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An Examination of Presentation Strategies for Textual Data in Augmented Reality

Kanrawi Kitkhachonkunlaphat
Purdue University, kanrawi_k@hotmail.com

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David C. Whittinghill
Chair

Mihaela Vorvoreanu

James Mohler

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AN EXAMINATION OF PRESENTATION STRATEGIES FOR TEXTUAL DATA IN AUGMENTED REALITY

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To my family, thank you for the never ending supports, encouragement, and patience.

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ABSTRACT

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Videos with embedded text have been widely used in the past and the text in the videos usually contained valuable information. However, it was difficult for people to fully understand the text in videos displayed on smartphones due to obstructions such as color conflicts between letters and the moving background. Adjustments to texts that would support the human visual system, such as changes to brightness and color contrast, increased legibility of text, and taking into account the phantom illumination (PI) illusion (the optical illusion that increases the perception of brightness in a certain area), should be able to improve peoples' ability to read text in augmented reality (AR) applications on smartphones. The researcher created a text presentation style implementing the PI illusion, using solid white text on a 50% transparent black billboard with a black-white shading PI illusion at the internal edge. An experiment was conducted to verify whether the text presentation style could improve reading performance. The experiment showed that the PI illusion was unable to improve legibility of text in AR applications on smartphones. However, the data suggested that, in some cases, certain participants, especially from some specific major groups, have difficulties text reading when the text is presented using the standard text presentation style without the enhancement of the PI illusion.

CHAPTER 1. INTRODUCTION

This chapter gives a general overview of this research study. The chapter covers the background of the research leading to the research question. It also defines the scope, assumptions, limitations, delimitations, and definitions of important terms in the research.

1.1 Background

In the world of information technology, videos and audios are a popular media through which to spread information. However, text is still needed to present more detailed information and is commonly embedded into videos. The combination of video and text is common in the television industry. Television news producers display crime scene videos with overlaid text to show detailed descriptions. In the film industry, filmmakers use subtitles to show translations of foreign dialogues. They also overlay text in films to show descriptions of the location in certain scenes. Even in some applications, such as mobile applications, videos with descriptive text are used to provide information to users. One example is augmented reality (AR) applications in which texts are used to label the name of locations and provide details about them rather than using real-world video scenes.

Mobile phones are one of the devices on which videos with embedded text from the above sources are frequently viewed. With the current development of smartphones, high performance processors and high resolution screens and cameras allow the devices to have all the required hardware for playing a high quality video in real time. In addition to the hardware, the portable characteristic of mobile phones enables people to use them to see a video anytime, anywhere, and for any purpose ranging from accessing important information to entertainment. One study reported the increasing number of mobile phone users in past few years, especially users with smartphones. The Pew study found that 35% of American adults owned smartphones in 2011 and that number was increased to 45% in 2012 (Smith, A, 2011; Brenner, J., 2013). According to these statistics, it can be assumed that people will view videos via mobile phones more and more. However, there were obstructions preventing people from understanding the text in videos on a mobile phone. These obstructions made it difficult for people to receive all of the information they expected to receive from the embedded text in the videos being watched.

1.2 Significance

As videos with embedded text were widely used and the text in videos usually contained valuable information, large groups of people needed to quickly and accurately understand the text. Nevertheless, it was hard for people to fully understand the text in videos on mobile phones due to two obstructions. One obstruction was the hardware limitation of the mobile phones themselves, such as the small screen size (Kruijff, E., Swan, J. E., & Feiner, S., 2010). The other obstruction was the specific characteristics of the videos themselves. The lack of a rewind function for most videos and the short appearance of the text on the screen made it difficult for people to obtain the information that they desired. Between the distractions from moving contents and the color conflicts between letters and background, the most significant interference in reading text embedded in a video, it was hard for people to fully catch the information (Harrison, B. L., & Vicente, K. J., 1996).

In most AR applications, the embedded text in real-world video scenes plays an important role in providing information to application users. These applications display information such as the names of locations, scientific information, and detailed descriptions to the users. In applications lacking important information, more time was required and more mistakes were made for general tasks while safety issues resulted due to the lack of this information in serious operations. There should be a way to increase human's ability to consume information from those texts.

1.3 Statement of Purpose

As it was well known that adjusting certain elements supporting human visual systems, such as brightness and color contrast, can increase the legibility of texts, other knowledge of visual human perception would be helpful for the enhancement text readability. The researcher found that certain visual illusions can increase the perception of brightness in a certain area of an image. The researcher posits that those visual illusions should be able to enhance text presentation in AR applications. The improved text presentation should thereby increase human's ability to read embedded text. Consequently, the goal of this study was to improve text presentation in real-world video scenes on portable devices by implementing the knowledge of visual illusions on human visual perception.

1.4 Research Question

Of all of the visual illusions, the researcher found that the phantom illumination illusion (PI) illustrated the strongest brightness illusion compared to other visual illusions. As Harrison el al. (1996) explained, color conflicts were the most serious interference for text reading and the adjustment of shade and hue could improve reading performance. Based on this research, the applied brightness effect from the PI illusion should be helpful in terms of reading text in videos; therefore, the researcher chose the PI illusion to enhance text presentation in the study. The main question to lead the study of this research was "Can the phantom illumination illusion improve text representation in augmented reality on a smartphone?"

1.5 Scope

The purpose of the research was to examine whether text presentation implementing the PI illusion could improve legibility of text in an AR application on smartphones. A text presentation style was developed implementing the PI illusion. The mere theoretical support did not ensure that the illusion could enhance reading performance, as the study proved that only the green plain color text presentation style provided good results even though humans are sensitive to both red and green colors (Gabbard, J. L., Swan, J. E., & Hix, D., 2006). The human subject experiment was conducted to compare the operating performance of participants between the developed text presentation style and the standard text presentation style suggested by Jankowski et al. (2010). The study used the result from the human subject experiment on an AR application on a smartphone to make its conclusion.

1.6 Assumptions

The assumptions in this study included:

1. The elements of the population correctly reported their visual acuity.
2. The subjects intently did the experiment to the best of their ability.
3. There was no hardware delay in the experiment.

1.7 Limitations

The limitations in this study included:

1. The lighting condition during the experiment was not completely controlled.
2. The environment around the experiment in the study was not completely controlled.

1.8 Delimitations

The delimitations in this study included:

1. The study was focused only on one text presentation style implemented by the PI illusion.

2. The study focused on text presentation in AR applications on smartphones only.
3. The study focused on common short words that have meaning.
4. The study was designed for people with normal or corrected-to-normal vision.
5. The research supported only English language in the study.
6. A text representation in the study had a low degree of overlapping with other texts.
7. The study controlled the illusions for depth perception.
8. The study controlled the motion perception, impacting the legibility of the represented text.

1.9 Definitions

Augmented reality (AR) – "AR is the ability to superimpose virtual, registered information over a user's view of the real world" (Thomas & Sandor, 2009, p.8).

Minima of curvature – The characteristic of human visual perception that is sensitive to the deepest curvature in a smooth boundary. This phenomenon allows humans to easily divide a shape into parts from the lowest points on its boundary (Hoffman, 1998).

Monocular depth cues – "Monocular depth cues are perceived just as strongly when viewed with one eye as when viewed with both eyes" (Schwartz, 2009, p. 229).

Negative image polarity – The use of light texts on a dark background (Jankowski, Samp, Irzynska, Jozwowicz, & Decker, 2010, p. 1325).

Phantom Illumination Illusion (PI) – The illusion created from pieces of gradient of two different colors. The direction of the gradient was toward a particular direction allowing humans to perceive a part of the background as brighter or darker (Zavagno, 2005).

Positive image polarity – The use of dark texts on a light background (Jankowski, Samp, Irzynska, Jozwowicz, & Decker, 2010, p. 1325).

Response Time (RT) – The time that a participant spent to perform a task.

Subject figure – The illusion created by human visual perception that allows humans to interpret fractions of shapes as a ghost shape overlaying on occluded shapes (Hoffman, 1998).

Transparent filter – The illusion created by human visual perception that allows humans to see some areas darker than other connecting areas of the same color. It is possible for humans can view this phenomenon as a dark filter with no clear starting and ending point (Hoffman, 1998).

