Eye Tracking of Text and Diagrams during the Interpretation of Economic Trends

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Abstract

We developed a method for conducting research on eye-tracking and comprehension of economic trends. This project examines and characterizes the relationships between eye-movement patterns and comprehension of stock prices, helping to better understand how different knowledge acquisition processes affect comprehension.

Executive Summary

People make very important decisions throughout their everyday lives based on their understanding of economic trends. For example, people have to make choices about their retirement funds, mortgages for housing, and the stock market. One of the most common ways that people acquire information is through text and graphics. Discovering the information acquisition processes that experts use could allow the average person to become better educated in more expert-like acquisition strategies. Eye-tracking allows us to look at the different strategies that people use to look at and interpret information. Despite the usefulness of eye-tracking in research on knowledge acquisition, there has been no research to our knowledge done using eye-tracking to record the knowledge acquisition processes used in economic data interpretation. We sought to develop a method that would use eye-tracking to observe the different information acquisition processes used in economic data interpretation and relate those processes to comprehension.

The method that we used here traces subject's eye-movement as they comprehend the given information of economic trends via text and graphics. Our participant pool consisted of nine undergraduate students. We used four screens each with a graph of four different stocks and a text related to the respective stock and comprehension questions for each stock. Before participants were given the screens they were asked background questions to determine prior

level of experience. We used a Mirametics eye-tracker. Texts consisted of events which occurred in September 2013 that related to each company (stocks were renamed to be anonymous) and the graph represented changes in stock price with respect to the beginning of the month for all four stock prices.

Participants were tested one at a time. First, we started by calibrating the eye-tracker. Next, they were asked the background questions. After this, they were asked to begin the experiment, where they had to interpret the text and graph to answer comprehension questions related to each stock. During this process, their eye gaze patterns were recorded. Their comprehension questions were scored and they were given monetary compensation based on their performance.

We investigated the relationship between: 1) the number of transitions between the text and graph and comprehension, 2) the amount of time spent on the tasks and comprehension, and 3) the amount of time spent focusing on the graph or text and comprehension. With our small dataset, individual differences were more salient than trends. For example, the participant with the median score (9 out of 16) made 164 total transitions, while the subject with the best score made 49 total transitions. Similarly, individual differences were also salient in other two analyses.

With a small sample size, we found that our procedure provided fine-grained data to characterize subjects' knowledge acquisition processes. It would be possible to use the same method in future studies with a larger pool to obtain possibly significant findings. Our method proved to be successful, and would provide a strong base for future studies to build off of within this unprecedented field of research.

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Introduction

Investors and economists often look at graphical and written representations of economic trends with the goal of economic knowledge acquisition. Many people seek to learn about current economic events as they make their economic decisions. These people will often look online at websites hosting all sorts of economic coverage. Finding the strategies that experts use to interpret these representations would allow us to develop methods to improve the ways that non-experts interpret economic data. While finding the strategies that experts use may be simple, it is more challenging to find the subtler actions experts use when interpreting data. Eye-tracking technology allows us to observe the subtle intricacies of what people are looking at as they analyze economic data. Eye-tracking has been used in many fields to provide a direct method of observing user attention. However, there is a lack of eye-tracking research on economic decision making and trends. We use eye-tracking to observe how people interpret economic trends on a deep level. This study is about the information acquisition processes used by people when interpreting economic trends. This will hopefully allow us to determine the most efficient ways for investors to acquire data on economic trends when text and graphics are used. We also explore how different eye-movement patterns correspond to different levels of comprehension of economic trends.

We observe and record eye movement behaviors of participants as they look at economic trends, such as the amount of focus given to specific sources of information and the amount of transitions between textual and graphical information. We can then look at subjects' eye-tracking data for possible correlations between eye movement patterns and levels of comprehension. The benefits of eye-tracking help to form our main motivating goals such as investigating the relationships between: 1) the number of transitions between the text and graph and

comprehension, 2) the amount of time spent on the tasks and comprehension, and 3) the amount of time spent focusing on the graph or text and comprehension.

This research is based on a foundation of previous studies that used eye-tracking to look at decision making processes. For example, in one study (Reutskaja, Nagel, Camerer, & Rangel 2011) researchers looked at the eye movement patterns of subjects under specific conditions such as time pressure and choice overload. Our study will observe subjects under different levels of prior knowledge. In another study (Arieli, Ben-Ami, & Rubinstein 2011), eye-movement patterns were tracked to see how they related to choices made under situations of uncertainty. We intend to avoid uncertain situations by providing subjects with all the information that they would need to comprehend the information fully. This allows us to ensure that subjects with better methods of information acquisition should be able to perform the task to the best of their abilities. While previous studies have used eye-tracking methods when observing the decision making in economic games, we have found that there has not been any research done observing eye-movement patterns in the interpretation of economic representations.

Background

Many groups have researched economic decision making in various situations. Studies such as Tversky & Kahneman (1971) tested how people think about choices, attempting to infer the thought processes behind these decisions and to reconstruct these processes. However, these observations were limited by what the researchers could measure and record. More recently, researchers have been able to use eye-tracking to observe eye-movement patterns. This provided an extra level of data that was previously unobservable. Arieli, Ben-Ami, & Rubinstein (2011) observed the eye movements of subjects given different procedures to follow during their decision making tasks. These were observed through looking at vertical and horizontal eye-

movement patterns. Eye-tracking has been used to deeply understand the levels of knowledge acquisition in subjects such as Geology, with an emphasis on task complexity (Brigham & Levin, 2012). Research has also been done on consumer decision making during shopping. The eye-tracking data showed fixations that demonstrated how consumers search for and acquire new information during the task of purchasing goods (Reutskaja, Nagel, Camerer, & Rangel, 2011).

Eye-tracking methods can be applied when observing economic decision making. This provides data on the techniques subjects use to acquire knowledge. Research involving this application is still developing, so far with a focus on economic game theory. Costa-Gomez, Crawford, & Broseta (2001) looked at subjects' behaviors in games in an effort to understand their decision making outcomes. Costa-Gomez & Crawford (2006) went on to test how subjects would act in two-person guessing games, finding that subjects were able to comprehend the games and attempted to receive the highest payoff, but that the subjects would assume that the decision making processes of the other player were simpler than their own, leading to deviations from their expected behaviors.

Colombo, Rodella, & Antonietti (2013) used eye-tracking methods differently, opting to observe the eye-tracking patterns of subjects that were watching people who were lying or telling the truth and then making decisions in economic games, finding that behaviors can be modified when confronted with dishonesty. Social preference has also been examined with eye-tracking, revealing a connection with the choices of subjects strengthened by the pattern of subjects' eye movements (Funaki, Jiang, & Potters, 2010). The participants' backgrounds had an effect on their decision making and their eye movements. We decided to test subjects with different levels of prior economic knowledge due to this finding. A study done by Müller & Schwieren (2011) looked at eye-tracking data recorded from subject participation in an economic game and found

that the eye-tracking data from these subjects hinted at methods reasoning used that were more sophisticated than what was expected.

Eye-tracking has also been used to look at eye-movement patterns during bargaining. A study by Johnson, Camerer, Sen, & Rymon (2002) revealed that subjects started off with little strategy when bargaining, but were able to learn strategies when taught them. They also found that even without prior background knowledge, proper knowledge acquisition techniques were able to help subjects with their decision making. Knoepfle, Wang, & Camerer (2009) looked at the eye movements of subjects taking part in economic games repeatedly over time in their data collection to better understand learning in games.

While there has been a good amount of research in economic decision making that has used eye-tracking information, this research has so far only focused on observing decision making in economic games. This is likely due to the intersection of the fields of eye-tracking and economic decision making being relatively recent. We have found that there has not been research done that has used eye-tracking to observe how people interpret economic representations. Research in this area should provide a deeper understanding of economic decision making as it relates to the interpretation of economic representations in a realistic context.

METHOD

Overview

We recorded subjects' eye movement patterns as they observed several written and graphical representations of economic data. Eye-movement patterns were tracked as subjects looked at representations and as they were tested on their comprehension of the information. By tracking their eye-movement patterns, we were able to observe what information they attended to

among the text and graphic. We were then able to look for relationships between how subjects acquired the information and their understanding of the information.

