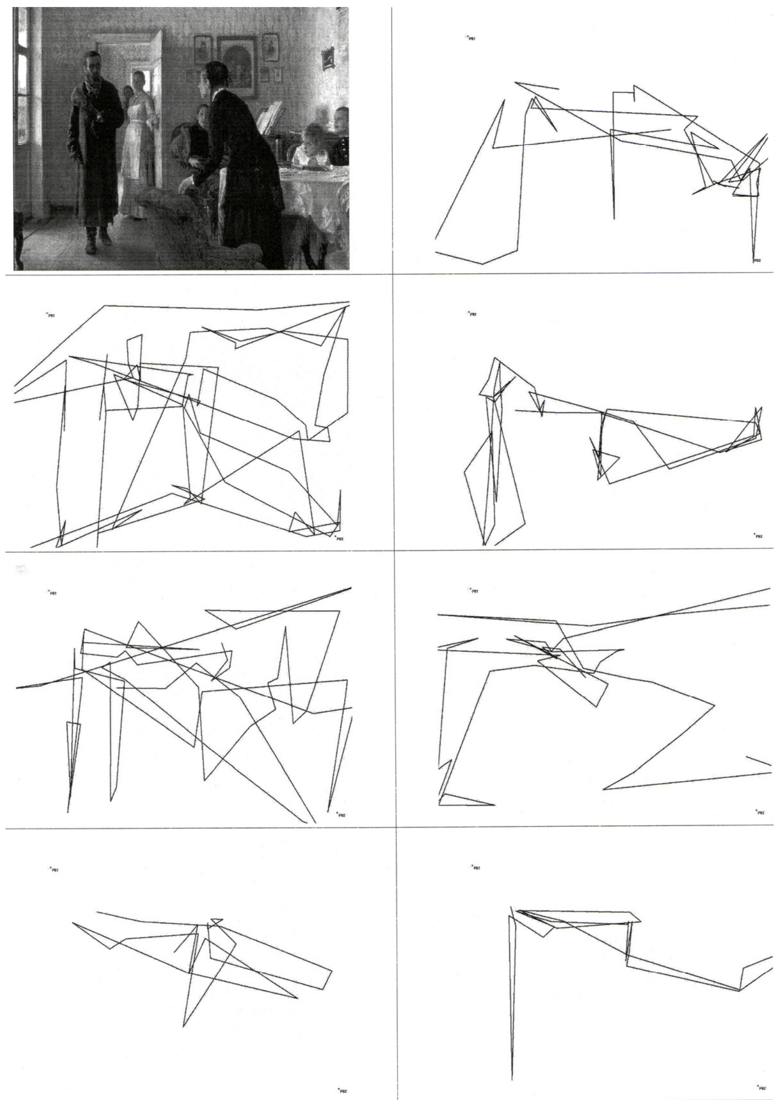
Participant 126



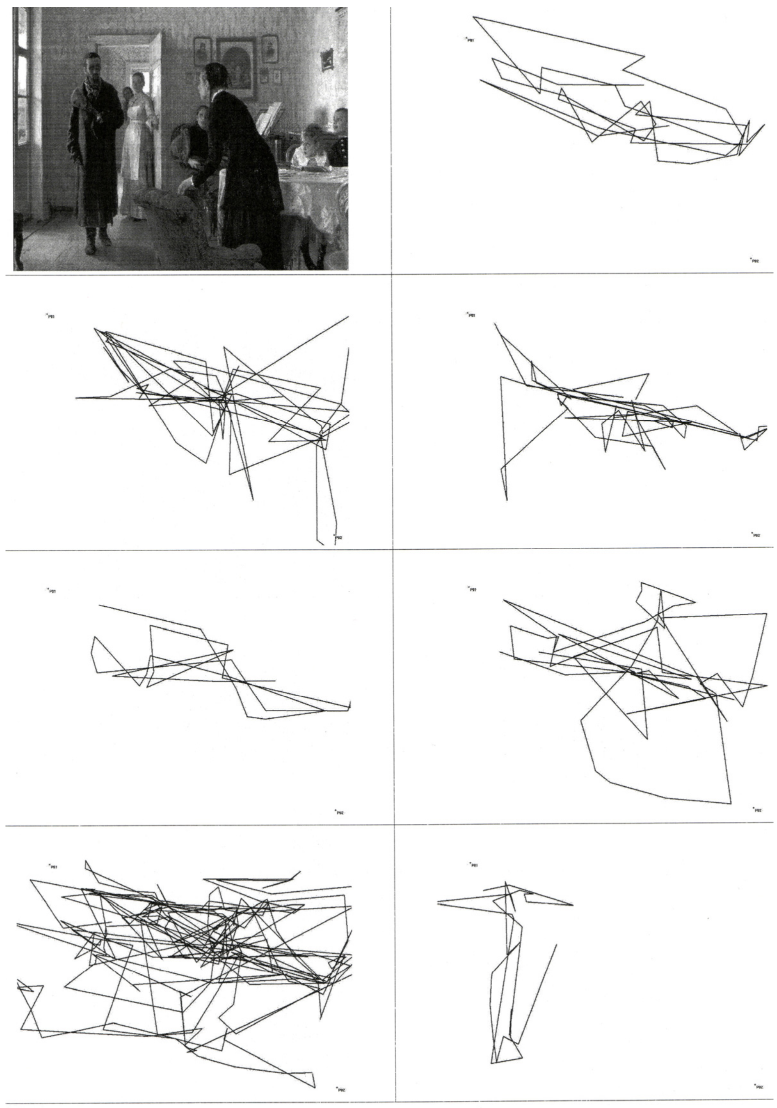
Participant 127



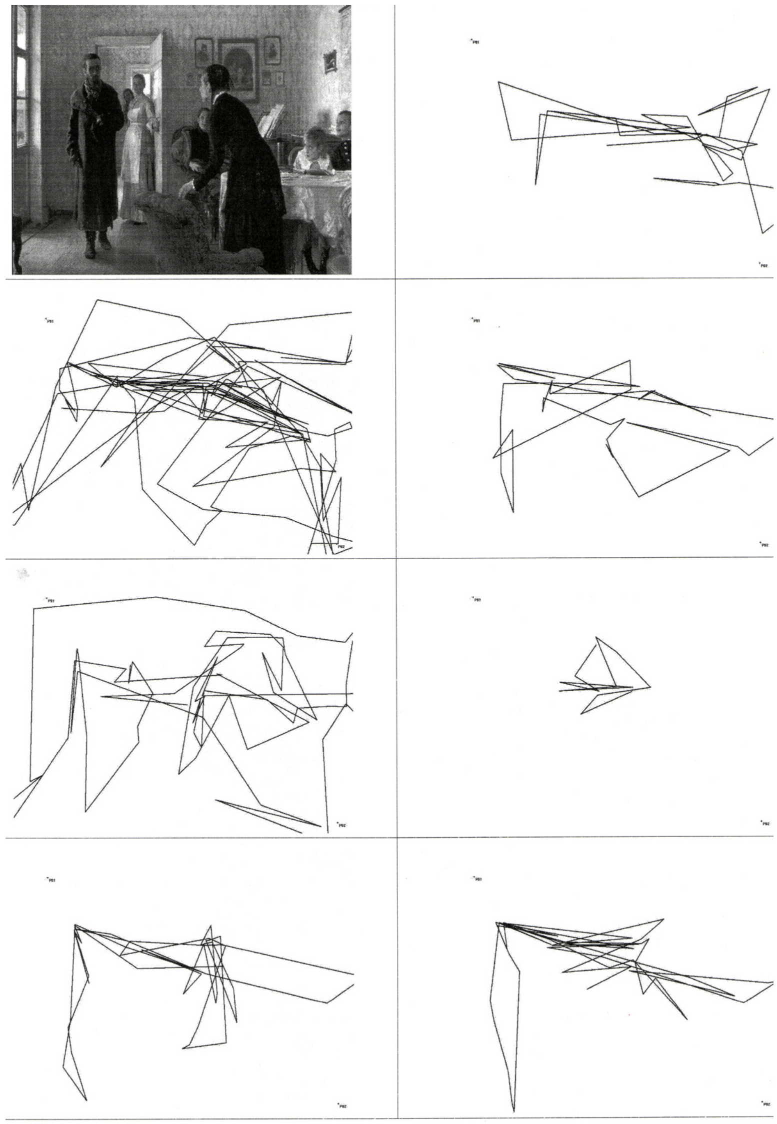
Participant 128



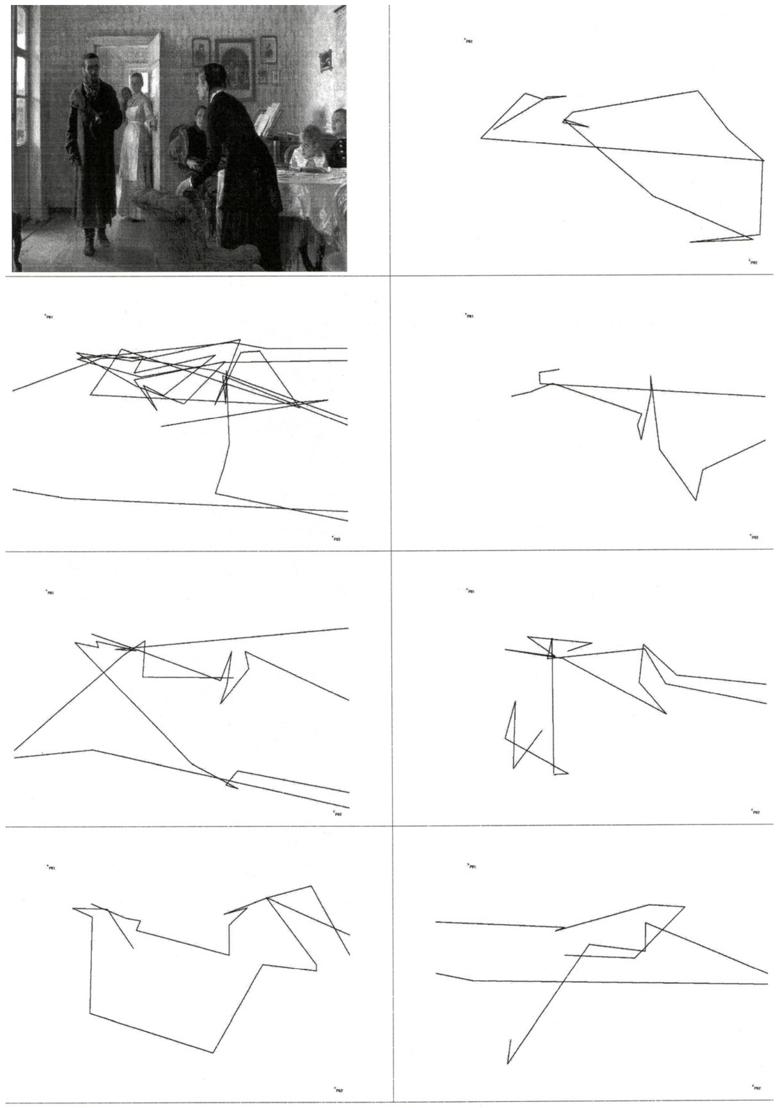
Participant 129