1.10 Summary

This chapter presented the overview of the study. The vision of the research was to improve human's ability to consume information from text embedded in videos. The research goal was to study whether it was possible to improve text presentation in AR applications on smartphones by applying knowledge of visual illusions in the human visual perception, specifically the PI illusion.

CHAPTER 2. REVIEW OF LITERATURE

This chapter introduces previous works that were the basis of this research study. Due to the multi-disciplinary nature of this study, the researcher collected the related literature from multiple research areas, especially the areas of augmented reality (AR) and human visual perception. The research the AR discipline provided information about was the nature of AR applications, the current text presentation techniques used in AR applications, and possible limitations of the technology. On the other hand, the research done in the discipline of visual perception provided ideas on how to improve text presentations in ways that support the human visual system as well as explaining the limitations of human visual system.

2.1 Text Display

In order to effectively presented text in an AR application, the researcher studied a number of papers in the areas of human factors and AR that discussed techniques used to efficiently present text in AR. The discussions covered everything from how to present a single character to how to decorate texts to improve text legibility.

Research on human factors gave suggestions on how to display the text itself. Sheedy, Subbaram, Zimmerman, and Hayes (2005) studied text display on computer screens and found that text that was nine pixels, or in ten-point font, provided optimal legibility. Larger font sizes conveyed better legibility, but they did not improve the overall threshold of legibility. For the font style, they claimed that Verdana and Arial are the most readable fonts. Sheedy et al. (2005) could not conclude that sans-serif fonts, font types without the features at the end of strokes, were more legible than serif fonts. The readability depended on individual font styles. However, recommendations from digital television described that sans-serif fonts were better (as cited in Jankowski, Samp, Irzynska, Jozwowicz, & Decker, 2010, p. 1324). Furthermore, the recommendations suggested that text decorations such as italicizing, underlining, and bolding text should be avoided. They also advised against using blinking and moving text. Conversely, Leykin and Tuceryan (2004) claimed that text legibility was increased if the text was of a much larger size or extremely bold. In conclusion, the Verdana or Arial font with the ten-point size or more should be used in text presentation. The text presentation should be static and should be neither italicized nor underlined.

2.2 Previous Text Presentation Styles

Going beyond the presentation of the characters themselves, a number of papers on AR raised the issue of the use of text presentation styles to increase text legibility.

The major problem faced when reading text in video sources is the interference from the background. Of all possible factors, Harrison and Vincente (1996) pointed out that color conflict from the background was the most crucial. Visual complexity of the background also interferes with and affects reading performance (Gabbard et al., 2007; Jankowski et al., 2010). However, Leykin and Tuceryan (2004) claimed that the background affected text legibility only in the case of low contrast texts. These studies showed that multiple interferences from the background were very important in terms of text legibility. Then, several researches in AR developed text presentation styles to solve the interference problem.

Gabbard, Swan, and Hix (2006) found that the billboard style, text with a solid rectangular band, resulted in the best reading performance. Furthermore, Gabbard, Swan, Hix, and Kim (2007) concluded that the contrast between text drawing style and text was more crucial than the contrast between the text presentation style and the background. It was clear that a particular style succeeded because it avoided direct interference from the background. However, the text presentation style completely occluded a part of the background video that may have contained important material for some applications.

Another technique discussed was the use of overlaying transparent backgrounds behind the texts. Instead of using a solid-colored band, some studies suggested a transparent band. Jankowski et al. (2010) studied the suitable transparency level and image polarity of overlaying transparent backgrounds for reading. Based on their experiment, the reasonable transparency level for the positive image polarity was solid black text on a 70% transparency white background while the negative image polarity was solid white text on a 55% transparency black background. Jankowski et al. (2010) also did the experiment on the text readability of long paragraphs of text with a video background. The study found that the billboard text presentation style with the negative image polarity was preferable. Based on that study, the researcher chose to apply the text presentation style they suggested as the control group for this study.

2.3 Visual Illusions

The researcher found that human visual perception was the area through which to study the mechanisms of the human visual system. The knowledge gained from this area was used to improve text legibility in areas such as the adjustment of brightness and contrast of texts. As the visual illusions used in this study also applied knowledge from human visual perception, the visual illusions should be able to enhance readability.

Human visual perception is the capability to see the world that all humans share together. Hoffman (1998) claimed that people perceive the world in the same way regardless of race, gender, religion or age. He called this ability “the rule of universal vision” (Hoffman, 1998, p. 14). Hoffman (1998) also explained that humans perceive their environment following certain sets of rules. Some of these rules allow us to perceive visual errors, which were called illusions. Illusions may distort what we see, but they help us to efficiently see the world. They help us to process visual images faster and more intelligently in order to fill in any missing information that is necessary to understand what is being seen.

There are a lot of visual illusions. However, based on the previous works, the illusions that could be helpful for the development of text presentation styles were subjective figures, transparent filters, minima of curvature, and the phantom illumination (PI) illusion.

2.3.1 Subjective Figures

While Hoffman (1998) described several illusions in his book, the idea of subjective figures was one of the concepts presented. He explained that humans could see an illusion of shape overlaying fractions of an occluded shape even if it was not there, as shown in Figure 2.1. Our brain automatically constructs the shape from the surrounding clues.

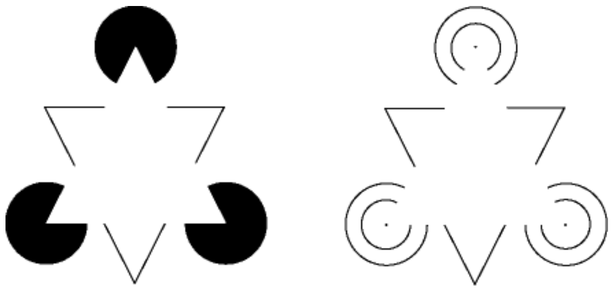

Figure 2.1 Kanizsa's Subjective Triangles, One of the Subject Figures
Hoffman, D. D. (2012) Kanizsa's subjective triangles [Image]. Retrieved from http://www.cogsci.uci.edu/~ddhoff/kanizsa-triangle.gif

As the dominant feature of subjective figures was the construction of shape with the minor feature of the change in brightness of the shape, the illusion had potential to be able to enhance text presentation. The construction of a shape made a text label with the illusion stand out more, which has the potential to increase the legibility of the text.

2.3.2 Transparent filters

Transparent filters was another illusion introduced by Hoffman (1998). He claimed that people saw colors relative to other surrounding colors. That was why transparent filters led humans to see the same color in some areas as darker than usual (see Figure 2.2). Moreover, Hoffman (1998) pointed out that humans do not perceive a single point of color, but a whole scene. Thus, he claimed that humans interpret the brightest color as white or self-luminous. After that, other colors with different lumina are arranged in the color range relative to other colors in the scene.

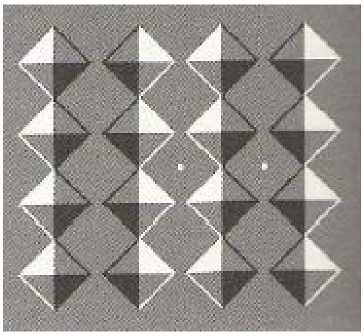

Figure 2.2 The Illusion of Transparent Filter Surrounding the White Point on the Right (Hoffman, 1998, p.124)

Use of transparent filters can cause humans to see some areas as darker than they are supposed to be. The change of brightness in a certain area of the scene should be useful to enhance the appearance of embedded text.

2.3.3 Minima of Curvature

Hoffman (1998) also described one characteristic of human perception that allows humans to easily divide a shape into parts. He said that humans were sensitive to the minima of curvature, the deepest part of a curve, of a smooth boundary (see Figure 2.3). Humans detect them very quickly and usually use them in object partitioning.