Subjects were tested individually at a specially designated testing station. This testing station included a computer equipped with the Mirametrics eye tracker that recorded a subject's eye-movement patterns unobtrusively. Subjects were asked to complete a short questionnaire before the experiment that was be used to determine their level of prior knowledge. For each task, subjects were provided with a graph that detailed the stock prices of four different companies over a one month period along with a short text that detailed events that took place during this time period that involved each of the different companies. This was designed to mimic mainstream economic news layouts found in print and online economic resources. The graph was designed around the stock price information of Apple, Google, Sony, and Samsung during the month of September in the year 2013. We decided that it would be important that the companies we chose were all in a similar field so that subjects would not be influenced by their varying levels of knowledge of different fields. We chose to have subjects interpret information about several companies in order to add a level of complexity to each task that would require deep interpretation. Rather than solely depending on the text or graph, subjects would have to acquire information from both sources in order to fully comprehend the information. We expected that subjects who were proficient in acquiring information would look towards the various intersections between these companies. The written information for each company was written to describe several events that took place within the time period shown in the graph. These events were chosen to correlate with changes found within the graph, requiring subjects to transition between both the written and graphical information in order to fully comprehend all of the information. Subjects were asked questions that were designed to test their understanding of

the material. These questions were devised to have various difficulties in order to look for subtle differences in subject skill level and give a more precise spectrum of subject proficiency. During the test, each participant had their eye movements tracked as they interpreted the economic representations.

Participants

This study consisted of 9 undergraduate students. In order to have subjects with different backgrounds in economics, students were recruited from a non-economics related class and were expected to have no prior knowledge of economics. Other students were recruited from an economics class, and were expected to have a basic knowledge of economics.

Materials

Interface

Four separate screens were involved in this experiment, each consisting of a separate stock. Each screen included a written representation that included information on one company and a graph that included the stock prices of all four companies during a one month time period. The graph was kept the same across all four screens, and is shown below:

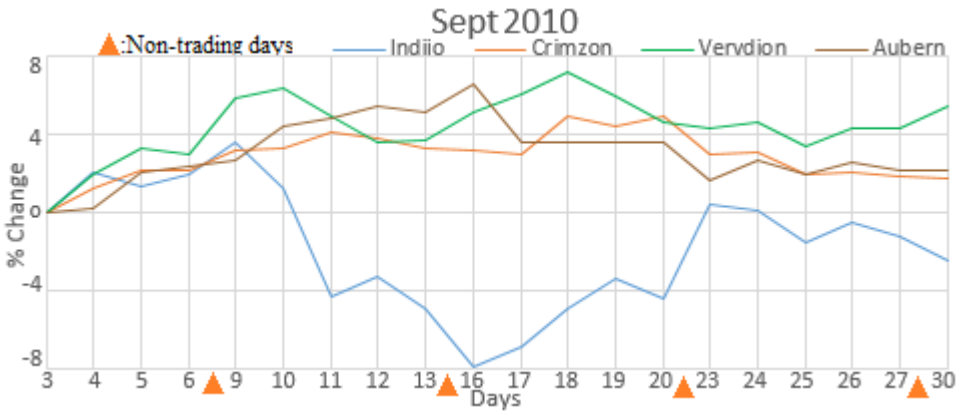

Figure 1: Four stock trends

As previously stated, the data shown in the graph was based on the stock prices of Apple,

Google, Sony, and Samsung during the month of September, 2013. These stock prices were collected from Yahoo Finance. The stock information was then included into one graph that was designed to fit the testing interface. We changed company and product names so that subjects would not be influenced by prior knowledge of each company's history. While designing the graph, we considered several potential time periods. We chose a one month time period because we thought it would allow subjects to consider small-scale changes as opposed to large changes over time. The chosen graph was also designed to show a large variety of changes, including increases and decreases of stock prices as well as intersections. All stock trends were based on stock prices taken from the same time period in order to ensure that the information would all be included within one graph. Line colors were chosen so that subjects would be able to easily distinguish between each company.

The written representations were based on events collected from multiple online resources (See Appendix A). One example is shown below:

"On September 10th, stockholders were not impressed with Indijo's new Azure phone. The next day, shareholders were worried that the new Azure was not low-priced enough to bring Indijo a lot of new revenue. It was supposed to be geared toward consumers in emerging markets who don't enjoy carrier subsidies and can't afford the lofty price of an unlocked Azure. This followed a trend of people buying the stock before the release of the new Azure. On September 15th, investors were still waiting to see how Indijo's new lineup would add to the company's bottom line. Indijo's Covalt operating system hit devices September 18th, representing a major shift for consumers, dropping the old layout for a more modern design."

The text was designed in conjunction with the graph. Based on the time period chosen, we investigated major events that affected each company. The texts were modified so that they

would include information that could not be determined from looking at the graph alone. The texts were also designed to include information that would show a clearer picture of what was occurring during the one month time period.

For each company, we developed four questions that would test understanding of the given representations (See Appendix B). One example of a question is shown below:

"1. How did investors react to the release of Indijo's new Covalt operating system?

a. They reacted positively, and Indijo's stock rose

b. They reacted neutrally, and Indijo's stock stayed the same

c. They reacted negatively, and Indijo's stock fell

d. Not enough information is provided"

We chose to make the questions based around a multiple choice format so that they could be easily scored during the experiment to expedite the process of participant compensation. We designed the questions so that they would vary in difficulty. This would allow us to ensure that we could detect varying levels of understanding within subjects. Questions were designed so that they would require different strategies of information acquisition. For example, some questions would require subjects to look at both the text and the graphic, whereas others could be answered on the basis of either the text or graphic alone. Due to the nature of the relationship between the two sources of information, we wrote the questions in a way that would require subjects to seek information from the two sources.

We designed the interface to separate each company into four separate screens that included four questions, a written paragraph that detailed events related to the company, and the graph. We ensured that scrolling would not be involved for any task so that subjects would be able to look at all of the information at once, which would help avoid the creation of "noise" in

our eye-tracking data. We developed each screen using Google Docs, as it provided a method of collecting subject responses that would be unobtrusive and not distracting to the subjects, as well as allowing us to score responses as the subjects performed each task. An example of how the interface appeared is below:

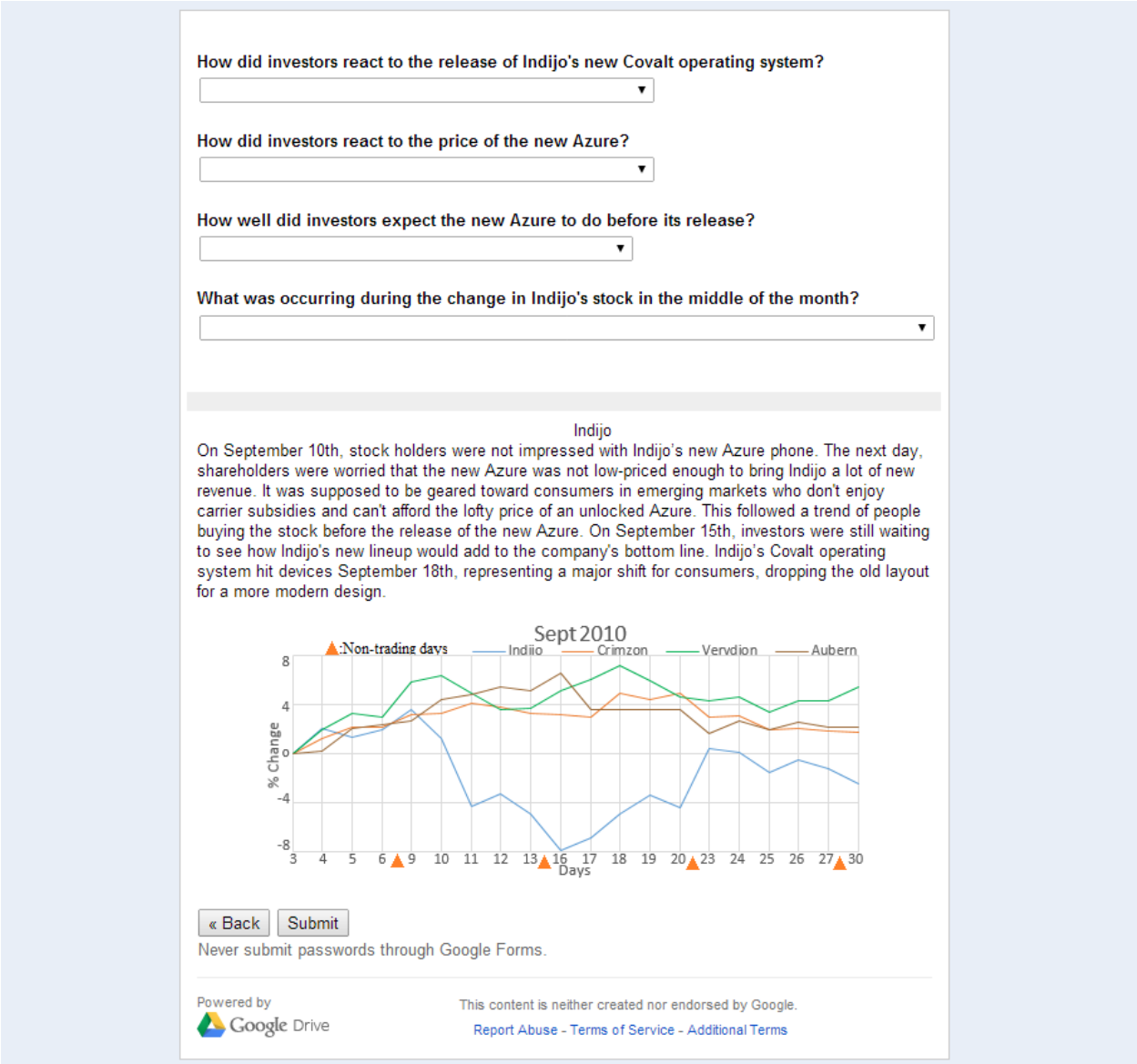

Figure 2: Layout Design

Experimental Design

Compensation

Participants were given a monetary reward as compensation for participating. This reward consisted of a $20 base value and an additional $1 for every correct answer in order to incentivize subjects to perform their best.