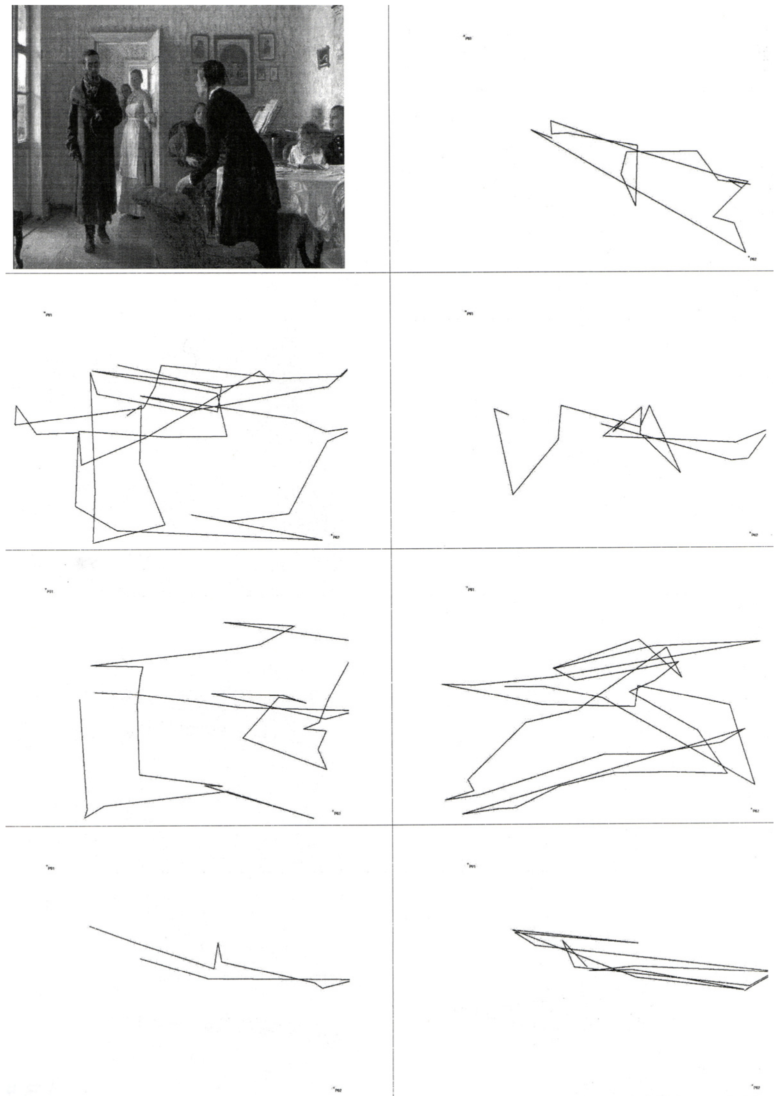
Participant 130



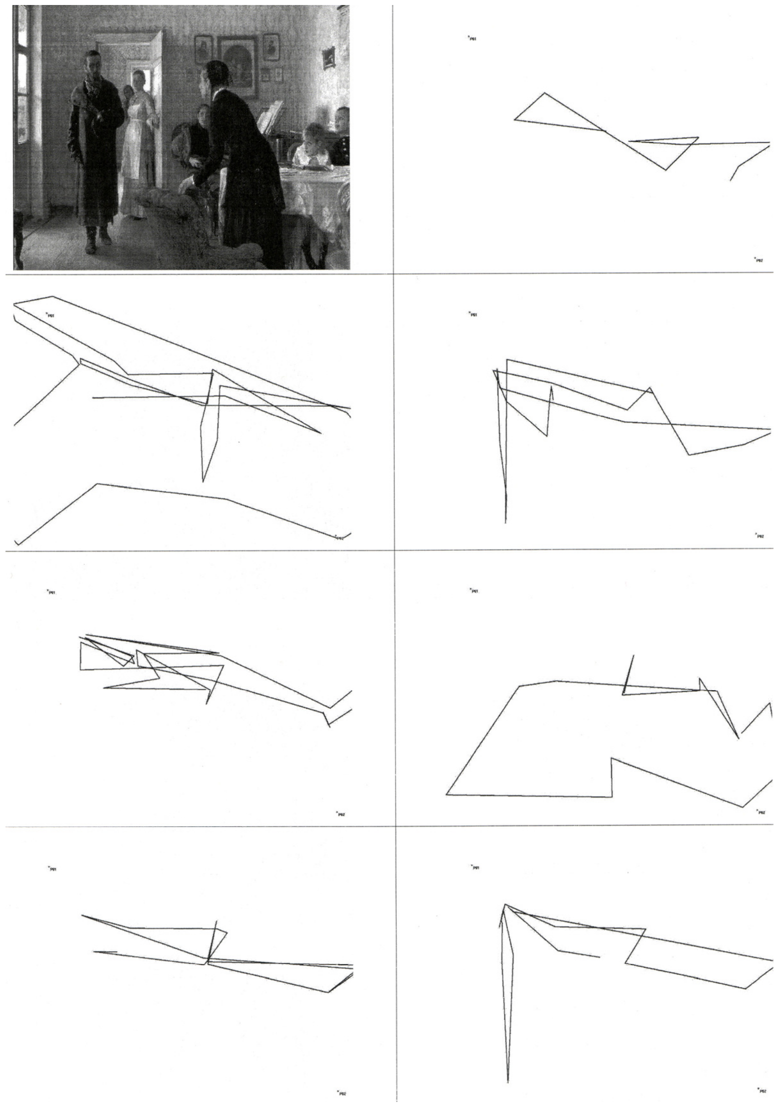
Participant 133



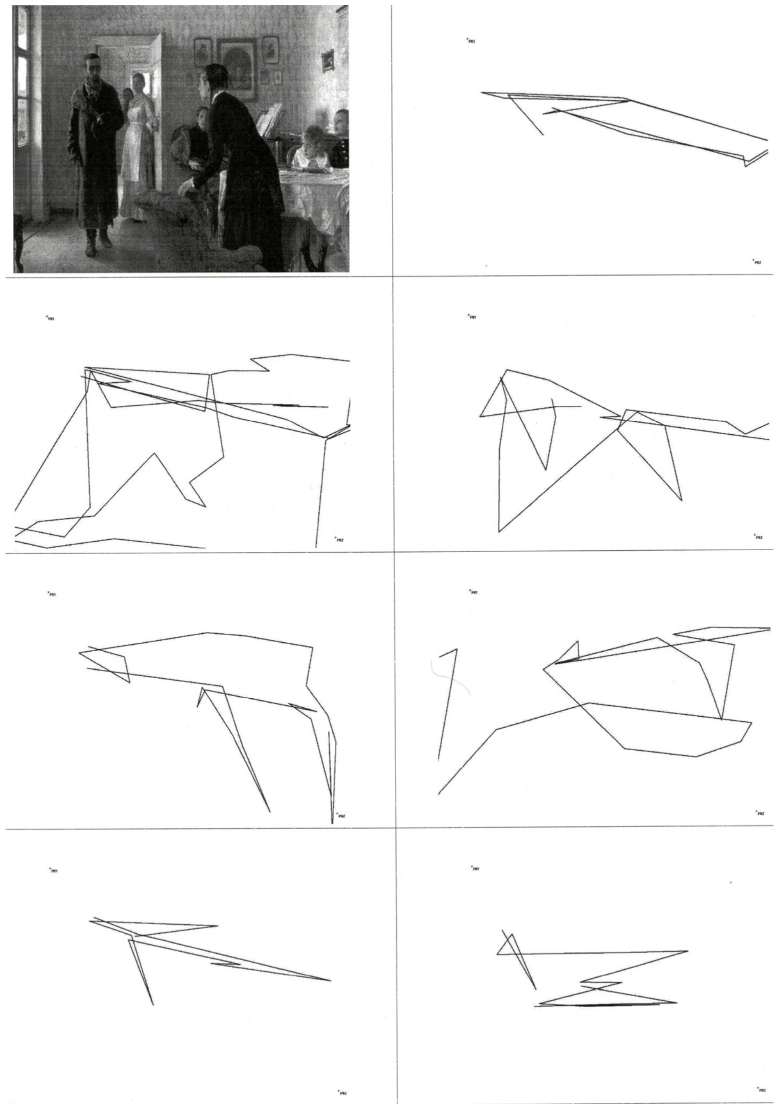
Participant 134



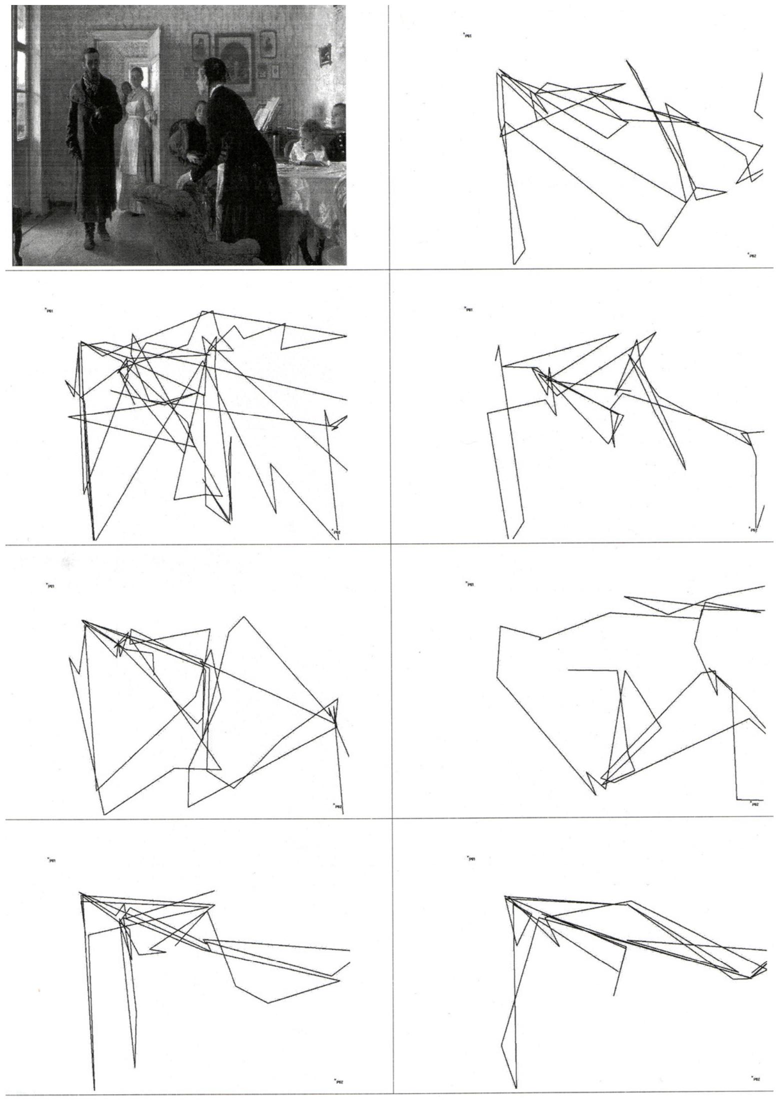
Participant 135