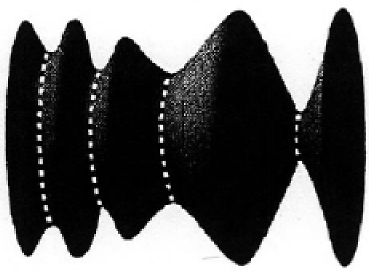

Figure 2.3 The Segmentation of a Shape by the Minima of Curvature
(Hoffman, 1998, p.89)

The minima of curvature could be useful for word identification. Word identification is the level of reading that allows a person to recognize a word regardless of its meaning. Sheedy et al. (2005) studied the relationship between appearance of the word and word identification. They found that people use the information provided by a word's shape in word identification. Nevertheless, the shape of each character plays a more important role for the identification. Consequently, people should be able to identify a word more quickly if the minima of curvature have been applied to enhance the appearance of the whole word or each character.

2.3.4 Phantom Illumination Illusion

A new type of visual illusion was introduced by Zavagno (2005) called the phantom illumination illusion. This illusion is the effect of the appearance of gradients with two different colors that the direction of the gradients is toward a particular direction (see Figure 2.4). The illusion allows humans to perceive a part of the image's background as brighter or darker than it actually is. Zavagno (2005) claimed that, on a black and white background, the background behind the phantom illumination with black-grey shading was always brighter. The background behind the phantom illumination with white-black shading was always darker. This illusion illustrates a strong brightness illusion compared to other visual illusions.

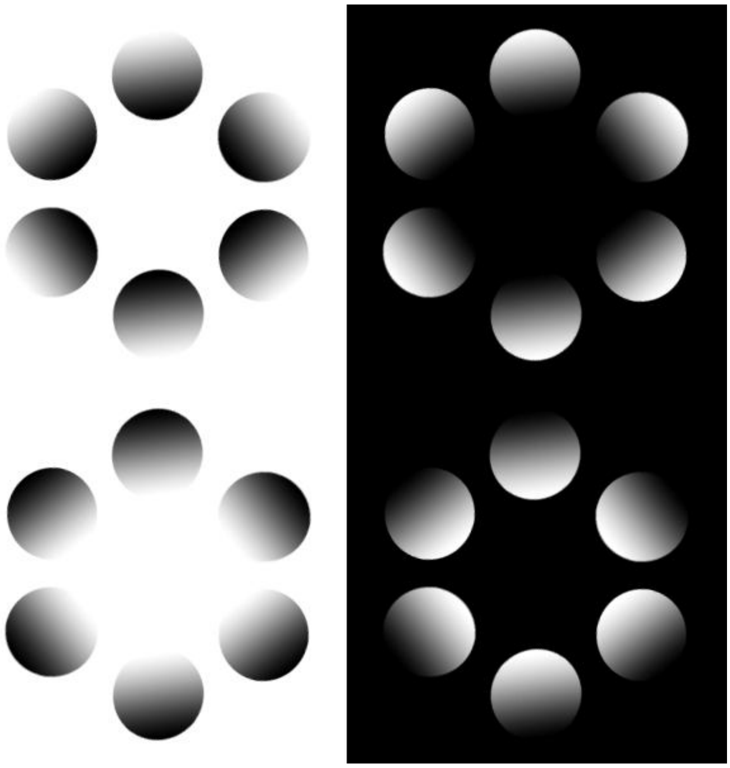

Figure 2.4 Examples of the Phantom Illumination Illusion

The distinguishing feature of this illusion is the strong brightness illusion aspect. The illusion can both increase and decrease the brightness of certain parts of an image. The phantom illumination illusion should be able to improve text presentation by changing the perception of brightness in a certain area.

Since Harrison el al. (1996) claimed that color conflicts were the most important interference in reading text, the researcher decided to apply illusions that affect the change in brightness that also distort the perception of colors to enhance the developing text presentation. Due to the fact that the phantom illumination illusion provided the strongest brightness among illusions, the researcher chose this illusion to improve the text presentation.

2.4 Other Issues in Human Perception

Even though the illusions in human visual perception were considered as the main hurdle to improving text presentation, there are other issues having to do with human perception that should be taken into consideration in order to prevent the unexpected perceptual errors.

Depth perception is one of the common visual perceptions in AR technology due to the use of 3D space. Depth perception is the ability of defining level of depth in human perception (Schwartz, 2009). In an AR system, correct depth cues are important for creating an accurate sense of depth for virtual objects in real-world video scenes (Drascic & Milgram, 1996). There are multiple categories of depth cues, but the monocular depth cues affected images displayed on a screen, like in an AR system, the most. Among monocular depth cues, the interposition provided the strongest sense of depth (Drascic & Milgram, 1996). Besides interposition, other depth cues are also crucial for depth level determination of different distances (Furmanski, Azuma, & Daily 2002). Binocular depth cues are important for short distances of less than three meters. Motion parallax is crucial for medium distances, between three to ten meters, while the size constancy plays an important role for long distances of more than ten meters.

There have been multiple research studies done that introduced techniques for the implementation of depth cues. Drascic and Milgram (1996) suggested that the brighter an object, the closer the sense of depth, while a darker object appears to be farther away. The lower the contrast and blur of an object the farther away the object seems (Kruijff, Swan, & Feiner, 2010). For the location of labels, Peterson, Axholt, and Ellis (2008) found that the heights of the labels did not need to match the heights of their objects. Labels can be elevated with different angles even when in the same group of labels.

Accordingly, as the researcher excluded the perception of depth from the study, the study needed to control the depth perception in the created AR application by controlling the size, brightness, contrast, overlapping of text, and elevation of the text presentation.

2.5 Perceptual Issues form Device Limitation

A video always requires a display device. However, even if the video was well prepared, the perceived result could be different from the expectation because of a distortion due to the limitations of the display device. Thus, the researcher was aware of the perceptual issues arising from device limitation.

Display devices usually have a limited rendering capability which means they could possibly present in a lower resolution than the direct view (Kruijff et al., 2010). Especially in low light conditions, devices normally yielded bad results (Drascic & Milgram, 1996). Only some high quality devices could handle this lighting condition. To improve the sense of depth in indoor scenes, Drascic and Milgram (1996) suggested applying a low level of ambient light in lighting the scene. However, using sunlight to illuminate a scene produces a much better result.

Kruijff et al. (2010) pointed out that the extremely high resolution of handheld devices also causes a problem in the interpretation of depth. The sharpness of the rendered images makes the images seem closer than they are in reality. Moreover, the small size of the screens of the devices also causes problem with object recognition and segmentation.

There was an issue with the rendered colors as well. Kruijff et al. (2010) called this issue color fidelity. Normally, humans perceive colors relative to the surrounding colors. However, some devices have a hardware limitation in terms of presenting extreme, high saturation colors. This limitation led to distortion in color perception due to the changes in surrounding colors.

Research has also pointed out the problem of colored text labels. Kruijff et al. (2010) illustrated that rendering a label with highly saturated color allowed the label to be detected more easily due to the separation of the label from the background. However, this technique also made the label looks closer than usual, which may have led to user misallocation.

An understanding of potential device limitation forced the researcher to control the lighting conditions and the device used in the experiment. Thus, the experiment was planned to run on the same day, in the same location, and using the same device. Moreover, the use of colors was avoided in the creation of text presentation.

2.6 Summary

This chapter introduced the background knowledge used for the study. There were two main disciplines from which the previous studies were acquired: AR and human visual perception. The research from the AR area suggested that the suitable text presentation style of AR applications is the transparent billboard text presentation style with negative image polarity. The studies in human visual perception gave the idea to enhance the text presentation style using visual illusions. Among the visual illusions, the phantom illumination illusion was chosen due to its strongest brightness illusion. Other research related to issues in human perception and device limitation resulted in the awareness of control conditions in the study.

CHAPTER 3. METHODOLOGY

This chapter introduces the methodology applied in this research study. Based on previous research, the phantom illumination (PI) illusion should be able to enhance the ability of people to read embedded text. However, one of the studies showed that even if human visual perception supported a characteristic of text presentation, the characteristic was not necessary to improve readability, such as low performance in text reading of the red text drawing style introduced by Gabbard et al. (2006). Accordingly, the researcher developed the methodology in order to answer the research question “Can the phantom illumination illusion improve text representation in augmented reality on a smartphone?” This research study was a quantitative study in association with human subjects.

3.1 Hypotheses

The following were the hypotheses addressed for the study:

H_0: The phantom illumination illusion does not affect the legibility of text representation in an augmented reality application on a smartphone.