Testing Procedure

Participants were tested individually at a designated eye tracker workstation. The workstation was set up prior to each test to have each testing screen preloaded. Participants were first given a consent form to review and sign. Once they were finished, participants were then moved to the eye-tracker workstation. Participants were asked to get into a comfortable position so that they would not have to move during testing. This was done to avoid calibration errors that could occur if they were to move their positioning too drastically. Once the participant was in a proper position, they were read the following instructions:

- Today you will be reading some materials about the stock information of four companies and then answer some questions about each.
- I want to point out that this is not a test of your abilities in any way. Rather this is a small pilot study to study how an eye tracking system can be used to track learners' knowledge acquisition processes in real time.
- Your data are anonymous. Your professors, friends, etc. will not see your performance on this activity.
- Thank you in advance for helping us test our eye tracking system. For your participation, you will be given $20.00 plus an additional 1.00 for each correct answer. You may stop your participation at any point if you wish.
- You will be tested on 4 different companies. You will be asked 4 questions on each. Each company is presented on a separate screen.

- All of the questions are multiple choice. You are expected to answer all of the questions. However, there is no guessing penalty. When in doubt, make your best guess.
- You will be given a graph and one paragraph of text about each of the companies on each screen where you can obtain the information needed to answer the questions.
- Please ask now if you have any questions about the task.
- First, we will begin by calibrating the eye tracker to your eye gaze patterns.
- Second, for data collection purposes, we will need to start recording the video at the beginning of the test and stop it after you finish all the tests of four different screens. Your data will be saved in two files which names will be formatted by "Your Last Name".

The eye tracker was then calibrated to the participant's eye movements. In order to ensure that the eye tracker was properly calibrated, subjects were asked to look at each corner of the screen and at each cardinal direction. Once the eye tracker was fully calibrated, the participant was reminded to make sure that they did not move their position to help prevent calibration errors during the experiment.

The participant was first tasked with filling out a pre-test that asked about their prior exposure to economics, and then proceeded to the main tasks. After they completed the final task, the participant was asked to inform the experimenter, who would finish the video recording. During the tasks, the questions were manually scored in real time as the participant finished each task. The amount of money needed for compensation was then calculated and provided to the participants as they left.

Results

Once all of the data was collected, each video was manually coded by the experimenters. This was done by slowing down the videos of the eye-tracking traces to a quarter speed due to

the rapid speed of subjects' eye movements. Each video was approximately 1 hour in length after the reduction in playback speed. Data was coded based on areas of focus after every second passed, designated by the red circles of the eye-tracking traces. Transitions were coded based on differences in location between seconds, designated by the red lines in between the red circles. Here is an example of the eye-tracking trace shown imposed on one of our screens:

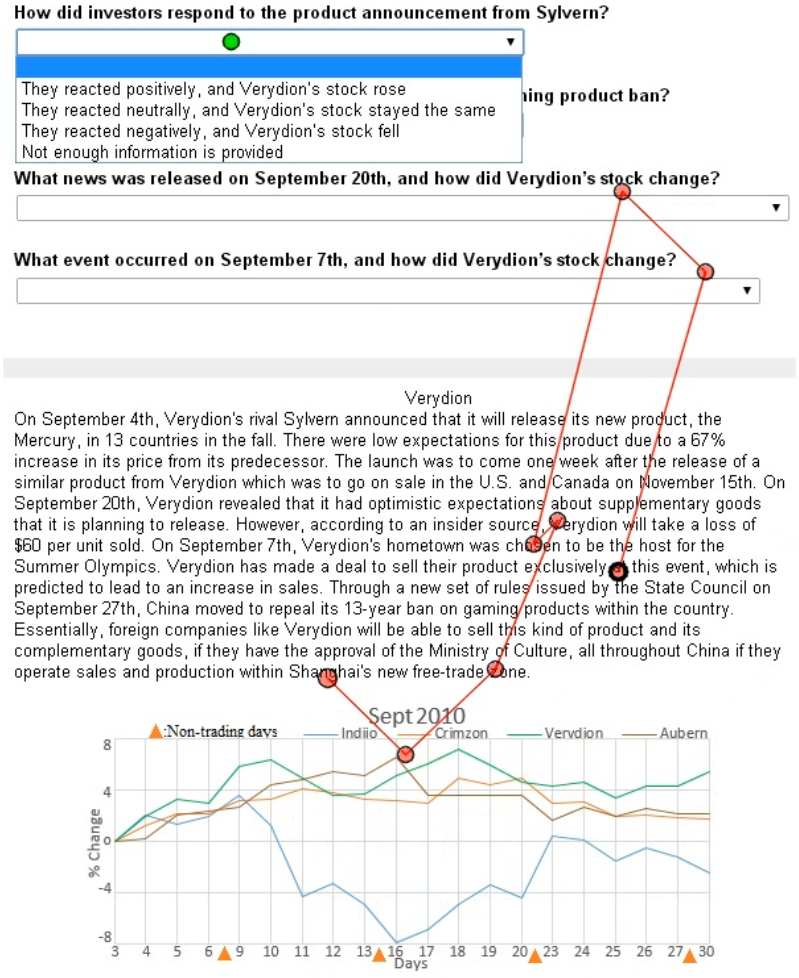

Figure 3: Eye-tracking trace

Areas of focus were categorized as either focusing on the graph, the text, the questions, and other, which encompassed anything outside of the other areas. Transitions and focus areas were coded both for the total task and separated by each screen. From this information, we were

able to produce tables of data showing both time spent focusing and well as transition counts (see Appendix D). From these areas of focus, we sought to quantify our dependent variables and produced several metrics: task time, transition counts between the text and graph, time spent focusing on the text and time spent focusing on the graph.

As previously mention, we investigated the relationship between: 1) the number of transitions between the text and graph and comprehension, 2) the amount of time spent on the tasks and comprehension, and 3) the amount of time spent focusing on the graph or text and comprehension. From our obtained dataset, we were able to plot out a graph to investigate the relationship between the number of transitions from graph to text as well as text to graph and comprehension score. We looked at both transition counts over the whole task as well as transitions counts per screen.