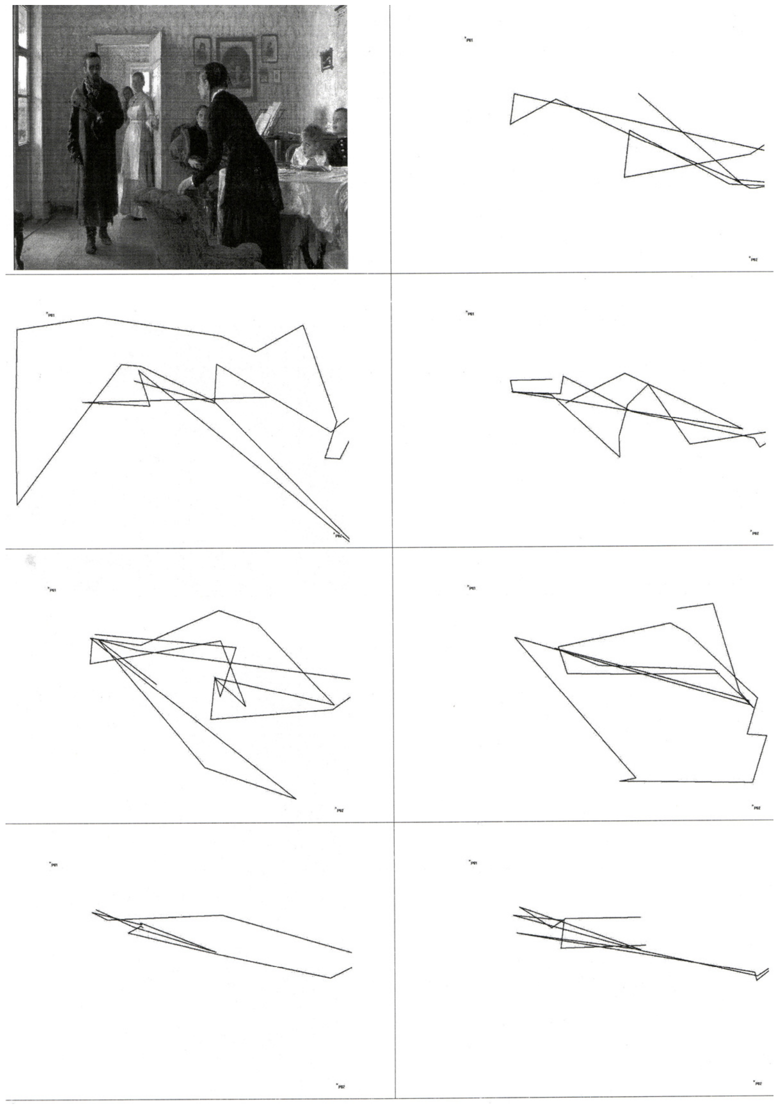
Participant 136



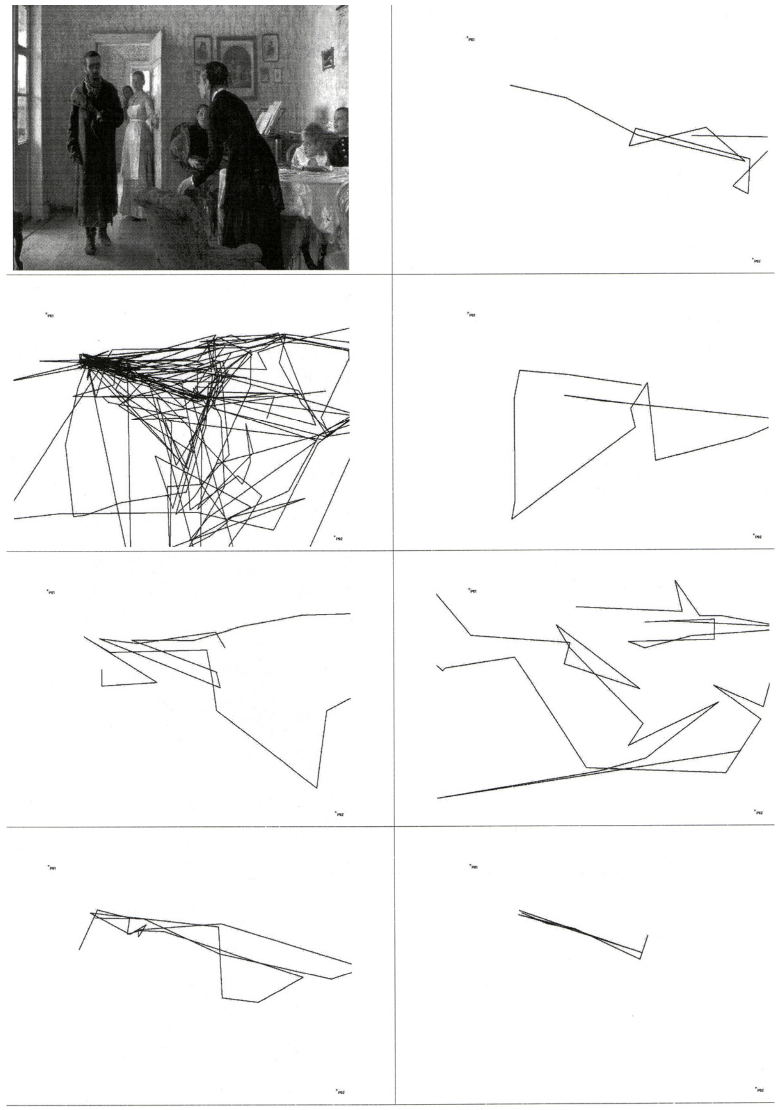
Participant 137



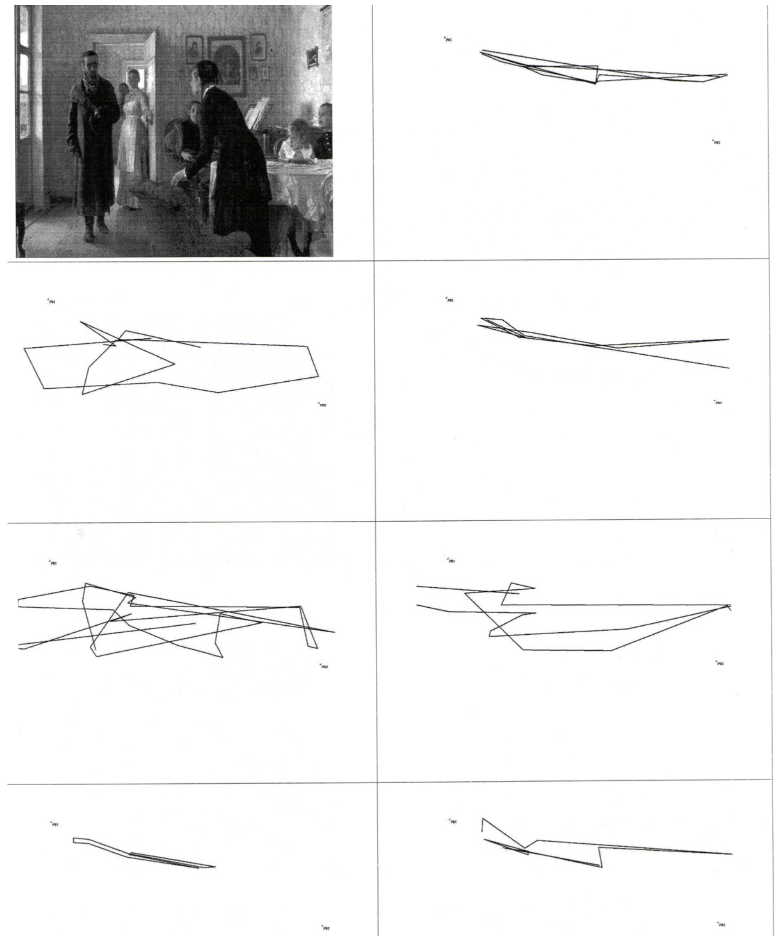
Participant 138



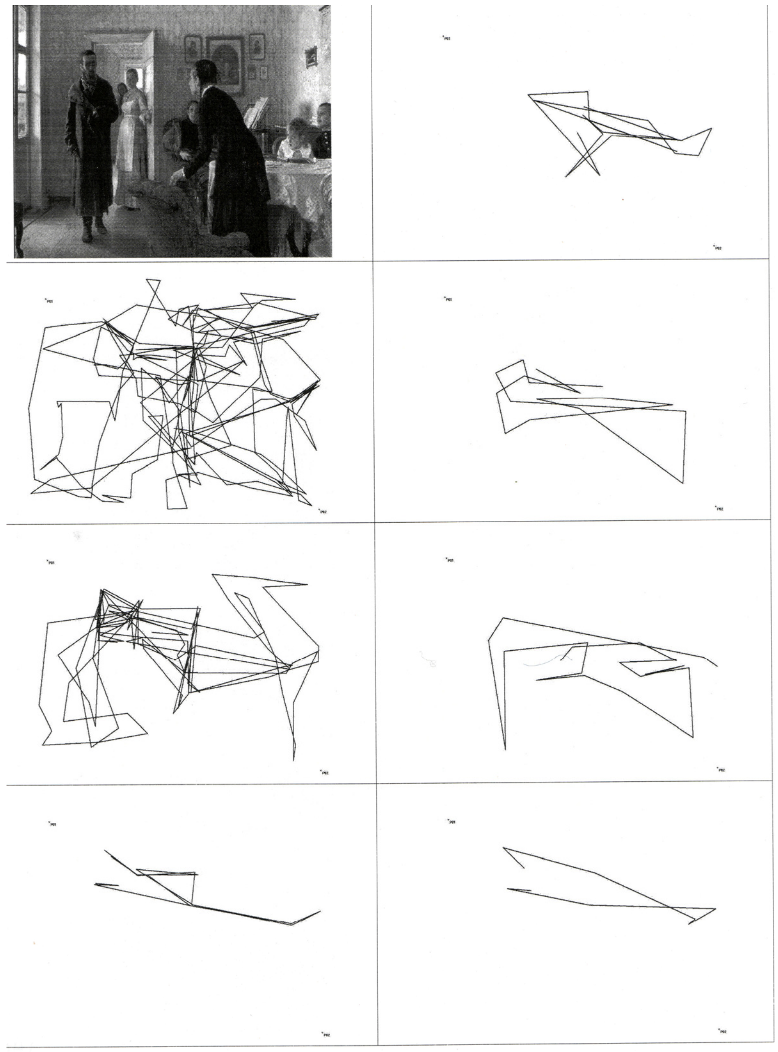