H_a: The phantom illumination illusion has a positive effect on the legibility of text representation in an augmented reality application on a smartphone.

3.2 Variables

In order to verify whether the PI illusion could enhance text presentation, a number of variables for the study were addressed.

3.2.1 Independent Variable

The independent variable of the study was the text presentation styles, which can be divided into the control group and the experimental group.

The control group derived from the text presentation style suggested by Jankowski et al. (2010). The style was a solid white text on the 50% transparent black billboard text presentation style as displayed in Figure 3.1. The presented text used ten-point font as recommended by Sheedy et al. (2005).

Figure 3.1 The Visual Presentation of the Standard Text Presentation Style

The researcher developed a text presentation style applying the PI illusion for the experimental group as shown in Figure 3.2. The text presentation style was also a solid white text on the 50% transparent black billboard text presentation style. However, the internal edge of the style was decorated with the black-white shading PI illusion to enhance the brightness of the text. The text was presented using ten-point font.

Figure 3.2 The Visual Presentation of the Phantom Illumination Illusion Text Presentation Style

3.2.2 Dependent Variables

There were two issues related to human performance in text reading. These issues were the dependent variables of the study and they were the reading speed and the reading accuracy of the individual participant. The independent variable should impact both dependent variables in the same direction.

3.3 Population and Sample

The target population of the study was people who have normal or corrected-to-normal vision. For the recruitment, the researcher randomly invited passersby to join the experiment as used by Schinke et al. (2010). The location of the recruitment was the main floor of the Materials Science and Electrical Engineering Building, Purdue University, where Purdue students and faculties spent their free time around the small coffee shop.

There was a self-reporting screening in the form of a short survey to exclude non-target participants from the study.

With the consideration of variance, the researcher calculated the sample size based on the testing result from the pilot study for the accurate sample size. The calculation of the sample size based on the paired t-test, which is the continuous response measure in two groups. As the study was not a critical issue, the researcher used 0.05 for the type I error probability (alpha) and 0.8 for the power. The data from the pilot study indicated that the difference in population means was 587.12, and the difference in the response of matched pairs was normally distributed with standard deviation 737.59. According the statistical analysis of the experimental result of the pilot study, the sample size of the study was 14 participants.

3.4 Experimental Design

The goal of the experiment was to verify whether the PI illusion could enhance text representation in augmented reality on a smartphone. The researcher created a survey and a mobile application to test the text presentation style in the experiment.

3.4.1 Survey

There were two parts to the experiment, a survey and a trial on a mobile application. The survey collected demographic information of the participants. The survey was also a tool for self-reporting screening. Any participants of the survey with vision deficiency, including people with uncorrected vision, were excluded from the experiment after the survey. There were eight questions in the survey which asked about gender, age range, academic role, major, smartphone usage experience, augmented reality application usage experience, vision, and familiarity with the high-frequency writing word list attached to the survey.

3.4.2 Experiment on the Mobile Application

The second part was the experiment with the mobile application. Before the experiment, a participant was asked to move to a specific location, a table near a large window of the Materials Science and Electrical Engineering Building, to control the testing environment. Then, the participant was informed to follow the instructions in the experimental application and do the experiment using a smartphone.

A mobile application was specifically developed for the experiment using Android 4.1. The purpose of the application was to evaluate the reading performance of the subjects on text presentation styles, of both control and experimental groups, in an augmented reality application. The experimental application consisted of experimental instructions, four mock trials, and 36 experimental trials. The mock trial familiarized the subjects with the interface of the application. Subject performances were not recorded during the mock trials. The researcher expected to eliminate the testing internal thread of validity using the mock trials. In the experimental trials, the application recorded subject performances, response times and errors, for further analysis.

The application allowed a subject to do the experiment through the experimental trials. In each trial, the subject measured only one out of two text presentation styles, the standard style or the style with the PI illusion. At the beginning of each trial, the application showed a task text on the screen.

The task text was randomly selected from the list of 182 most frequently used words with six characters. The researcher acquired the words from Rebecca Sitton's List of 1200 High Frequency Words (The SUU Teacher Education Programs, Southern Utah University, 2009, October 27). The focus of the study was on short texts because they are commonly used as links in mobile applications. People expect to understand the short text quickly and accurately in order to refer to the relevant longer text when necessary. The words in the study were common six character words with meaning.

A subject was instructed to remember the displayed word in order to do a visual search task. A subject tabbed on the “Next” button in order to start the visual search task (see Figure 3.3).

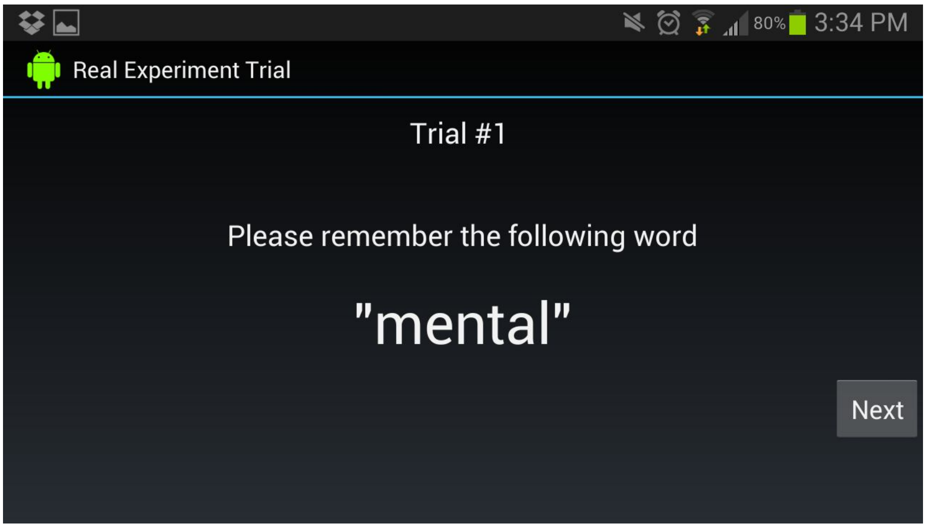

Figure 3.3 The Application Displayed the Task Text at the Beginning of Each Trail

After the click, the mobile screen displayed the real-world video scenes captured from the mobile camera. There were two seconds of delay before the random text with the text presentation appeared. The purpose of the delay was to remove the image from the subject's visual sensory register, a sensory store which keeps the image stored for a short period of time after the disappearance of the image (Proctor & Zandt, 2008). The application generated nine words on the screen, of which the locations were fixed through each of the trials. All text appeared with the same text presentation style, the standard style or the style with the PI illusion style as shown in Figure 3.4 and Figure 3.5. The position of the task text was random through trials. The appearing text was static while the video scene dynamically moved.

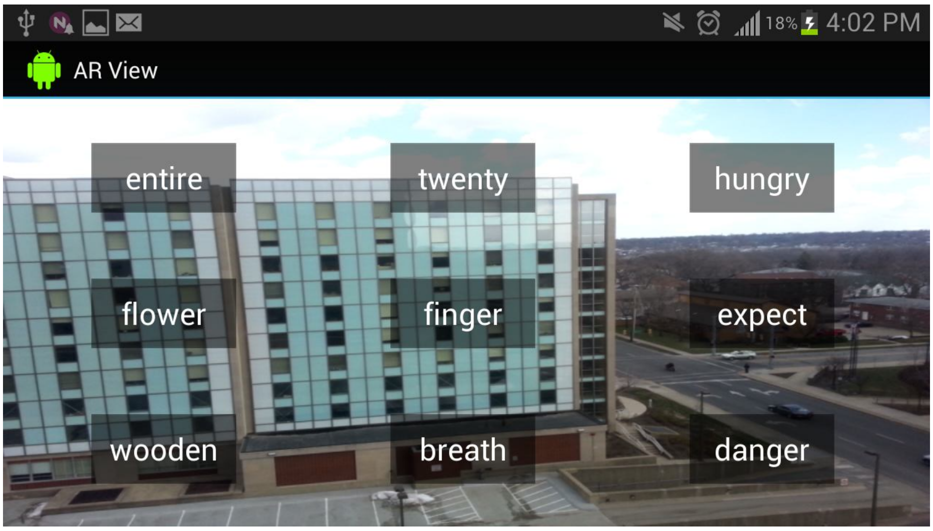

Figure 3.4 A Screenshot of the Random Text with the Standard Text Presentation Style from the Experimental Application