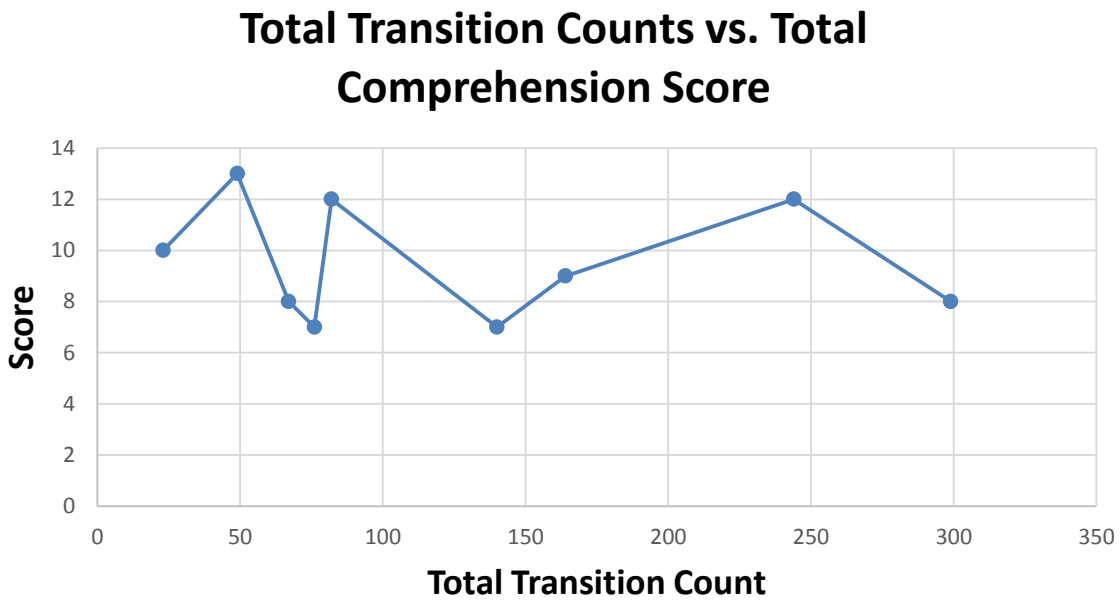

Figure 4: Graph of total transition counts for 9 subjects

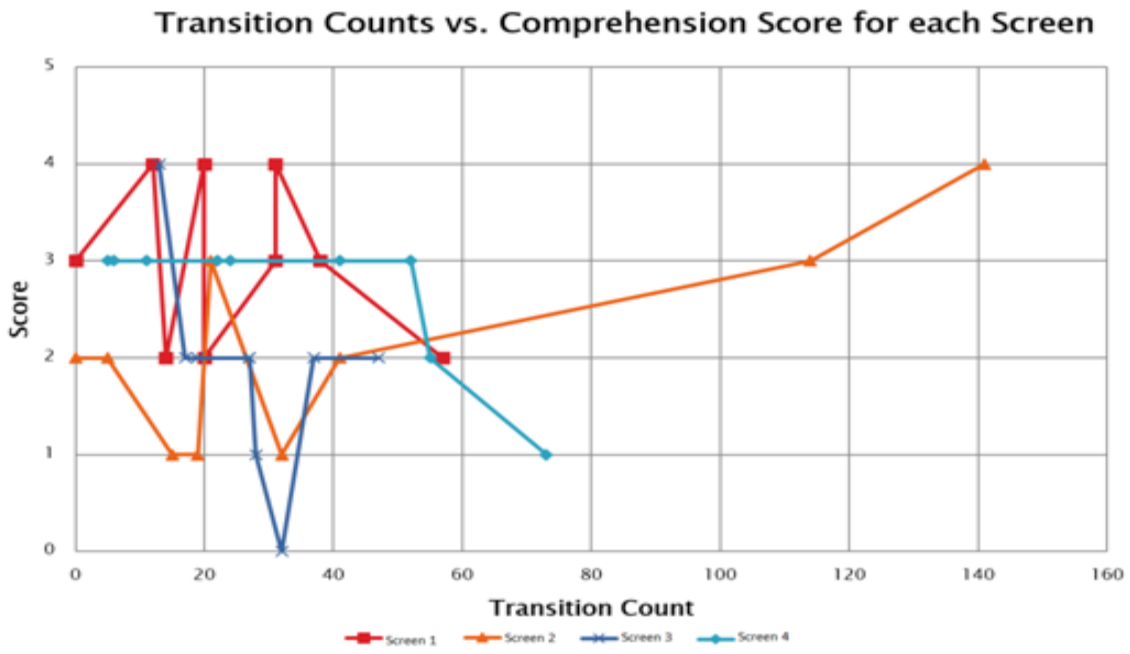

Figure 5: Graph of transition counts for each screen

It was expected that the relationship between transitions and comprehension would be positive based on earlier research (Yasar, Gobert, & Toto, 2014). However, our small sample did not permit a statistically significant relationship. We found that there were large individual differences between subjects. For example, while one subject with a large number of transitions scored well on comprehension, the subject with the largest amount of transitions had a below average comprehension score. The subject who scored highest in terms of comprehension actually had a relatively small amount of transitions.

We also examined the relationship between the total amount of time spent on task and comprehension scores, as well as the relationship between task times and comprehension scores per screen.

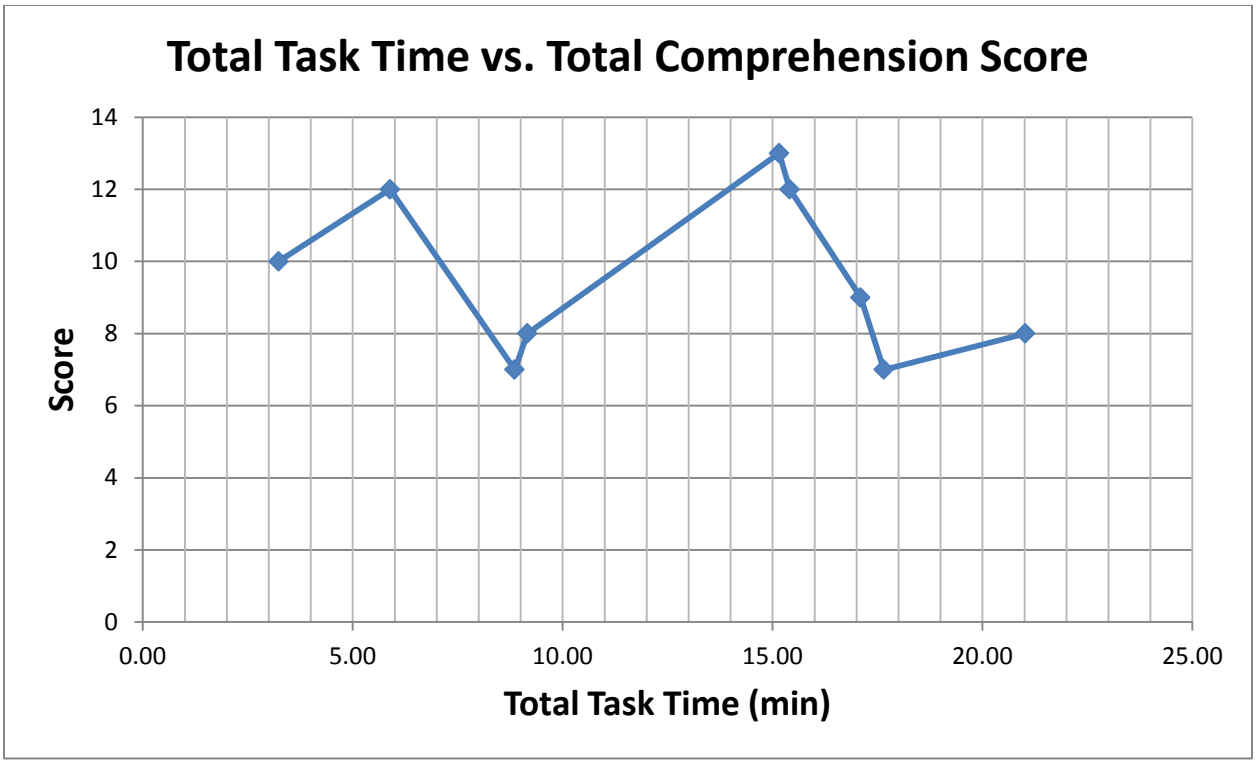

Figure 6: Graph of total task time for 9 subjects

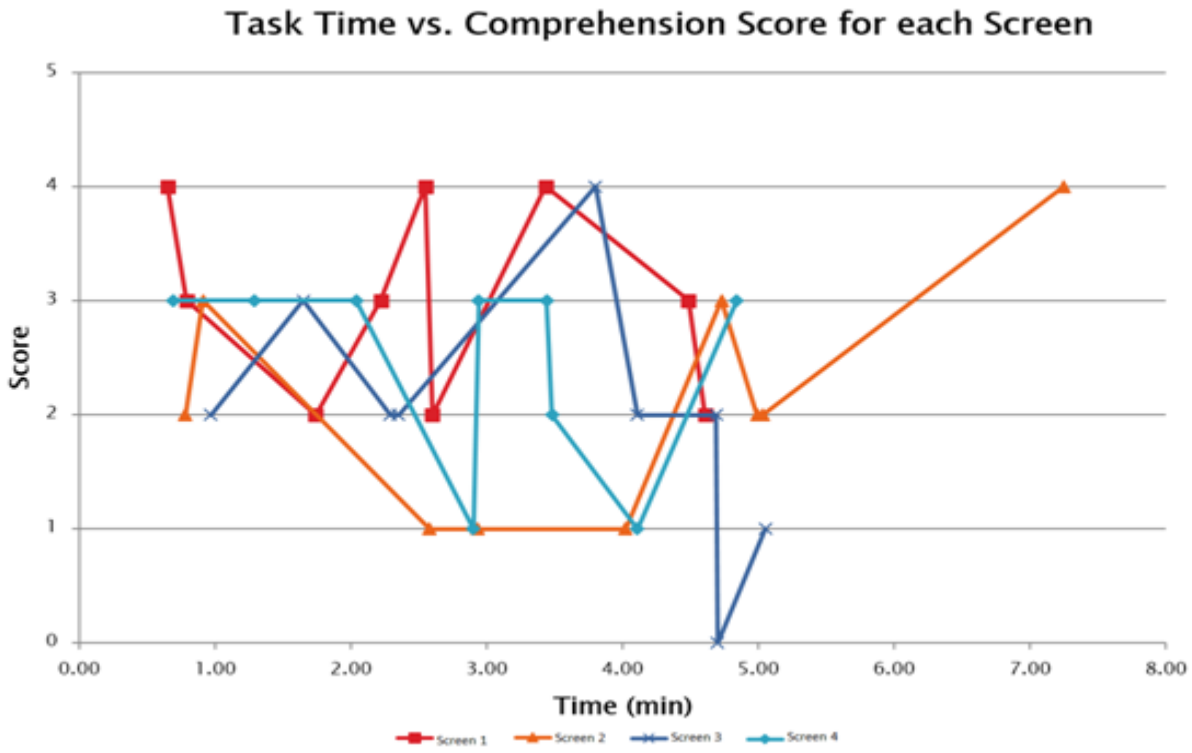

Figure 7: Graph of task time for each screen

Due to our small sample, we did not find a statistically significant relationship between task times and comprehension scores. However, we found that there were large individual differences. For example, the subject who spent the least amount of time had an average comprehension score of 10. The subject who spent the second least amount of time had an above average score of 12, while the subject who had the highest comprehension score spent approximately 15 minutes total on every task.