Participant 139



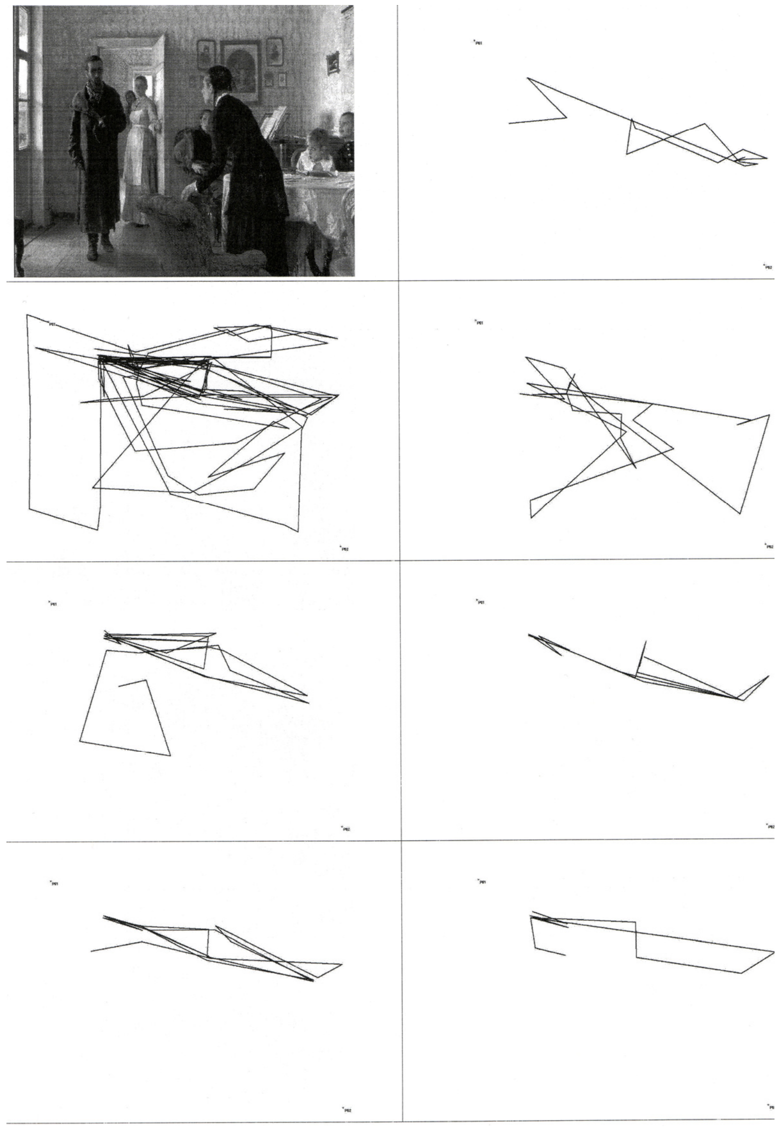
Participant 140



Participant 141

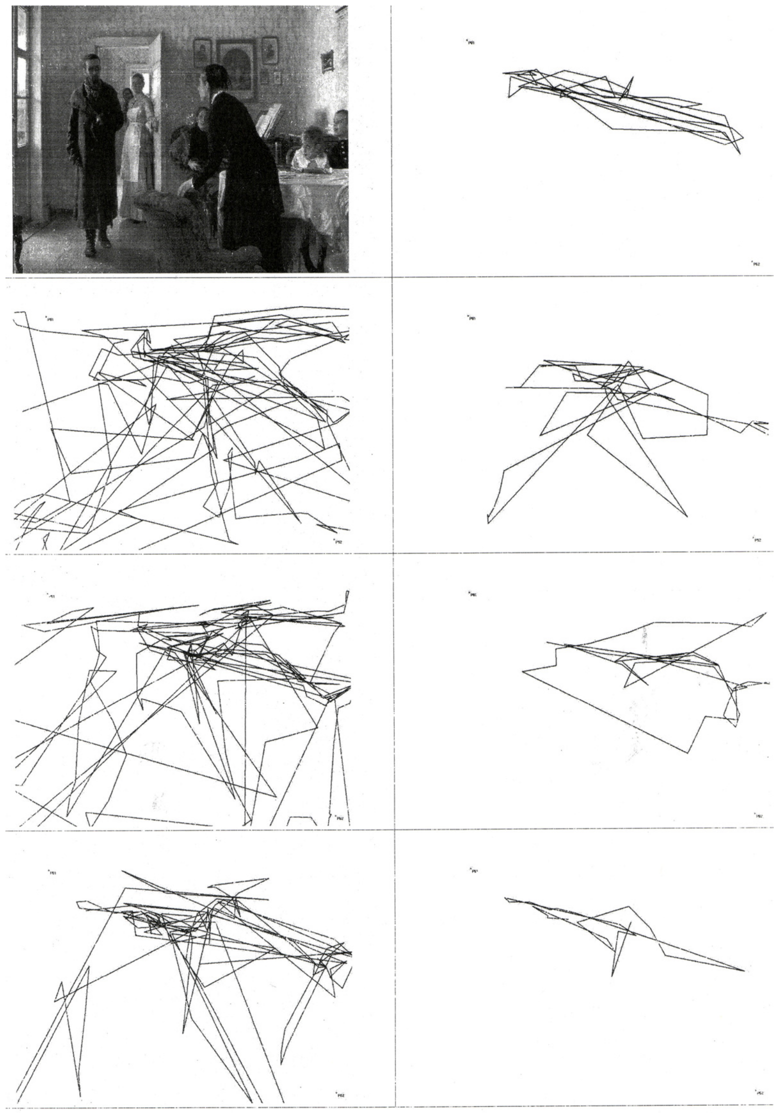


Participant 142

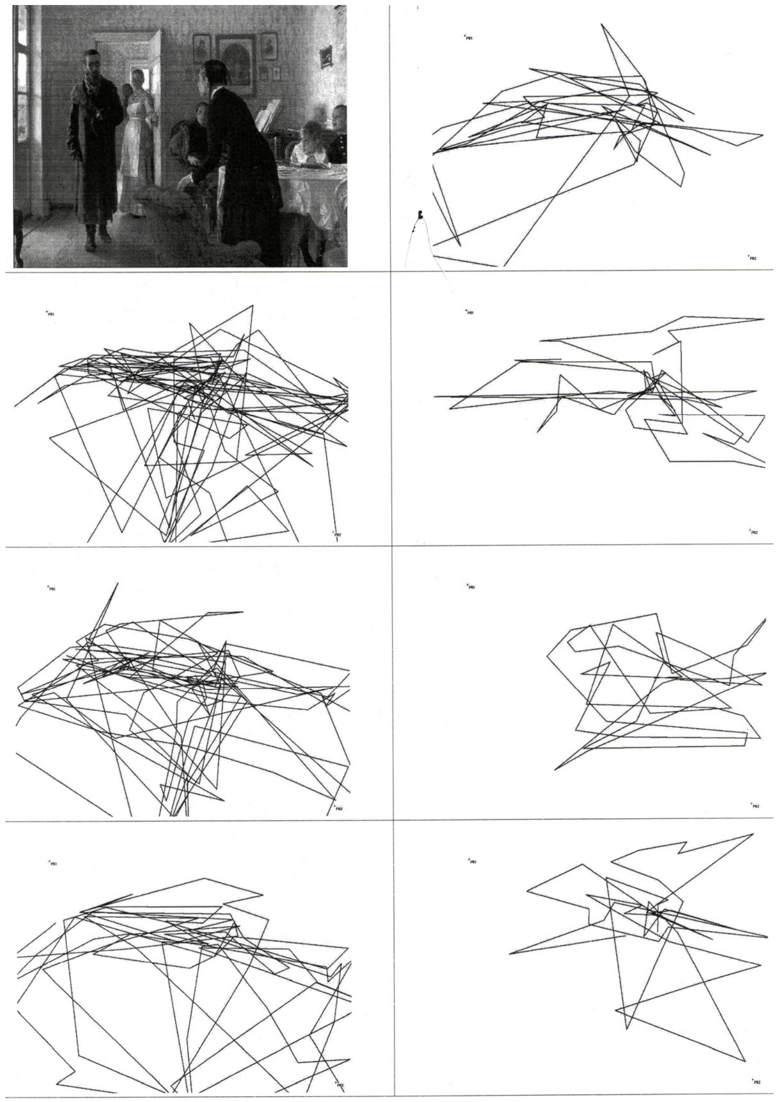


Scanpaths for Participants with Intellectual Disabilities