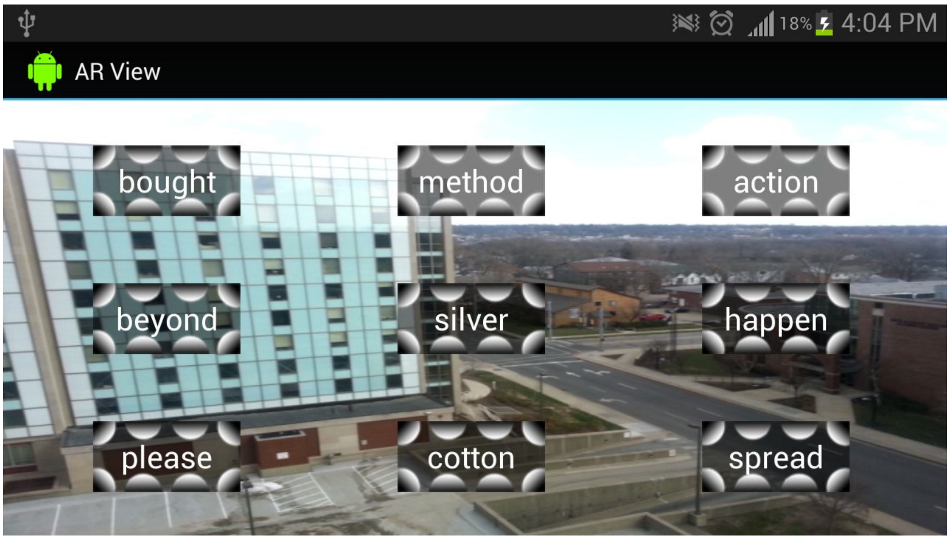

Figure 3.5 A Screenshot of the Random Text with the Phantom Illumination Illusion Text Presentation Style from the Experimental Application

The task of the subject was to search for the task text. Then, the subject had to tab on it in order to end the trial. The subject was encouraged to complete the task as fast as possible without an error. When a participant made a mistake, a dialog popped up to notify and ask the participant to try again. After the correct answer was chosen, a screen defining the end of the trial appeared.

Each participant encountered both text presentation styles (2) on all positions of the screen (9), and each participant involved two repetitions (2). In total, a participant created 36 samples.

The application collected two types of data, RTs and errors. The response time (RT) was in ratio scale. It was the time in milliseconds from the appearance of the text to time the participant tabbed on the correct text. The RTs represented the reading speed.

The error represented the reading accuracy. The error was also in ratio scale counting the number of errors for each participant.

3.5 Pilot Testing

There was a pilot testing done before the experiment on real participants. Two pilot testers used the mobile application to evaluate the text presentation styles. The goal of the pilot testing was to calculate the variance from the experimental result for the statistical calculation of the accurate sample size.

The result from the pilot testing also revealed two types of errors, slip and random guess. The slip was a human error that was unintentionally made when the participant knew the correct answer (Proctor & Zandt, 2008). An example of a slip is when a participant would like to tab on a button in the middle, but unintentionally touches a button on the right. This error related to the appearance of the text presentation styles, so the researcher included the time of participants making this error in the RT.

The other type of error was random guess. Sometimes, the participants forgot the task text and then randomly tabbed on a text in order to finish the trail. The text presentation styles did not relate to this type of error. Therefore, when a participant made more than one mistake, the application recorded the time as -1 to mark as a random guess.

Moreover, the researcher used the comments from a short interview after the pilot testing to improve the experimental application. There was a complaint about the number of experimental trials, which caused fatigue. Two short breaks of 30 seconds each were added to the application with the purpose of solving the problem of fatigue in participants.

3.6 Statistical Tool and Analysis Procedure

In this study, there were two styles of text representation, the standard style and the PI illusion style. Each style appeared on nine positions on the mobile screen, represented by nine different words. Due to the uniform size of subgroups of the text presentation styles and locations on the screen, the researcher applied the pairwise balanced design (PBD) to the study. This tool treated the experiment as blocks that had text presentation styles as the super set and position on the screen as the subset. This helped the comparison of elements between blocks.

The researcher applied the analysis of variance (ANOVA) as the technique to analyze the RT from the PBD. The mixed model was applied because of the appearance of multiple factors - text presentation styles, location on screen, and participants' background. Participants' background was considered as a random effect, while text presentation styles and location on the screen was considered as fixed effects. As the study was not a critical issue, the researcher set the alpha level at 0.05.

3.7 Threat of Validity

There was only one representative text presentation style developed from the PI illusion in the study. However, there were several ways to implement the illusion to text representation. Other implementation of the illusion may return different results from this research study.

The study focused on augmented reality applications on smartphones. The result from the study may not be applicable to other types of applications and devices.

Due to the fact that the experimental application required physical movement of hands in order to provide the response, the time in physical movement could have an effect on the internal validity. The response time was the combination of both time in text recognition and time in physical movement.

3.8 Summary

This chapter described the methodology that was applied in the study. It explained the methodology from the research question to variables and hypotheses. Then, the chapter defined how the researcher did the sampling, experiment, and analysis of data.

CHAPTER 4. EXPERIMENTAL RESULTS

This chapter reports the experimental results. The researcher conducted the experiment on March 7, 2013, at the Materials Science and Electrical Engineering Building, Purdue University. That day was a cloudy day and the sky was completely covered by clouds. The lighting condition was the same throughout the day. Fourteen participants joined the experiment. The collected data can be divided into two parts, the demographic information from the survey and the participants' performance from the experimental mobile application.

4.1 Information from the Survey

The researcher used a paper-based survey to collected participants' demographic information. The survey was also a tool to screen non-target participants. Fortunately, all participants had normal or corrected-to-normal vision. No participant from the survey was excluded from the mobile application experiment.

The survey consisted of eight questions asking about demographic information, smartphone usage experience, augmented reality application usage experience, vision, and familiarity with words in the high-frequency writing word list. The researcher used this data as the random effect in the random effect model in further analysis.

4.1.1 Demographic Information

The researcher randomly recruited participants from the main floor of the, the Materials Science and Electrical Engineering Building, Purdue University. The participants consisted of 12 undergraduate students, a graduate student, and a Purdue faculty member, with the age ranging from a group of 16 to 20 years old to a group of 41years old and above. Six males and eight females participated in the experiment. Eight out of fourteen participants were majoring in engineering and technology. Three participants were a member of the health, human science, pharmacy, and veterinary medicine group. The rest of the participants were in other major fields. Eleven out of fourteen participants had corrected-to-normal vision while the rest had normal vision. The detailed results from the survey are shown below.