Our final goal was to address the relationship between time spent focusing on the graph or text and comprehension score. To observe this, we calculated the ratio of time spent focusing on the graph versus time spent focusing on the text and compared this to subject's comprehension scores both in terms of overall success and in terms of each separate screen.

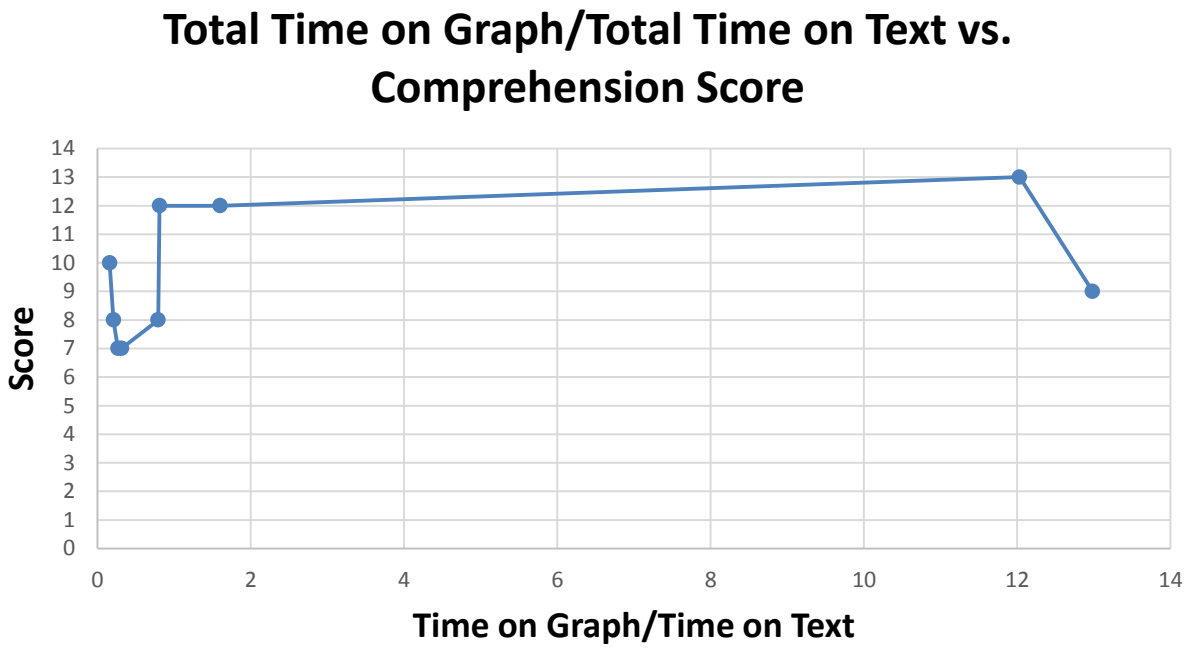

Figure 8: Graph/Text Ratio for 9 subjects

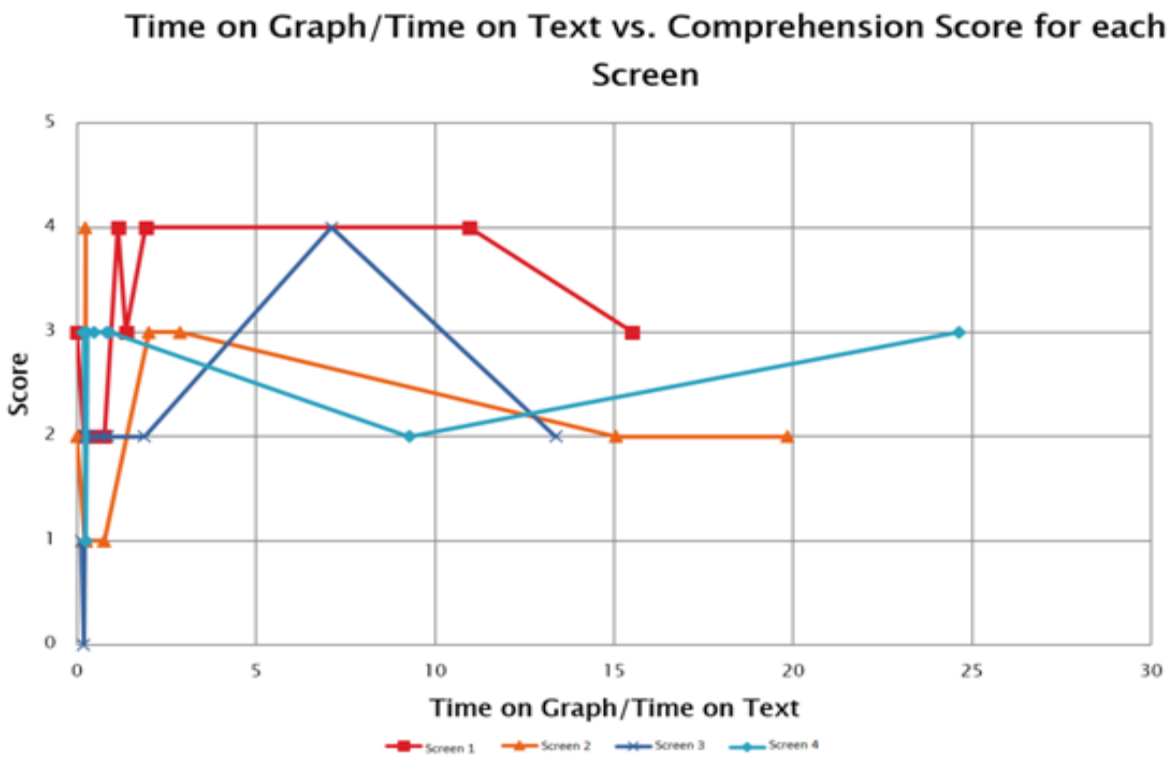

Figure 9: Graph/Text Ratio for each screen

Due to our small subject sample, we did not find a statistically significant relationship between time spent on the graph versus the text and comprehension scores. However, we found that many subjects spent much more time focusing on the text, with a wide range of comprehension scores. For example, there were two subjects who spent a much larger amount of time focusing on the graph, with comprehension scores of 13 and 9. The wide range of comprehension scores at both ends of the spectrum again point towards large individual differences.

Conclusion & Recommendations

While we were not able to find statistically significant relationships within our small sample, we found that the method that we developed worked very well. Due to the unprecedented nature of this research, our biggest goal was to develop a method that could be

used for future research in this field. We found that our procedure was able to provide the type of fine-grained data that could address knowledge acquisition strategies in this domain. A larger scale study using this method could potentially yield significant results. An increase in scale would not only provide a larger pool of data from which to draw conclusions, but also a way to look at larger differences among subjects.

From our data, we found that there were large individual differences between our subjects. We speculate that there could be several reasons for these differences. One possibility is that there may be individual differences due to working memory. It is potentially possible that subjects with low transitions may have had better comprehension of the material due to retaining the information in working memory better than other subjects, thus they did not need to do as many transitions between text and graphics. Future research could control for differences in working memory among subjects, and/or address how differences in working memory affect information acquisition. Another source of individual differences could be varying levels of prior knowledge. While we did a short pre-test for levels of prior knowledge, we did not address this in depth because it was outside the scope of this research. A larger scale study would be able to address differences in prior knowledge and its relationship to comprehension. We also speculate that the individual differences we found among our subjects could be due to differences in processing preferences. It is possible that subjects may have different preferences as to whether they received information from text or from graphics. Further research could address this and may prove fruitful.