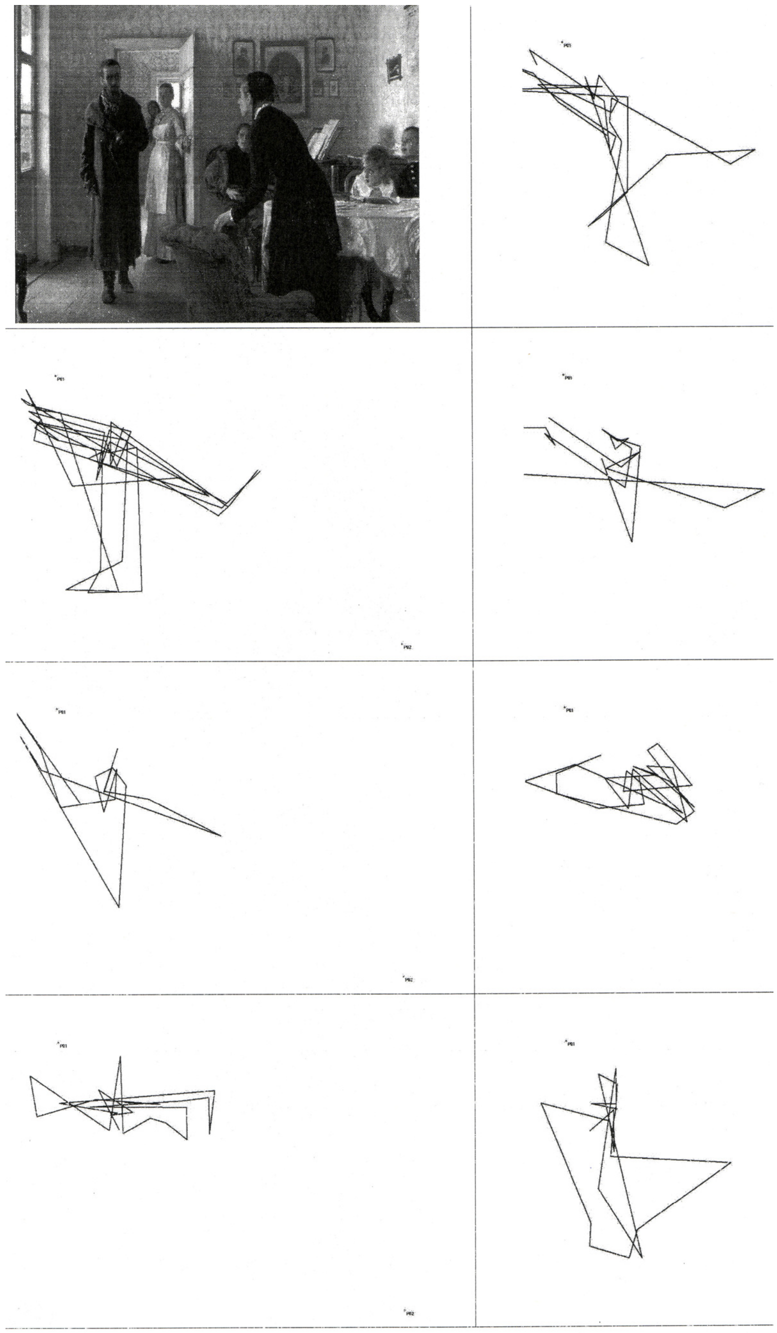
Participant 147



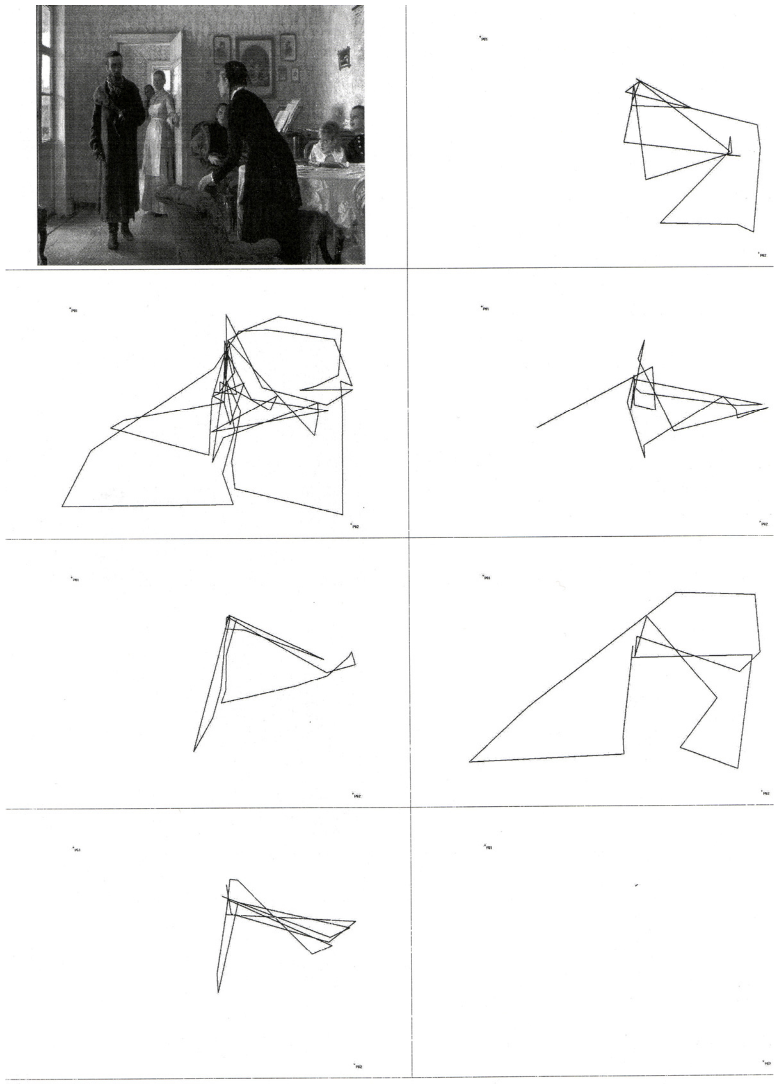
Participant 148



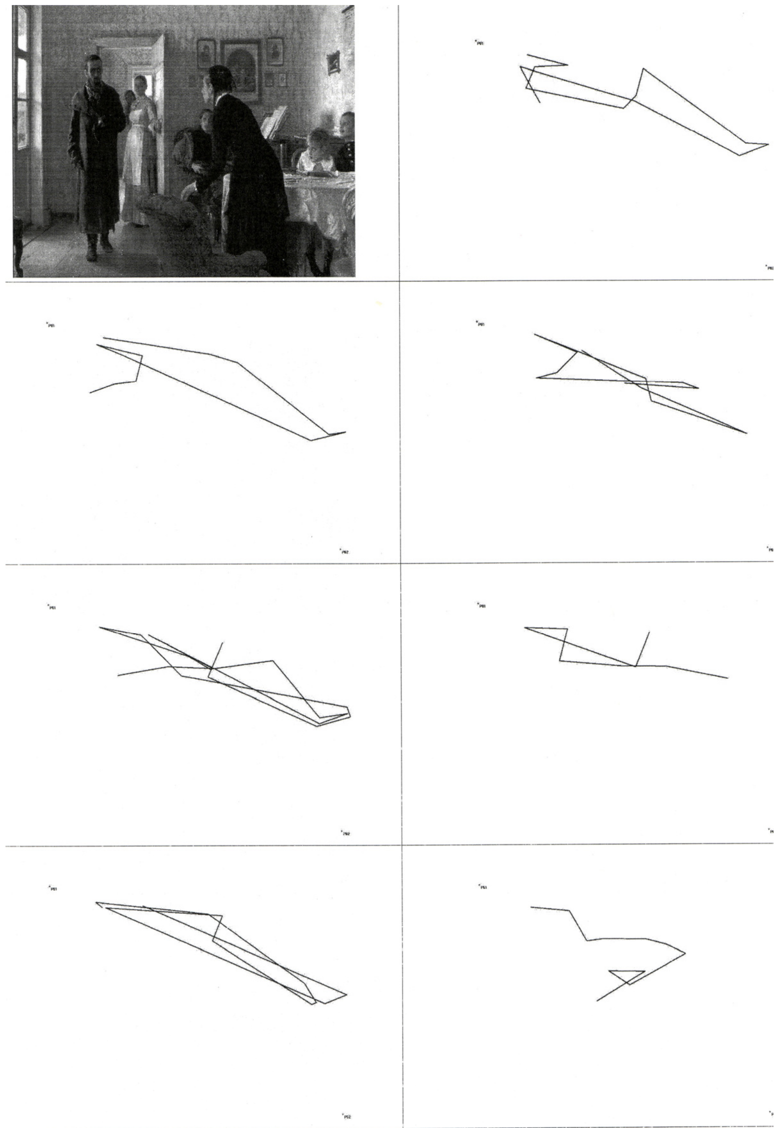
Participant 149



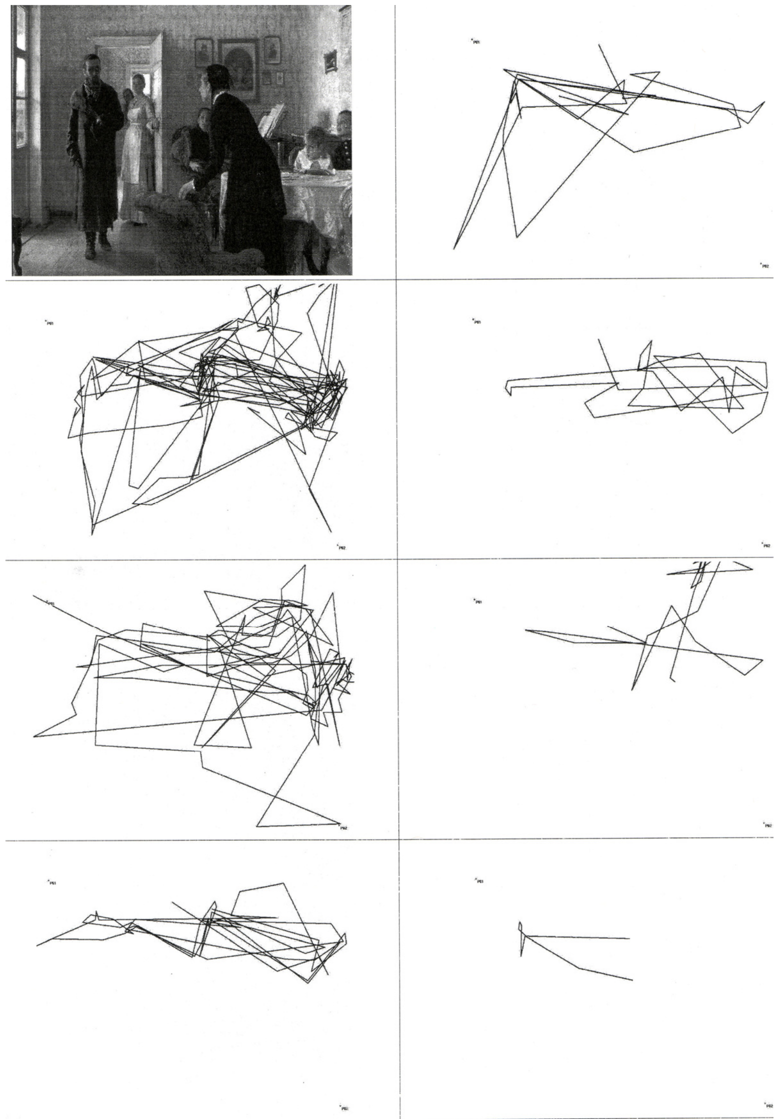