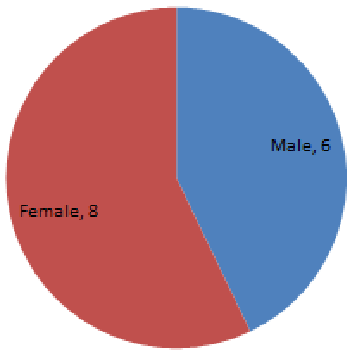

Figure 4.1 Gender

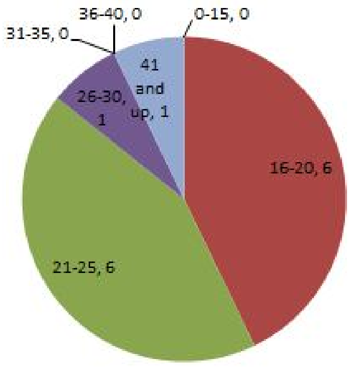

Figure 4.2 Age Range

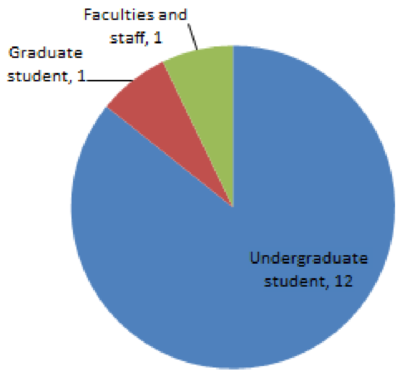

Figure 4.3 Academic Role

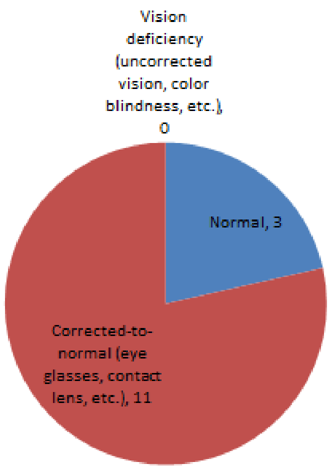

Figure 4.4 Vision

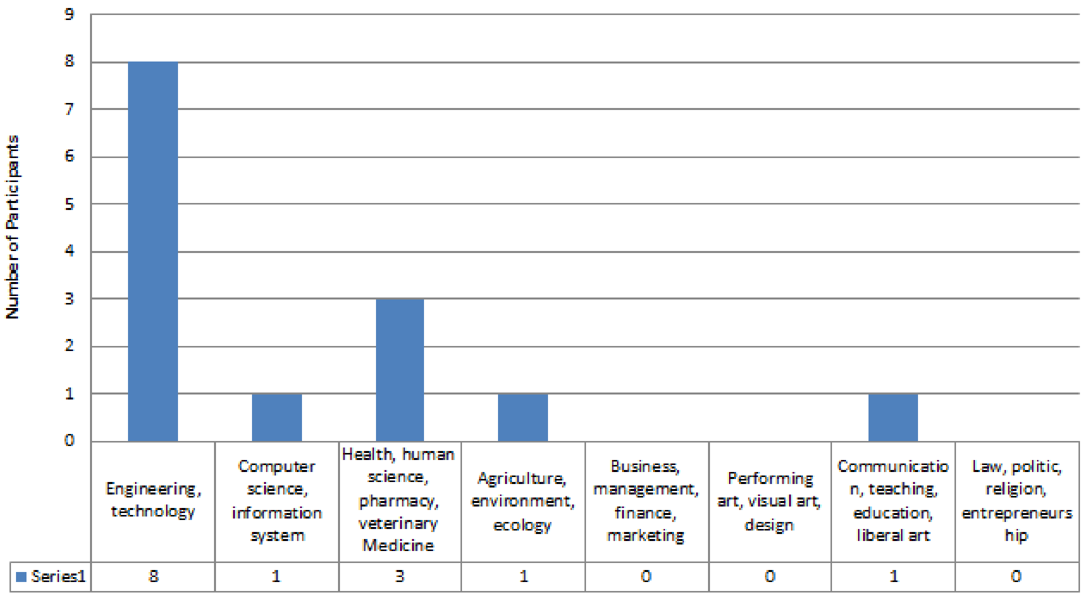

Figure 4.5 Major

4.1.2 Participants' Experiences

Part of the survey asked the participants about their past experiences related to smartphones, augmented reality technology, and familiarity with the words in the high-frequency writing word list attached to the survey. Most participants had spent 2 to 3 hours of the previous 24 hours using a smartphone. None of them had ever used an augmented reality application on a smartphone before. Ten out of fourteen of the participants were familiar with the words in the word list. The details of from the survey are shown below.

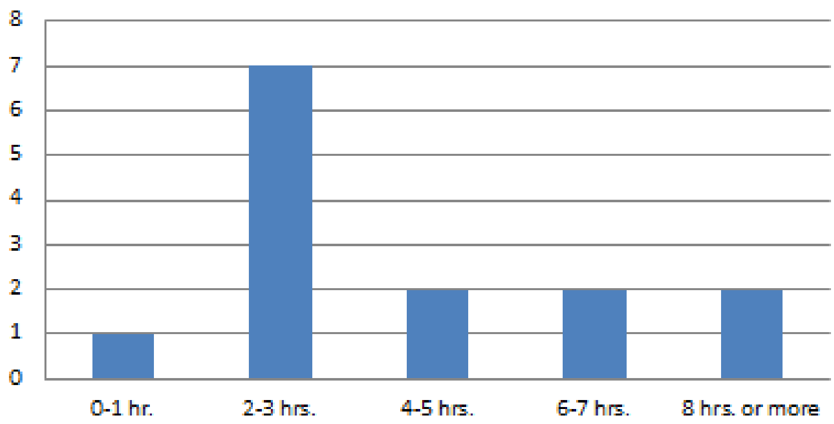

Figure 4.6 The Time Spent on Smartphones in the Previous 24 Hrs.

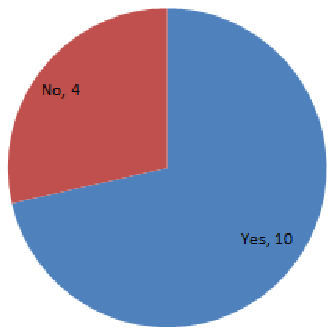

Figure 4.7 Familiarity with words in the high-frequency word list

4.2 Experimental Data

The second part was the experimental data of the participants' performance. The experimental mobile application recorded subjects' response times (RT) and errors in the application's database during the experiment. Fourteen participants took part in the experiment. The application provided 36 trials for each participant. However, according to the regulation from the institutional review board (IRB), a participant must be allowed to quit the experiment anytime. Consequently, the application did not get the complete set of data from some participants. On the other hand, one participant reported that he unintentionally tabbed on the quit button and voluntarily repeated the experiment from the beginning. In total, the experimental application collected 521 RTs and errors. The application recorded data for each text presentation style and each of the nine locations on the screen separately.

4.2.1 Average Response Time

The RT was the time from the appearance of the text to the time that the task text was chosen in milliseconds. In the case of random guess, the application automatically set the RTs to -1. One type of data describes participants' performance toward each text presentation style was average RT. The experiment showed that the average RT, excluding random guesses, of the standard text presentation style, which was the control group, was 2236.906 milliseconds, while the phantom illumination illusion (PI) text presentation style, which was the experimental group, was 2194.382 milliseconds. Since the average RTs for each location on the screen were different, the detail of the average RT for each location on the screen is illustrated in the Figure 4.8. The average RT of the middle position was a lot shorter than other positions. The average RTs of each position of the standard and the PI text presentation style were relatively the same. Additionally, the boxplot in Figure 4.9 suggested that there was a difference in response time between different locations on the screen.