Applying this methodology to different kinds of economic representations such as interest rates and housing mortgages would provide rich data that could be used to observe the types of strategies that allow for better comprehension of these representations. The importance

of being able to properly understand these forms of real world economic representations and the rich data that eye-tracking provides on how people interpret these representations both serve to make this methodology an important basis for research on economic interpretation. In closing, the methodology developed and used in this study can be applied to many domains where text and graphics are used. The type of research that can be done with this methodology scales very well due to the large number of domains in which text and graphics are used.

References

Arieli, A., Ben-Ami, Y., & Rubinstein, A. (2011). Tracking Decision Makers under Uncertainty. *American Economic Journal: Microeconomics*, *3*(4), 68-76.

Brigham, M., & Levin, E. (2012). *Eye Tracking And Prompts For Improved Learning* (Doctoral dissertation, Worcester Polytechnic Institute).

Cartsen, Paul. "Samsung Invests $500 million in New China Facility: Media."Yahoo Finance. N.p., 14 Sept. 2013. Web. <http://finance.yahoo.com/news/samsung-invests-500-million-china-075515209.html>.

Ciaccia, Chris. "Samsung Smartwatch Live Blog." The Street. N.p., 4 Sept. 2013. Web. <http://www.thestreet.com/story/12025935/1/samsung-smartwatch-live-blog.html>.

Colombo, B., Rodella, C., Riva, S., & Antonietti, A. (2013). The Effects of Lies on Economic Decision Making. An Eye-Tracking Study. Science and Education, *1*(3), 38-47.

Costa-Gomes, M., Crawford, V. P., & Broseta, B. (2001). Cognition and Behavior in Normal Form Games: An Experimental Study. *Econometrica*, *69*(5), 1193-1235.

Costa-Gomes, M. A., & Crawford, V. P. (2006). Cognition and Behavior in Two-Person Guessing Games: An Experimental Study. *The American Economic Review*, 1737-1768.

Funaki, Y., Jiang, T., & Potters, J. (2010). *Eye Tracking Social Preferences*. Working Paper.

Gallagher, Dan. "Microsoft Sets Xbox One Release for Nov. 22." MarketWatch. N.p., 4 Sept. 2013. Web. 11 Jan. 1111. <http://www.marketwatch.com/story/microsoft-sets-xbox-one-release-for-nov-22-2013-09-04?siteid=yhoof2>.

Gongloff, Mark. "Apple Stock Turns Ugly After Much-Hyped iPhone Announcement." The Huffington Post. N.p., 10 Sept. 2013. Web.

<http://www.huffingtonpost.com/2013/09/10/apple-stock-new-iphone-5c-5s_n_3901699.html>.

Johnson, E. J., Camerer, C., Sen, S., & Rymon, T. (2002). Detecting Failures of Backward Induction: Monitoring Information Search in Sequential Bargaining. *Journal of Economic Theory*, *104*(1), 16-47.

Kenwell, Bret. "Samsung Is Such a Poser." The Street. N.p., 25 Sept. 2013. Web. <http://www.thestreet.com/story/12048774/1/samsung-is-such-a-poser.html>.

Knoepfle, D. T., Wang, J. T. Y., & Camerer, C. F. (2009). Studying Learning in Games Using Eye- Tracking. *Journal of the European Economic Association,7*(2- 3), 388-398.

Lahiff, Keris. "Google (GOOG) Rolls Out Social Marketing Strategy." The Street. N.p., 11 Oct. 2013. Web. <http://www.thestreet.com/_nasdaq/story/12066899/1/google-goog-rolls-out-social-marketing-strategy.html?&cm_ven=nasdaq&cm_cat=free&cm_ite=na>.

Minyanville. "China to End Ban on Video Game Consoles, May Open Market to Microsoft, Sony, Nintendo." NASDAQ. N.p., 27 Sept. 2013. Web. <http://www.nasdaq.com/article/china-to-end-ban-on-video-game-consoles-may-open-market-to-microsoft-sony-nintendo-cm280927>.

Molina, Brett. "Tech Stocks: Apple Shares as iOS 7 Launches." USA Today. Gannett, 18 Sept. 2013. Web. <http://www.usatoday.com/story/tech/2013/09/18/tech-stocks-apple/2830321/>.

Müller, J., & Schwieren, C. (2011). More than Meets the Eye: An Eye-Tracking Experiment on the Beauty Contest Game. *University of Heidelberg Discussion Paper Series No. 516.*

Ogg, Jon. "Why Apple's Stock Price Will Look So Much Better After September."Yahoo Finance. N.p., 16 Sept. 2013. Web. <http://finance.yahoo.com/news/why-apple-stock-

price-look-160053207.html>.

Reeves, Jeff. "GOOG Stock Watch -- Google Is a Great Buy Now." The Slant. N.p., 18 Sept. 2013. Web. <http://slant.investorplace.com/2013/09/goog-stock-watch-why-google-is-a-great-buy-now/>.

Reeves, Jeff. "GOOG Stock - Is Google Getting Evil as a Teenager? | InvestorPlace." InvestorPlace RSS. N.p., 27 Sept. 2013. Web. <http://investorplace.com/2013/09/goog-stock-google-evil-15/#.U1lmb_ldXmc>.

Reutskaja, E., Nagel, R., Camerer, C. F., & Rangel, A. (2011). Search Dynamics in Consumer Choice Under Time Pressure: An Eye-Tracking Study. *The American Economic Review, 101*(2), 900-926.

Tversky, A., & Kahneman, D. (1971). Belief in the Law of Small Numbers. *Psychological bulletin, 76*(2), 105.

Whitney, Lance. "Apple Stock Tumbles Following Debut of New iPhones - CNET."CNET. N.p., 11 Sept. 2013. Web. <http://www.cnet.com/news/apple-stock-tumbles-following-debut-of-new-iphones/>.

Yasar, O., Gobert, J., & Toto, E. (2014). Using Eye Tracking to Measure Students' Knowledge Acquisition Processes from Text and Graphics. In Scaffolding Computer-Supported Inquiry Learning, Raes, A. (organizer). Symposium will be held at the 18th meeting of the Junior Researchers Conference of European Association for Research on Learning and Instruction, June 30-July 4, Nicosia, Cyprus.

Yousuf, Hibah. "Google Stock Hits All-Time High - The Buzz - Investment and Stock Market News." The Buzz Investment and Stock Market News RSS. N.p., 24 Sept. 2013. Web. <http://buzz.money.cnn.com/2012/09/24/google-stock/>.

Zacks.com. "Microsoft to Launch Xbox One on Nov 22 - Analyst Blog." NASDAQ. N.p., 5 Sept. 2013. Web. <http://www.nasdaq.com/article/microsoft-to-launch-xbox-one-on-nov-22-analyst-blog-cm272830>.

Appendices

Appendix A: Text Design

Indijo Firm

On September 10th, stock holders were not impressed with Indijo's new Azure phone. The next day, shareholders were worried that the new Azure was not low-priced enough to bring Indijo a lot of new revenue. It was supposed to be geared toward consumers in emerging markets who don't enjoy carrier subsidies and can't afford the lofty price of an unlocked Azure. This followed a trend of people buying the stock before the release of the new Azure. On September 15th, investors were still waiting to see how Indijo's new lineup would add to the company's bottom line. Indijo's Covalt operating system hit devices September 18th, representing a major shift for consumers, dropping the old layout for a more modern design.

Crimzon Firm

Crimzon's stock hit an all-time high in late trading September 21st, before pulling back to a record high closing price as the company continued to dominate in search, integrating its search engine with its mobile platform. Crimzon shares traded in a tight range on September 30th, but Crimzon has recouped most of the losses on product sales sustained throughout the month. Crimzon's Scarlet device was released on September 4th, and has equal or better specs than a comparable Oceana from Indijo that starts at $100 more in price. And the halt of Scarlet sales on September 18th in the Crimzon online store hinted at a refresh in the coming month that could further move Crimzon forward in tablet market share. Despite its growing revenue during the week of September 16th, the company underperformed compared to the industry average.

Verydion Firm

On September 4th, Verydion's rival Sylvern announced that it will release its new product, the Mercury, in 13 countries in the fall. There were low expectations for this product due to a 67% increase in its price from its predecessor. The launch was to come one week after the release of a similar product from Verydion which was to go on sale in the U.S. and Canada on November 15th. On September 20th, Verydion revealed that it had optimistic expectations about supplementary goods that it is planning to release. However, according to an insider source, Verydion will take a loss of $60 per unit sold. On September 7th, Verydion's hometown was chosen to be the host for the Summer Olympics. Verydion has made a deal to sell their product exclusively at this event, which is predicted to lead to an increase in sales. Through a new set of rules issued by the State Council on September 27th, China moved to repeal its 13-year ban on gaming products within the country. Essentially, foreign companies like Verydion will be able to sell this kind of product and its complementary goods, if they have the approval of the Ministry of Culture, all throughout China if they operate sales and production within Shanghai's new free-trade zone.