Participant 150



Participant 151



Participant 152



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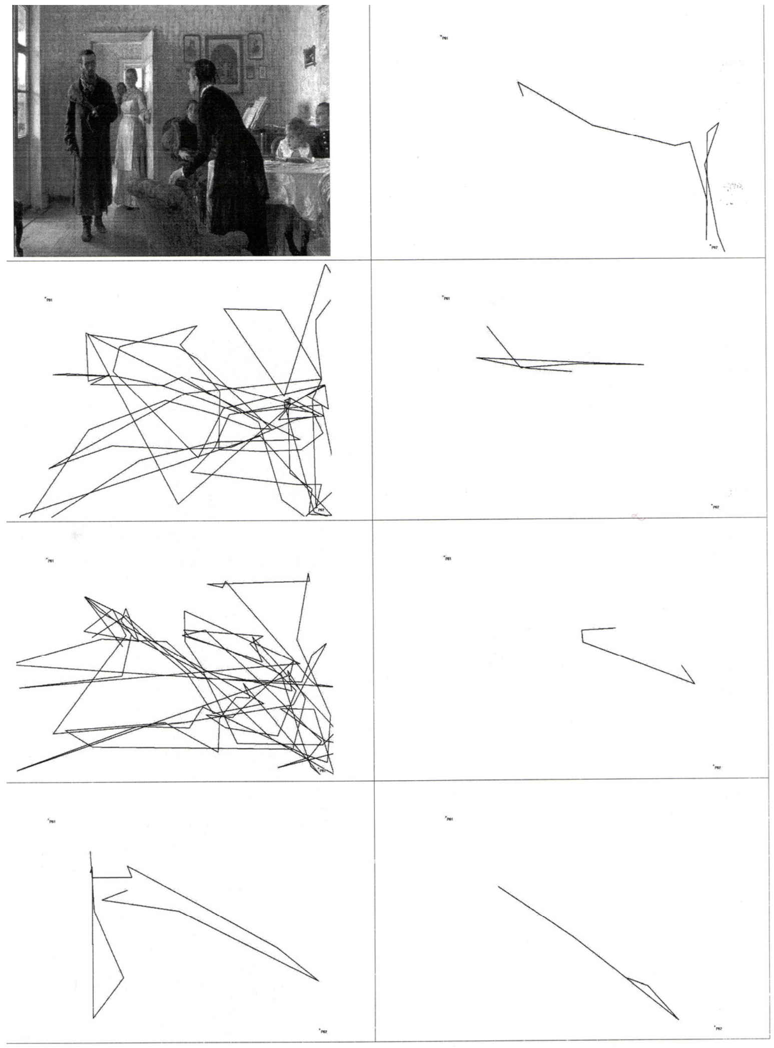
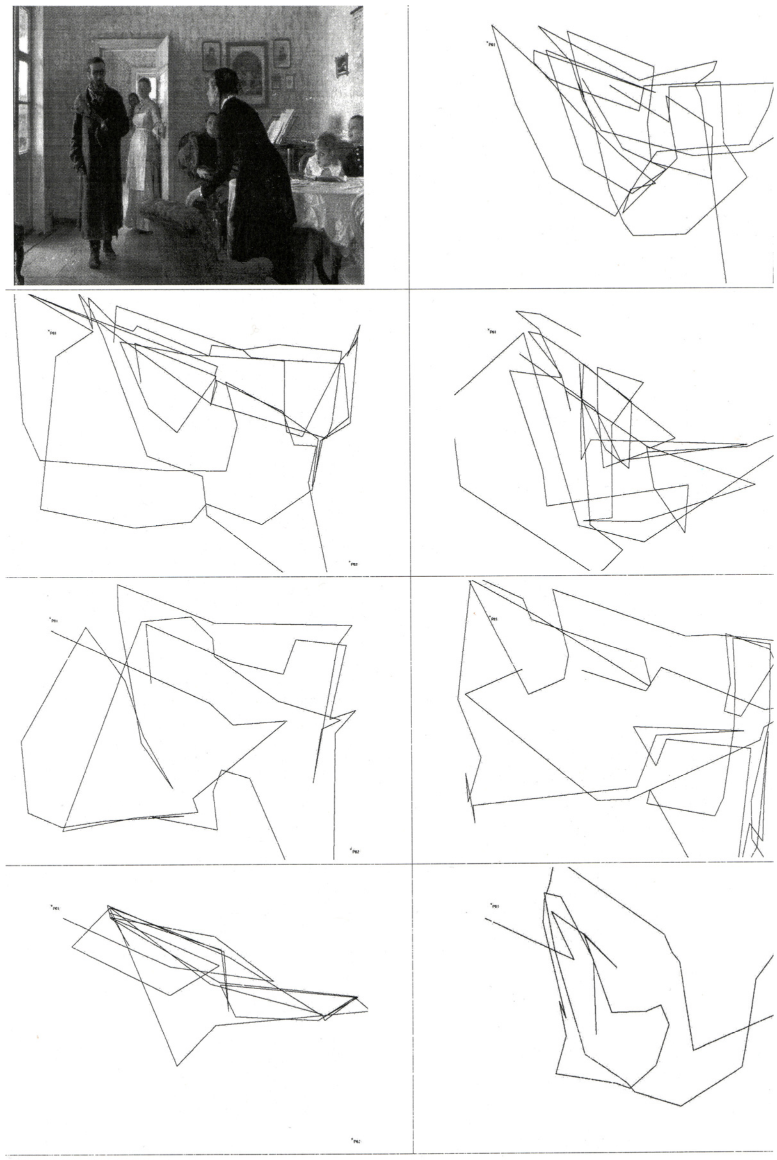
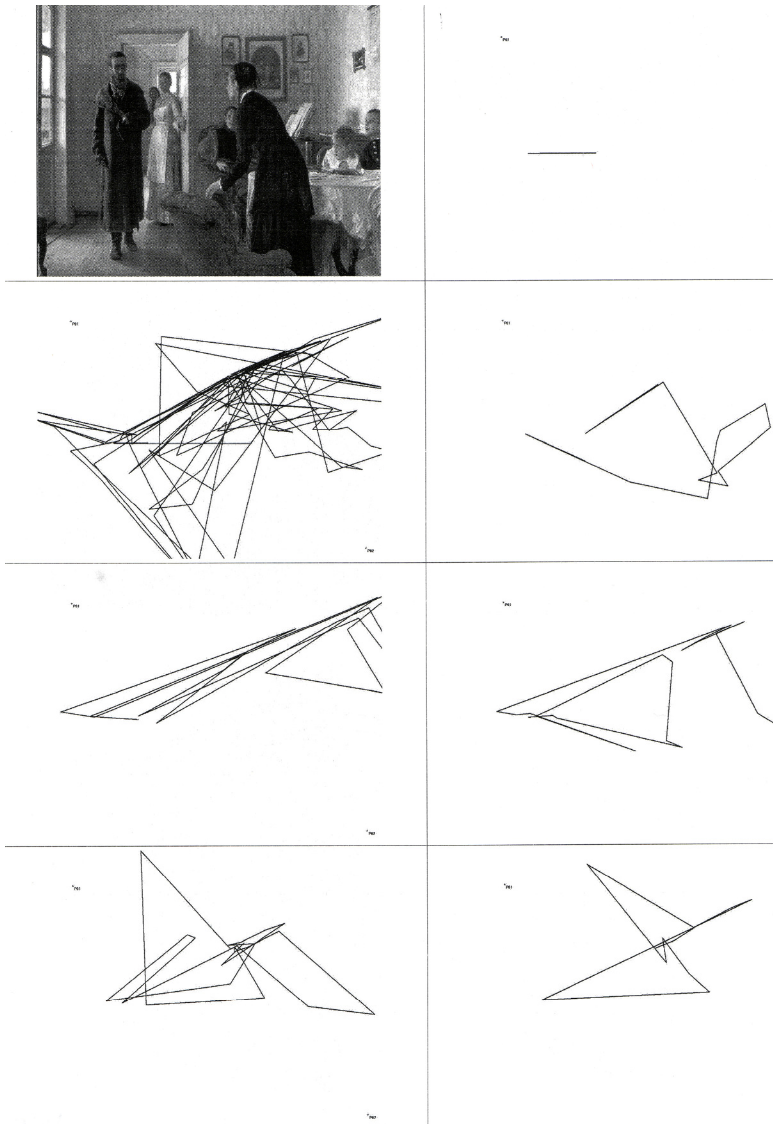