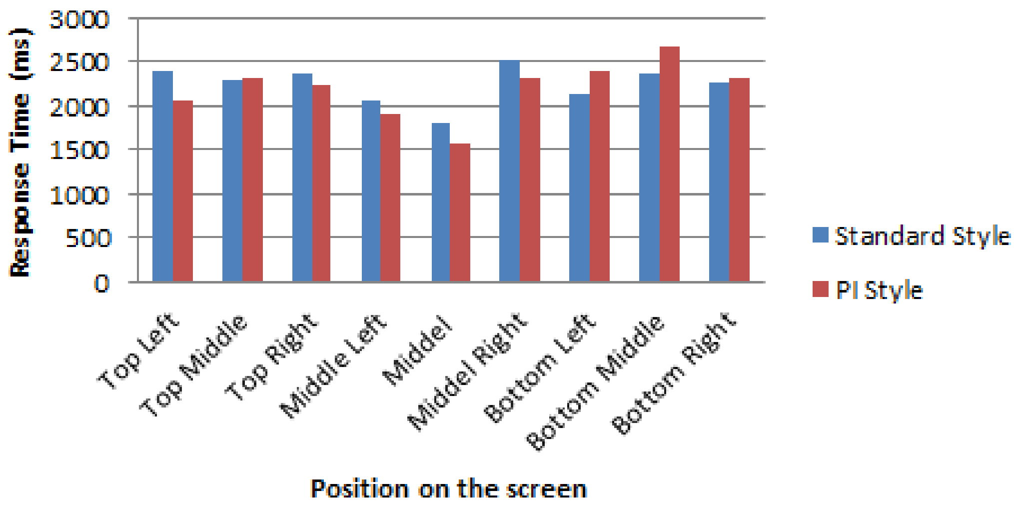

Figure 4.8 The Average Response Time of Each Location on the Screen

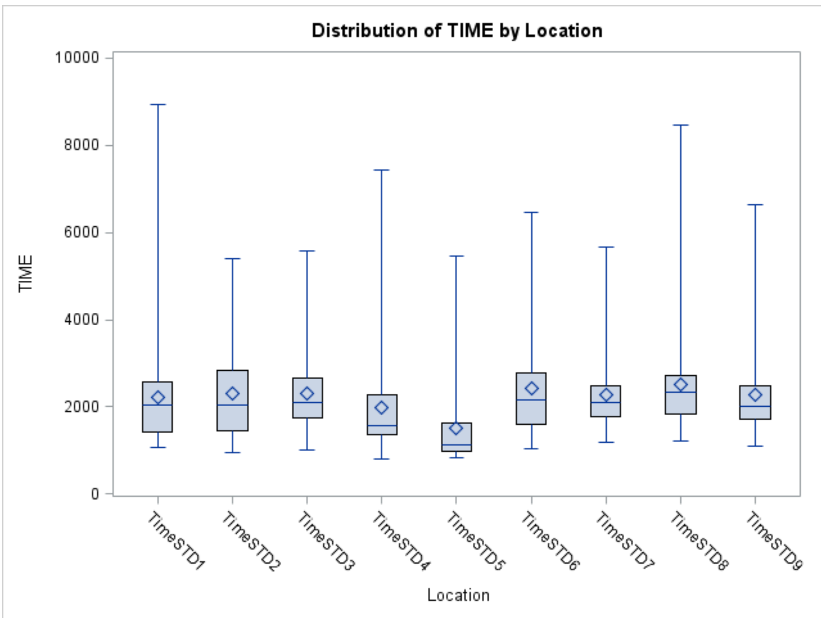

Figure 4.9 The Relation of Response Time and Location on the Screen

4.2.2 Error

In the study, they were two types of errors, slip and random guess. The slip was human error that was unintentionally made when the participant knew the correct answer

(Proctor & Zandt, 2008). The response time of slip errors was also included in the RT. The study showed that there was only one slip in the experiment, which was from the top middle location of the standard text presentation style.

The second type of the error was the random guess. The experimental application detected four random guesses in total, as illustrated in Figure 4.10. All of them were detected from the positions on the top row.

The numbers of errors for both slip and random guess in the experiment were too small to statistically make a conclusion.

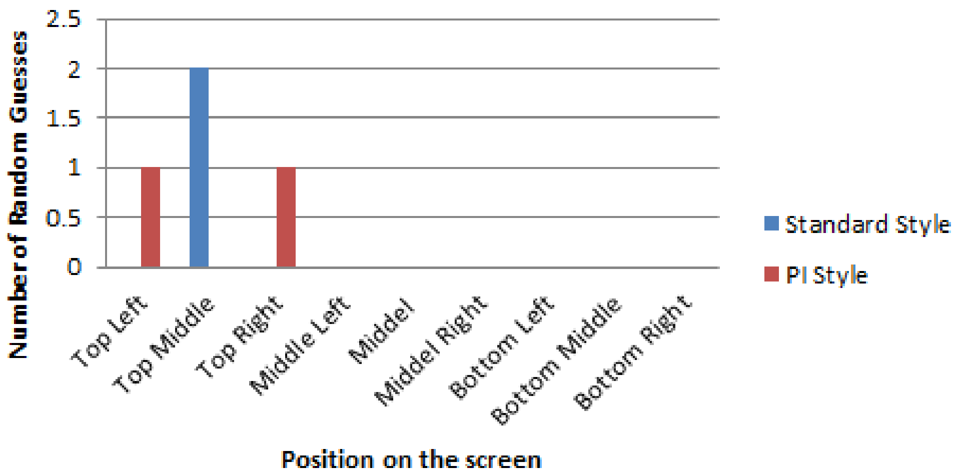

Figure 4.10 Random Guess Error

4.3 Summary

This chapter introduced the collected data from the study. There were two parts of the data, demographic information from the survey and the user performance data from the experimental application. Both sets of data were used in further analysis in the next chapter.

CHAPTER 5. ANALYSIS AND CONCLUSION

The discussions in this chapter are on the analysis of data from the previous chapter as well as the findings made in the study. The goal of the experiment was to verify whether the PI illusion could enhance text representation in augmented reality on a smartphone. The researcher analyzed the data in order to find relation to fulfill the goal. The collected data was compared in many ways in order to find their relations. Due to the fact that the random guess was not the result of the text presentation styles and there was only one slip that was too few to make a conclusion, the researcher focused on the comparison of response times (RT). There are two parts of the analysis, relation of RT and the statistical analysis using the analysis of variance (ANOVA).

5.1 The Relations of Response Times

The study planned to apply the mixed model to the analysis of variance because of the appearance of multiple factors - text presentation styles, location on screen, and background of participants. Before the researcher started the analysis with ANOVA, the researcher considered the relation between each factor and RT to find out important factors to focus.

The researcher used boxplot to find the approximated relation between each factor and RT. Three boxplots demonstrated interesting relations - location on the screen, text presentation style, and participants' major. The boxplot of the location on the screen in Figure 4.9 suggests difference in RTs between different locations on the screen. The participants' responses in some locations were distinctively quicker than others. The boxplot of the text presentation style in Figure 5.1 shows that the average RTs between text presentation styles were not different, but that the distributions of the RTs were different. The maximum RT of the standard text presentation style was a lot higher than the maximum RT of the phantom illumination illusion text presentation style. The boxplot of the major in Figure 5.2 shows a difference in response times among majors. In total, there were participants from five major groups that took part in the experiment. The distributions of RTs of participants' responses from each major were not the same. The boxplot of some majors demonstrates the extreme difference between maximum and minimum RT while some majors were not.

From the interesting fact about maximum and minimum RTs, the researcher compared the maximum and the minimum RTs of two factors, text presentation style and position on the screen. The researcher found their relation as shown in Figure 5.3. The chart shows that the minimum RTs between the two text presentation styles were relatively the same. In contrast, the maximum RTs were clearly different. The maximum RTs of the standard text presentation style were more than the maximum RTs of the PI text presentation style in seven out of nine locations with 2080 milliseconds more on average.