Aubern Firm

On September 4th, Aubern introduced its new smartwatch, the Aubern Mahogan Luxury, a perfect companion watch that further integrates the Aubern Mahogan experience into everyday life. To compete with this new product from Aubern, many investors thought that Indijo would launch its own smartwatch within the next several months. However, as of September 25th, online surveys about the Aubern Mahogan Luxury noted that it works only with the Aubern Mahogan Mary, not any of Aubern's other smartphones. This wearable device runs for $299,

which is believed to be a rather lofty price tag, according to investors. Moreover, the official China Daily newspaper revealed that Aubern announced that it will invest $500 million to build a packaging and testing facility in northwestern China on September 14th as South Korea's biggest company expands operations in China. On September 28th, Aubern and Mugatu, a famous fashion company, unveiled premium accessories for the Mahogan Gold and Mahogan Mary at the 2010 Derelicte Collection. They expected the new expensive leather clutches for the Mahogan Gold and Mary to offer their customers the option to express their sophisticated taste with high quality, premium accessories.

Appendix B: Question Design

Indijo Firm

1. How did investors react to the release of Indijo's new Covalt operating system?

a. They reacted positively, and Indijo's stock rose

b. They reacted neutrally, and Indijo's stock stayed the same

c. They reacted negatively, and Indijo's stock fell

d. Not enough information is provided

2. How did investors react to the price of the new Azure?

a. They reacted positively, and Indijo's stock rose

b. They reacted neutrally, and Indijo's stock stayed the same

c. They reacted negatively, and Indijo's stock fell

d. Not enough information is provided

3. How well did investors expect the new Azure to do before its release?

a. They expected it to do poorly and it performed well

b. They expected it to do poorly and it performed poorly

c. They expected it to perform well and it performed poorly

d. They expected it to perform well and it performed well

4. What was occurring during the change in Indijo's stock in the middle of the month?

a. Indijo revealed a price cut on the recent Azure, and Indijo's stock rose

b. Investors were waiting to see how Indijo's new line-up would perform, and Indijo's stock fell, then rose

c. The new Azure saw large sales to consumers in emerging markets, and Indijo's stock rose

d. The new Azure was experiencing random locks that would cause them to be unusable, and Indijo's stock fell

Crimzon Firm

1. How did investors react to the temporary halt of Scarlet sales?

a. They reacted positively, and Crimzon's stock rose

b. They reacted neutrally, and Crimzon's stock stayed the same

c. They reacted negatively, and Crimzon's stock fell

d. Not enough information is provided

2. How did investors react to the addition of a search engine to Crimzon's new phone?

a. They reacted positively, and Crimzon's stock rose

b. They reacted neutrally, and Crimzon's stock stayed the same

c. They reacted negatively, and Crimzon's stock fell

d. Not enough information is provided

3. How did investors react to Crimzon recouping its product sale losses?

a. They reacted positively, and Crimzon's stock rose

b. They reacted neutrally, and Crimzon's stock stayed the same

c. They reacted negatively, and Crimzon's stock fell

d. Not enough information is provided

4. What event was occurring on September 4th, and what effect did it have on Crimzon's stock?

a. Crimzon underperformed compared to the industry average, and its stock fell

b. Crimzon's Scarlet phone was released and had good specs, and its stock rose

c. Crimzon's Scarlet phone was released but had a higher price than competitors, and its stock fell

d. Crimzon over performed compared to the industry average, and its stock rose

Verydion Firm

1. How did investors respond to the product announcement from Sylvern?

a. They reacted positively, and Verydion's stock rose

b. They reacted neutrally, and Verydion's stock stayed the same

c. They reacted negatively, and Verydion's stock fell

d. Not enough information is provided

2. How did investors react to China's decision to remove its gaming product ban?

a. They reacted positively, and Verydion's stock rose

b. They reacted neutrally, and Verydion's stock stayed the same

c. They reacted negatively, and Verydion's stock fell

d. Not enough information is provided

3. What news was released on September 20th, and how did Verydion's stock change?

a. Verydion was not given the approval of China's Ministry of Culture to sell its product in China, and Verydion's stock fell

b. Verydion expected that it would make profit off of supplementary goods to its new product, and Verydion's stock rose

c. Verydion's hometown was chosen to be the host of the Summer Olympics, and Verydion's stock rose

d. Verydion will be taking a loss of $60 on each unit of its new product, and Verydion's stock fell

4. What event occurred on September 7th, and how did Verydion's stock change?

a. Verydion's new product release exceeded their expectations, and Verydion's stock rose

b. Verydion made a deal to sell its product at the Summer Olympics, and Verydion's stock rose

c. Verydion's exclusivity deal with the Summer Olympics fell through, and Verydion's stock fell

d. Verydion's rival has withdrawn from the market, and Verydion's stock rose

Aubern Firm

1. How did investors react after Aubern introduced its new expensive leather clutches for the Mahogan Gold and Mahogan Mary?

a. They reacted positively, and Aubern's stock rose

b. They reacted neutrally, and Aubern's stock stayed the same

c. They reacted negatively, and Aubern's stock fell

d. Not enough information is provided

2. What event occurred on September 4th, and how did this affect Aubern's stock?

a. Aubern revealed a high price tag for its new smartwatch, and Aubern's stock rose

b. Aubern introduced its new smartwatch to a lukewarm reception, and Aubern's stock fell

c. Indijo announced a new smartwatch to compete with Aubern's smartwatch, and Aubern's stock fell

d. Aubern introduced its new smartwatch to a positive reception, and Aubern's stock rose

3. Aubern invested $500 million to build a packaging and testing facility in northwestern China. What happened to Aubern's stock price?

a. Aubern's stock rose

b. Aubern's stock stayed the same

c. Aubern's stock fell

d. Not enough information is provided

4. How did Aubern's stock change before its new smartwatch was reviewed by its consumers via online surveys?

a. Aubern's stock rose

b. Aubern's stock stayed the same

c. Aubern's stock fell

d. Not enough information is provided

Appendix C: Background questions

1- Which economics courses have you taken? (Please include any ISP/IQP or graduate level courses)

a. ECON 1110:INTRODUCTORY MICROECONOMICS

b. ECON 1120:INTRODUCTORY MACROECONOMICS

c. None

d. Other:

2. Are you currently enrolled in any courses with ECON prefix? (If yes please indicate)

a. ECON 2110:INTERMEDIATE MICROECONOMICS

b. ECON 1120:INTRODUCTORY MACROECONOMICS

c. None

d. Other:

3. Which of the following finance/business/economics publications do you follow?

a. Wall Street Journal

b. Yahoo Finance

c. Bloomberg Businnes

d. None

e. Other:

4. Have you owned stocks?

a. Yes

b. No

Appendix D: Dataset Tables

Table 1: Counts and Focusing Time Spent on Graph and Text Area

	graph	graph time	graph ratio	text	text time	text ratio
Subject 1 Total	**2960**	**12:20**	**0.708**	**228**	**0:57**	**0.056**
Subject 1 Indijo	713	2:58	0.663	46	0:11	0.043
Subject 1 Crimzon	783	3:16	0.649	52	0:13	0.043
Subject 1 Aubern	842	3:30	0.853	63	0:16	0.064
Subject 1 Verydion	622	2:36	0.745	67	0:17	0.08
Subject 2 Total	**1913**	**7:58**	**0.526**	**159**	**0:40**	**0.044**
Subject 2 Indijo	405	1:41	0.492	37	0:09	0.045
Subject 2 Crimzon	397	1:39	0.332	20	0:05	0.017
Subject 2 Aubern	569	2:22	0.624	80	0:20	0.088
Subject 2 Verydion	542	2:16	0.769	22	0:06	0.031
Subject 3 Total	**465**	**1:56**	**0.211**	**587**	**2:27**	**0.267**
Subject 3 Indijo	138	0:34	0.221	181	0:45	0.29
Subject 3 Crimzon	131	0:33	0.187	174	0:44	0.248
Subject 3 Aubern	159	0:40	0.282	187	0:47	0.332
Subject 3 Verydion	37	0:09	0.119	45	0:11	0.145
Subject 4 Total	**514**	**2:09**	**0.364**	**635**	**2:39**	**0.449**
Subject 4 Indijo	64	0:16	0.407	56	0:14	0.357
Subject 4 Crimzon	146	0:37	0.667	51	0:13	0.233
Subject 4 Aubern	189	0:47	0.344	287	1:12	0.523
Subject 4 Verydion	115	0:29	0.235	241	1:00	0.493
Subject 5 Total	**814**	**3:24**	**0.192**	**2596**	**10:49**	**0.613**
Subject 5 Indijo	262	1:00	0.492	192	0:47	0.361
Subject 5 Crimzon	158	0:40	0.164	656	2:44	0.68
Subject 5 Aubern	128	0:32	0.114	714	2:59	0.634
Subject 5 Verydion	128	0:32	0.11	714	2:59	0.615
Subject 6 Total	**31**	**0:08**	**0.04**	**194**	**0:49**	**0.25**
Subject 6 Indijo	0	0:00	0	43	0:11	0.226
Subject 6 Crimzon	0	0:00	0	23	0:06	0.122
Subject 6 Aubern	22	0:06	0.094	79	0:20	0.339
Subject 6 Verydion	9	0:02	0.054	49	0:12	0.295
Subject 7 Total	**281**	**1:11**	**0.132**	**1054**	**4:24**	**0.496**
Subject 7 Indijo	55	0:14	0.132	136	0:34	0.325
Subject 7 Crimzon	74	0:19	0.12	347	1:27	0.561
Subject 7 Aubern	56	0:14	0.142	235	0:59	0.595
Subject 7 Verydion	96	0:24	0.138	336	1:24	0.483
Subject 8 Total	**1626**	**6:47**	**0.44**	**1016**	**4:14**	**0.275**
Subject 8 Indijo	238	1:00	0.389	124	0:31	0.203
Subject 8 Crimzon	568	2:22	0.501	284	0:71	0.25
Subject 8 Aubern	529	2:13	0.47	281	1:11	0.25
Subject 8 Verydion	291	1:13	0.352	327	1:22	0.396
Subject 9 Total	**537**	**2:15**	**0.106**	**2565**	**10:41**	**0.508**
Subject 9 Indijo	101	0:25	0.091	505	2:06	0.457
Subject 9 Crimzon	236	0:59	0.136	995	4:09	0.572
Subject 9 Aubern	54	0:14	0.045	459	1:55	0.379
Subject 9 Verydion	146	0:37	0.148	606	2:32	0.615