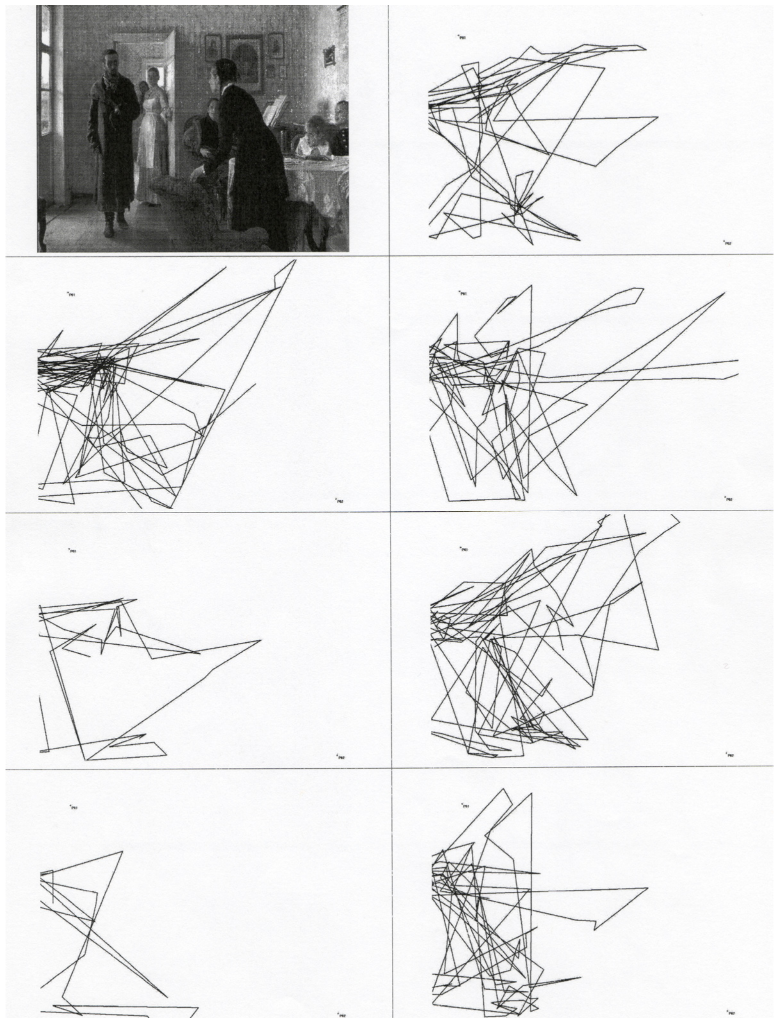
Participant 154



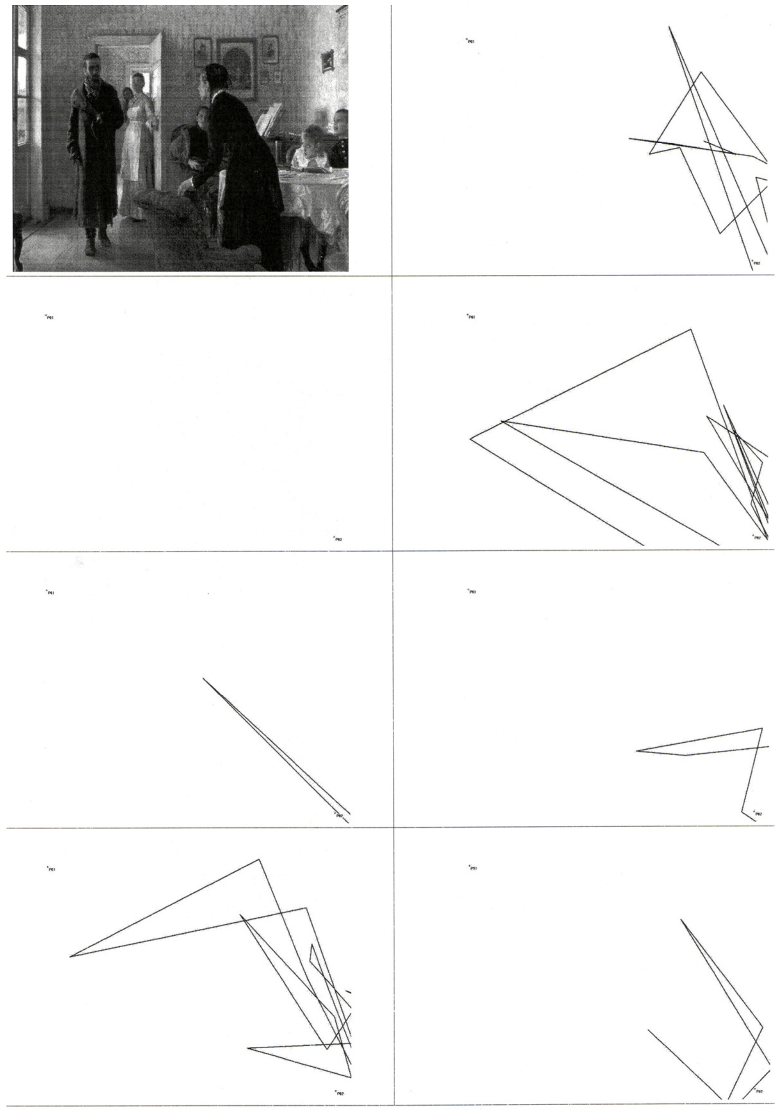
Participant 155



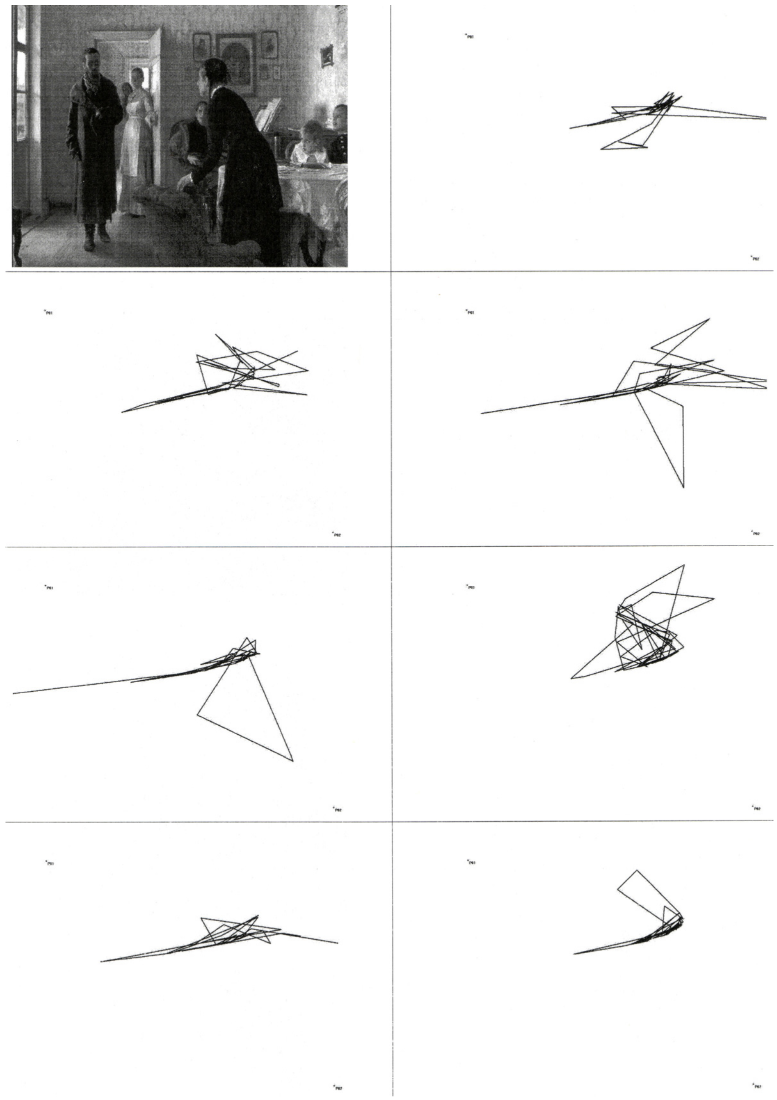
Participant 157



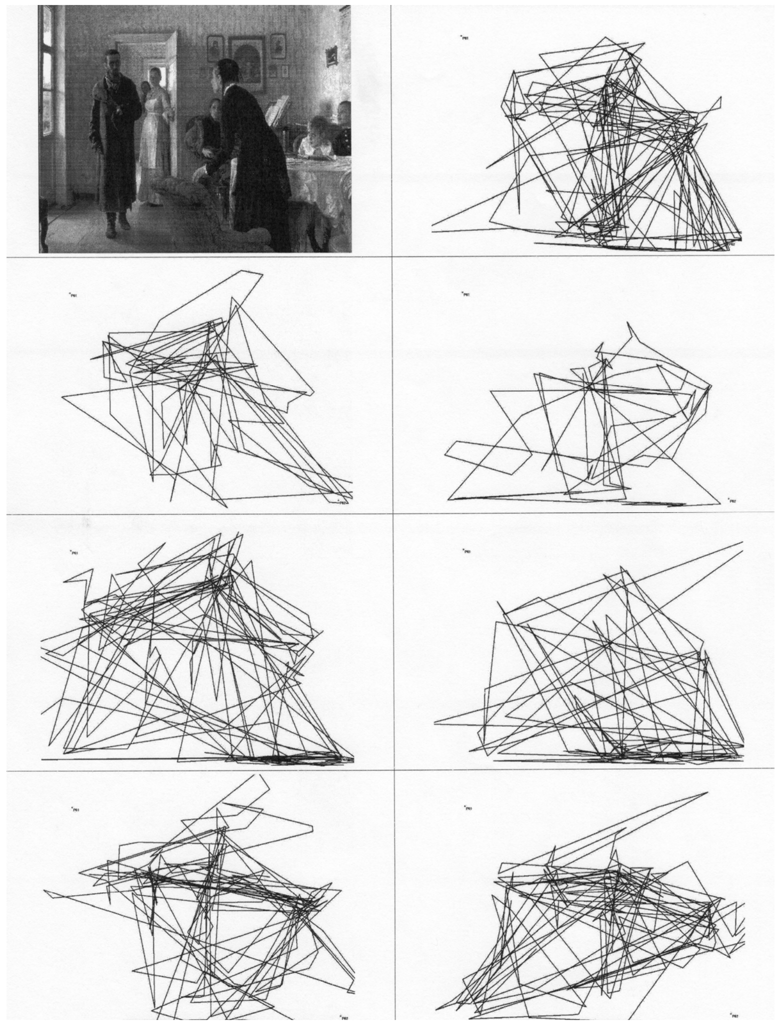
Participant 158



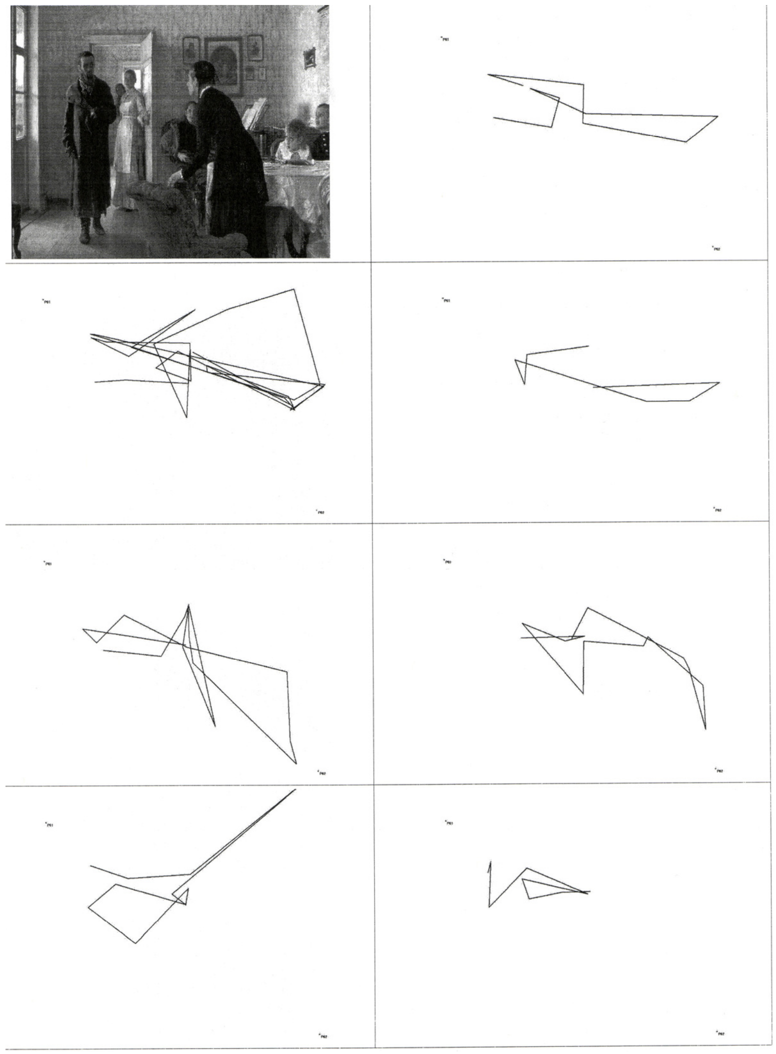
Participant 159



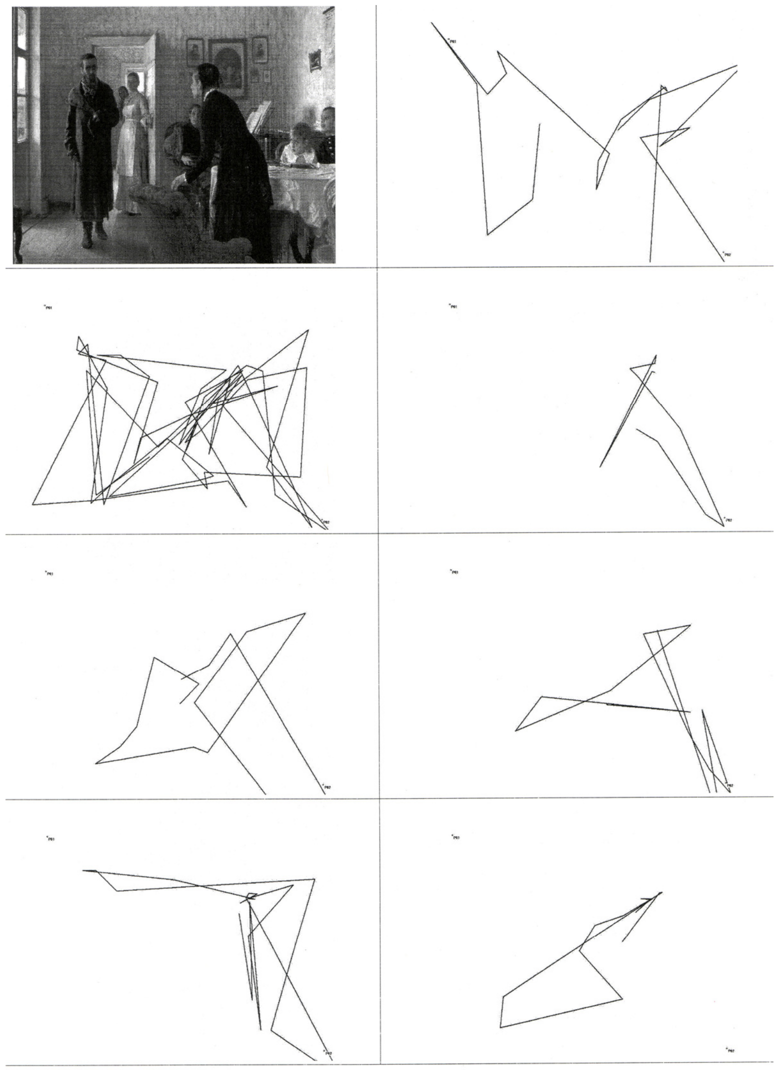
Participant 160



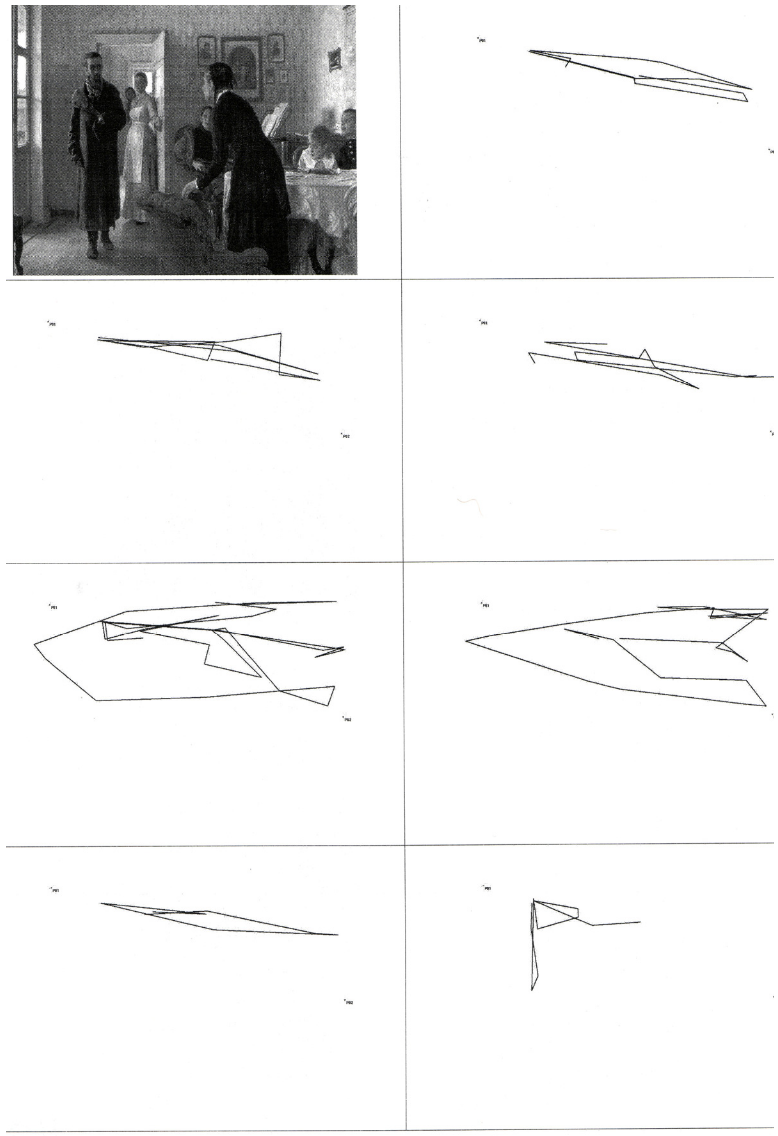
Participant 164



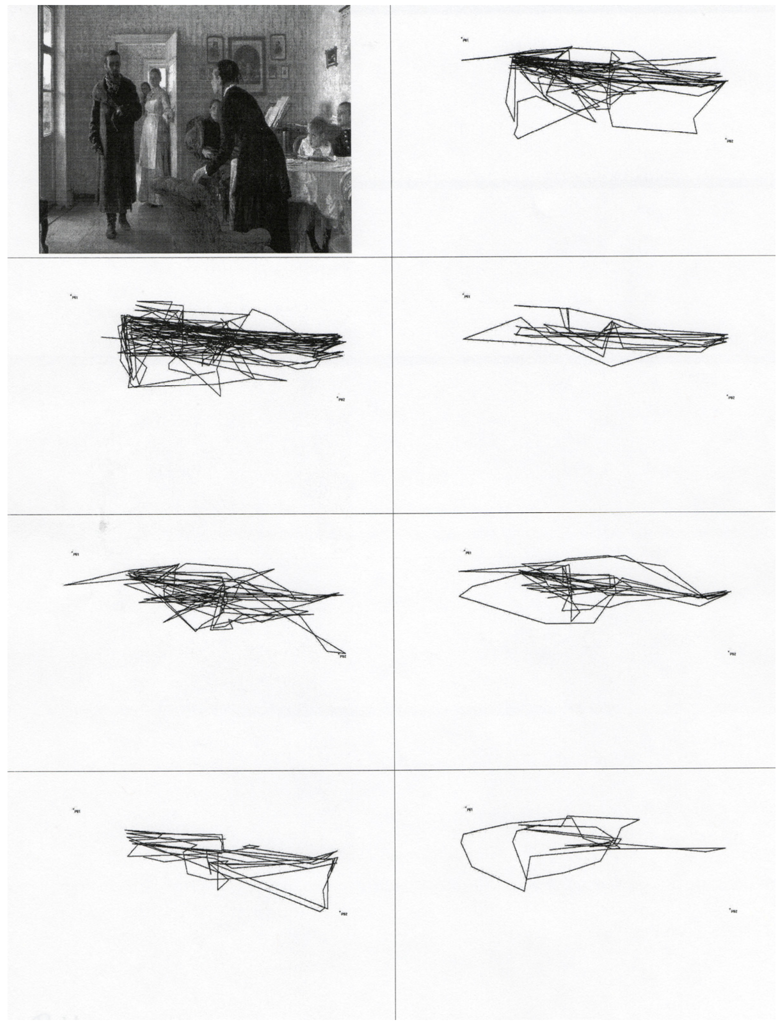
Participant 165



Participant 168



Participant 169



Appendix Y
Rater Scanpath Decisions

(D – Different, S – Same)

Diagram	Person	Group	CR	1	2	3	4	5	6	7	8
1	154	ID	D	D	S	D	S	D	D	D	S
2	136	Non-ID	D	D	D	D	D	D	D	D	D
3	127	Non-ID	D	D	S	D	D	D	D	D	S
4	135	Non-ID	D	D	S	D	S	D	D	D	S
5	141	Non-ID	D	D	D	D	D	D	D	D	D
6	128	Non-ID	D	D	S	D	S	D	D	D	S
7	140	Non-ID	S	D	S	S	S	S	D	D	S
8	129	Non-ID	D	S	S	D	D	D	D	D	D
9	169	ID	S	D	S	S	S	S	D	S	S
10	168	ID	S	S	S	D	D	D	D	D	S
11	165	ID	D	S	D	D	D	D	D	D	D
12	164	ID	S	D	S	D	D	D	D	D	S
13	130	Non-ID	D	D	D	D	D	D	D	D	D
14	138	Non-ID	D	D	D	D	S	D	D	D	S
15	160	ID	S	D	S	S	S	S	S	S	S
16	124	Non-ID	D	D	D	D	D	D	D	D	D
17	125	Non-ID	D	D	D	D	D	D	D	D	D
18	137	Non-ID	D	D	D	S	S	D	D	D	S
19	155	ID	D	D	D	D	D	D	D	D	S
20	157	ID	S	D	D	S	S	D	D	S	S
21	149	ID	D	D	D	D	S	D	S	D	S
22	159	ID	S	S	D	S	S	S	S	D	S
23	151	ID	S	S	D	S	S	S	D	S	S
24	152	ID	D	D	D	D	D	D	D	D	D
25	153	ID	D	D	D	D	D	D	D	D	D
26	142	Non-ID	D	D	D	S	S	S	D	D	S
27	133	Non-ID	D	D	D	D	S	D	D	D	D
28	150	ID	D	D	D	D	D	D	D	D	S
29	148	ID	D	D	D	D	S	D	D	D	D
30	139	Non-ID	D	D	D	D	D	D	D	D	D
31	158	ID	D	D	D	S	D	D	D	D	D
32	126	Non-ID	D	D	D	D	S	S	D	D	S
33	134	Non-ID	D	D	D	S	S	D	D	D	D
34	147	ID	D	D	D	D	S	D	D	D	S

Appendix Z
Predicting Person Type

Correct (Yes) or Not (No)

Diagram	Person	Group	CR	1	2	3	4	5	6	7	8
1	154	ID	No	No	Yes	No	No	No	No	No	No
2	136	Non-ID	No	No	No	Yes	Yes	No	No	No	No
3	127	Non-ID	Yes	Yes	No	Yes	No	Yes	No	Yes	Yes
4	135	Non-ID	No	No	No	Yes	Yes	No	No	Yes	Yes
5	141	Non-ID	Yes	Yes	No	Yes	No	No	No	No	No
6	128	Non-ID	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
7	140	Non-ID	No	No	No	No	Yes	No	Yes	Yes	Yes
8	129	Non-ID	Yes	Yes	Yes	Yes	No	Yes	No	No	No
9	169	ID	Yes	Yes	Yes	Yes	Yes	No	No	No	No
10	168	ID	Yes	Yes	Yes	No	No	Yes	Yes	No	No
11	165	ID	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes
12	164	ID	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
13	130	Non-ID	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
14	138	Non-ID	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
15	160	ID	No	No	Yes	Yes	Yes	No	No	No	No
16	124	Non-ID	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No
17	125	Non-ID	No	Yes	Yes	Yes	No	Yes	No	Yes	Yes
18	137	Non-ID	Yes	Yes	No	No	Yes	Yes	Yes	No	No
19	155	ID	Yes	Yes	No	No	Yes	Yes	Yes	No	No
20	157	ID	No	No	No	Yes	Yes	No	No	Yes	Yes
21	149	ID	Yes	Yes	Yes	No	Yes	No	No	Yes	Yes
22	159	ID	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes
23	151	ID	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
24	152	ID	No	No	No	No	Yes	No	Yes	No	No
25	153	ID	No	No	Yes	No	Yes	No	Yes	No	No
26	142	Non-ID	Yes	No	No	No	Yes	Yes	No	Yes	Yes
27	133	Non-ID	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes
28	150	ID	Yes	No	Yes	No	No	No	Yes	No	Yes
29	148	ID	No	No	No	No	Yes	No	No	Yes	No
30	139	Non-ID	Yes	Yes	No	Yes	No	Yes	Yes	Yes	No
31	158	ID	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
32	126	Non-ID	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No
33	134	Non-ID	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes
34	147	ID	Yes	No	No	No	Yes	Yes	Yes	No	No

Appendix AA
Permission to Use Yarbus' Images

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To: Permissions Heidelberg, Springer DE
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REFERENCES

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CURRICULUM VITAE

Nancy Bazar holds the Ph.D. in Education (Instructional Technology) from George Mason University. She holds undergraduate degrees in Mathematics (McGill University) and Economics (Memorial University of Newfoundland). She also holds graduate degrees in Economics (Georgetown) and Education (Mount St. Mary's University).

Her career spans 40 years, primarily in the telecommunications industry, working in technical and senior management positions for major international telecommunications companies in the area of Customer Relationship Management. She has worked as a consultant for the last ten years, including five years at Accenture and five years at Noblis, a non-profit science and technology company which consults to the federal government. She taught Principles of Economics as an adjunct instructor at Pennsylvania State University.

Her primary professional interest is Web accessibility and she has published two papers, an introduction to Web accessibility and an introduction to eye-tracking technology.