Table 2: Counts and Focusing Time Spent on Question and Other Area

	question	question time	question ratio	other	other time	other ratio
Subject 1 Total	**61**	**0:15**	**0.015**	**855**	**3:34**	**0.208**
Subject 1 Indijo	34	0:08	0.032	283	1:11	0.263
Subject 1 Crimzon	10	0:03	0.008	361	1:30	0.299
Subject 1 Aubern	8	0:02	0.008	74	0:19	0.075
Subject 1 Verydion	9	0:02	0.011	137	0:34	0.164
Subject 2 Total	**90**	**0:23**	**0.025**	**1476**	**6:09**	**0.406**
Subject 2 Indijo	38	0:10	0.046	344	1:26	0.417
Subject 2 Crimzon	8	0:02	0.007	772	3:13	0.645
Subject 2 Aubern	37	0:09	0.041	226	0:57	0.248
Subject 2 Verydion	7	0:02	0.01	134	0:33	0.19
Subject 3 Total	**376**	**1:34**	**0.171**	**771**	**3:12**	**0.351**
Subject 3 Indijo	138	0:35	0.221	167	0:42	0.268
Subject 3 Crimzon	122	0:30	0.174	275	1:08	0.392
Subject 3 Aubern	73	0:18	0.13	144	0:36	0.256
Subject 3 Verydion	43	0:11	0.139	185	0:46	0.597
Subject 4 Total	**212**	**0:53**	**0.15**	**53**	**0:13**	**0.037**
Subject 4 Indijo	14	0:03	0.089	23	0:06	0.146
Subject 4 Crimzon	5	0:01	0.023	17	0:04	0.078
Subject 4 Aubern	64	0:16	0.117	9	0:02	0.016
Subject 4 Verydion	129	0:33	0.264	4	0:01	0.008
Subject 5 Total	**771**	**3:13**	**0.182**	**54**	**0:13**	**0.013**
Subject 5 Indijo	73	0:18	0.137	5	0:01	0.009
Subject 5 Crimzon	129	0:32	0.134	21	0:05	0.022
Subject 5 Aubern	266	1:07	0.236	19	0:05	0.017
Subject 5 Verydion	303	1:16	0.261	16	0:04	0.014
Subject 6 Total	**430**	**1:48**	**0.553**	**122**	**0:31**	**0.157**
Subject 6 Indijo	71	0:18	0.374	76	0:19	0.098
Subject 6 Crimzon	154	0:39	0.819	11	0:03	0.059
Subject 6 Aubern	105	0:26	0.451	27	0:07	0.116
Subject 6 Verydion	100	0:25	0.602	8	0:02	0.048
Subject 7 Total	**526**	**2:13**	**0.247**	**266**	**1:07**	**0.125**
Subject 7 Indijo	174	0:44	0.416	53	0:13	0.127
Subject 7 Crimzon	123	0:31	0.199	75	0:19	0.121
Subject 7 Aubern	78	0:20	0.197	26	0:07	0.066
Subject 7 Verydion	151	0:38	0.217	112	0:28	0.161
Subject 8 Total	**312**	**1:20**	**0.084**	**744**	**3:06**	**0.201**
Subject 8 Indijo	15	0:04	0.025	235	0:59	0.384
Subject 8 Crimzon	69	0:18	0.061	213	0:53	0.188
Subject 8 Aubern	127	0:32	0.113	189	0:47	0.168
Subject 8 Verydion	101	0:26	0.122	107	0:27	0.13
Subject 9 Total	**746**	**3:07**	**0.148**	**1197**	**4:59**	**0.237**
Subject 9 Indijo	318	1:20	0.288	182	0:46	0.165
Subject 9 Crimzon	203	0:51	0.117	307	1:17	0.176
Subject 9 Aubern	178	0:45	0.147	521	2:10	0.43
Subject 9 Verydion	47	0:12	0.048	187	0:47	0.19

Table 3: Transition Counts and Comprehension Score

	graph-tex	text-graph tran	graph-question	question-	text-questi	question-tex	Score
Subject 1 Total	**77**	**87**	**25**	**20**	**6**	**13**	**9**
Subject 1 Indijo	12	19	18	16	2	6	3
Subject 1 Crimzon	18	23	5	2	1	3	2
Subject 1 Aubern	18	19	2	0	0	3	2
Subject 1 Verydion	29	26	0	2	3	1	2
Subject 2 Total	**23**	**26**	**13**	**10**	**3**	**5**	**13**
Subject 2 Indijo	10	10	3	3	2	2	4
Subject 2 Crimzon	3	2	2	2	0	0	2
Subject 2 Aubern	5	8	5	4	1	2	4
Subject 2 Verydion	5	6	3	1	2	1	3
Subject 3 Total	**35**	**32**	**11**	**20**	**36**	**30**	**8**
Subject 3 Indijo	10	10	3	4	11	12	2
Subject 3 Crimzon	10	5	5	8	10	9	1
Subject 3 Aubern	14	13	2	8	13	7	2
Subject 3 Verydion	1	4	1	0	2	2	3
Subject 4 Total	**36**	**46**	**12**	**10**	**19**	**20**	**12**
Subject 4 Indijo	3	9	1	2	3	4	4
Subject 4 Crimzon	11	10	1	1	2	2	3
Subject 4 Aubern	12	15	8	4	6	6	2
Subject 4 Verydion	10	12	2	2	8	8	3
Subject 5 Total	**65**	**75**	**17**	**9**	**52**	**60**	**7**
Subject 5 Indijo	19	19	3	3	13	11	3
Subject 5 Crimzon	16	16	2	2	14	15	1
Subject 5 Aubern	16	16	4	2	12	16	0
Subject 5 Verydion	17	24	8	2	18	13	3
Subject 6 Total	**11**	**12**	**1**	**2**	**36**	**25**	**10**
Subject 6 Indijo	0	0	0	0	5	5	3
Subject 6 Crimzon	0	0	0	0	10	5	2
Subject 6 Aubern	9	8	0	1	9	7	2
Subject 6 Verydion	2	4	1	1	12	8	3
Subject 7 Total	**38**	**38**	**13**	**13**	**18**	**14**	**7**
Subject 7 Indijo	9	5	2	7	4	2	2
Subject 7 Crimzon	8	11	6	4	6	4	1
Subject 7 Aubern	10	9	1	0	3	3	3
Subject 7 Verydion	11	13	4	2	5	5	1
Subject 8 Total	**119**	**125**	**36**	**16**	**39**	**36**	**12**
Subject 8 Indijo	13	18	3	1	4	5	4
Subject 8 Crimzon	56	58	27	5	12	13	3
Subject 8 Aubern	25	22	4	5	10	10	2
Subject 8 Verydion	25	27	2	5	13	8	3
Subject 9 Total	**149**	**150**	**26**	**26**	**109**	**131**	**8**
Subject 9 Indijo	27	30	11	7	58	64	2
Subject 9 Crimzon	73	68	13	15	38	49	4
Subject 9 Aubern	14	14	1	2	6	7	1
Subject 9 Verydion	35	38	1	2	7	11	1