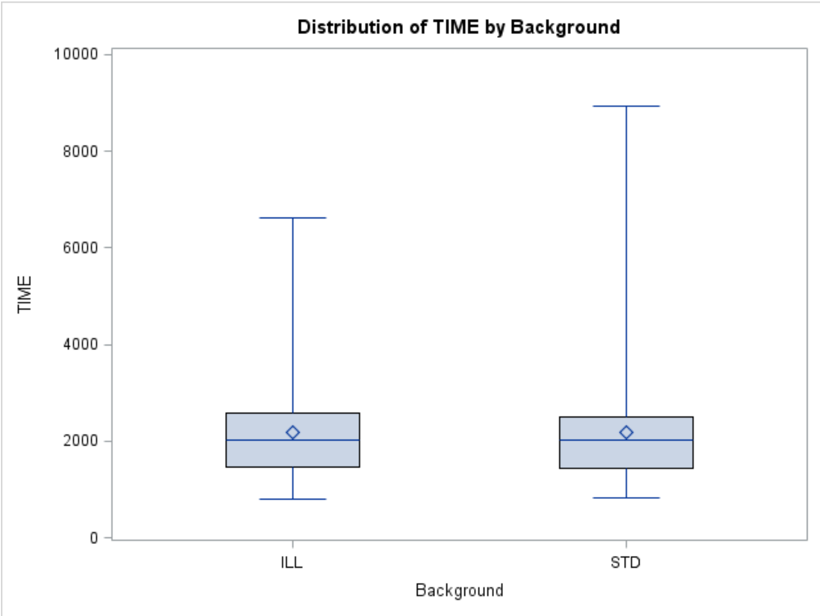

Figure 5.1 Response Time and Text Presentation Style

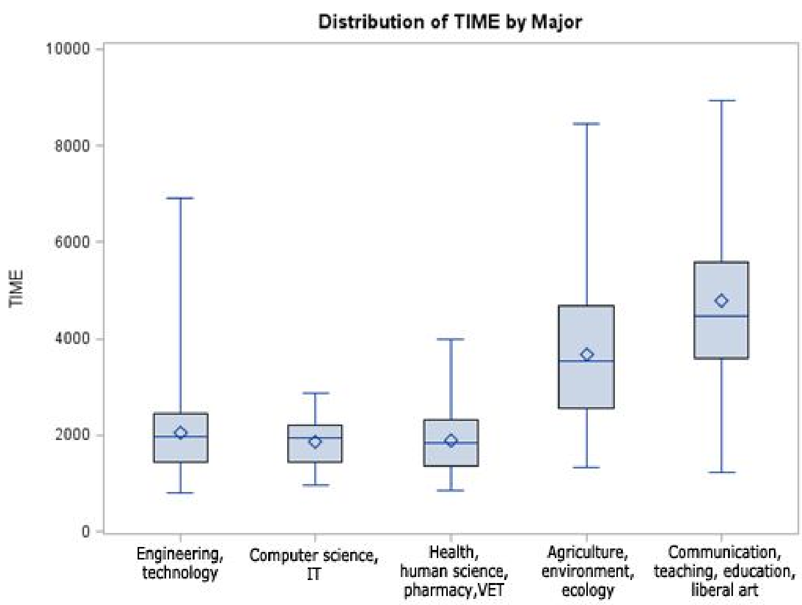

Figure 5.2 Response Time by Major

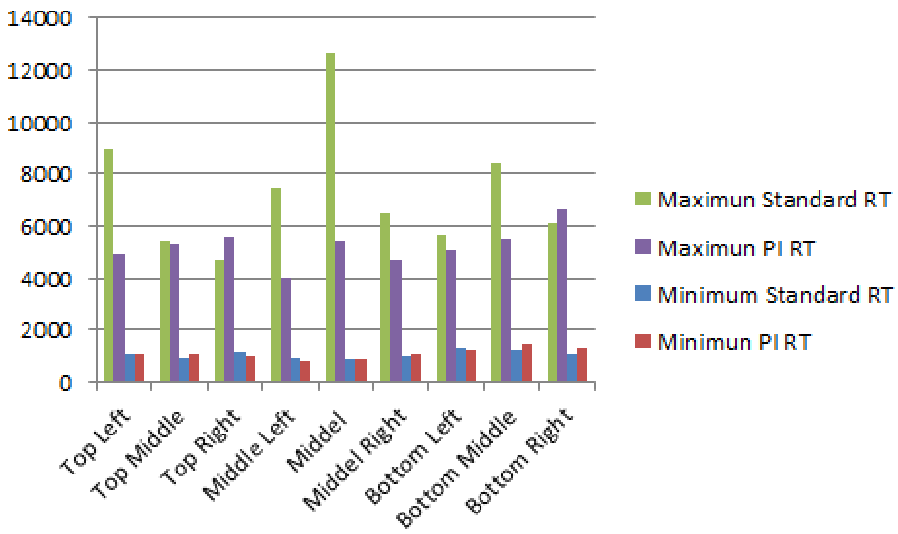

Figure 5.3 Comparison between Maximum and Minimum Response Times

Finding the relation between the maximum RTs and major, the researcher found that the majority of the maximum RTs were made by two subjects – Subject1 who was the only one from the major group of agriculture, environment, and ecology, and Subject11 who was the only participant from the group of communication, teaching, education, and liberal art.

Consequently, the researcher found three factors to focus in the next step of the analysis - location on the screen, text presentation style, and participants' major. The researcher also discovered the interesting fact about maximum RTs. The average response time of the two text presentation styles was the same. However, in some cases, participants took much more time to complete a task displayed with the standard text presentation style than the PI text presentation style.

5.2 The Analysis of Variance using Random Effect Model

The researcher applied the ANOVA for the statistical analysis. Mixed model was applied due to multiple factors in the study.

5.2.1 Mixed model

The mixed model can be described as the following formula.

$$RT = \mu + \alpha + \beta$$

RT was the response affected from the model. The μ represented the average observed RT. The fixed model, α, considered the text presentation styles and locations on the screen. Participants' background was selectively considered as the random effect, β.

5.2.2 Statistical Analysis with the SAS Glimmix procedure

The researcher chose the SAS Glimmix Procedure as the tool used to analyze the relation of factors to the RT. The mixed model was applied considering multiple factors. The focus was on text presentation styles, one of the fixed effects. Due to the fact that the location on the screen was another fixed effect, the researcher also took the interaction between the location on the screen and the text presentation style into account. The detailed results from the analysis are shown in Table 5.1. The results introduced the significant differences of the location on the screen and participants' major with P-values less than 0.05. The text presentation style showed no significant difference. Even though the location interacted with text presentation style, there was no significant difference.

Table 5.1 SAS Glimmix Result for the Mixed Model

Type III Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Location	8	85.89	7.78	<.0001
Text Presentation Style	1	13.18	0.13	0.7286
Location* Text Presentation Style	8	372.6	1.09	0.3700
Experience with Smartphone	4	4.489	0.50	0.7383
Vision	1	4.567	0.03	0.8780
Major	4	4.899	21.54	0.0026

Since the boxplot in Figure 4.9, The Relation of Response Time and Location on the Screen, suggested similar patterns of the response time of some locations, the researcher combined similar locations. Then the researcher refitted the model to find whether the grouping of the location factor affected the factor of text presentation style. Based on the boxplot in Figure 4.9 and Tukey pairwise comparison, the locations on the screen can be categorized into three groups, as shown in Figure 5.4 The Location Grouping. The top left, top right, middle left, bottom left, and bottom right position were in the same group. The top middle, middle right, and bottom middle position were in the second group and the middle position alone was in the last group.

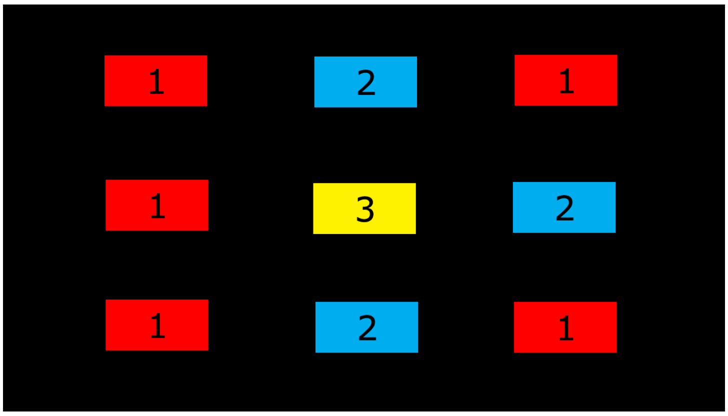

Figure 5.4 The Location Grouping

After the researcher refitted the model, there were some changes in the result. The Glimmix output suggested that the groups of locations as well as the random effect have the significant difference as shown in Table 5.2 SAS Glimmix Result for the Mixed Model with the Grouping of Locations on the Screen. However, the text presentation style and the interaction of location and text presentation style still have no statistically significant difference.

Table 5.2 SAS Glimmix Result for the Mixed Model with the Grouping of Locations on the Screen

Type III Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Group of Locations	2	485.4	28.41	<.0001
Text Presentation Style	1	21.87	0.00	0.9785
Group of Locations * Text Presentation Style	2	485.5	0.29	0.7510
Experience with Smartphone	4	4.502	0.50	0.7421
Vision	1	4.582	0.03	0.8791
Major	4	4.902	20.77	0.0028

5.3 Hypotheses Interpretation

The statistical analysis suggested that both text presentation style and the interaction of location and text presentation style have no statistically significant difference. This means that the enhancement of the standard text presentation style with the decoration of black-white shading PI illusion at the internal edge, the PI style, cannot distinctly improve human's ability to read embedded text. Therefore, the study cannot reject the null hypotheses; the phantom illumination illusion does not affect the legibility of text representation in augmented reality applications on a smartphone.

5.4 Discussion

Surprisingly, the study did not demonstrate the positive effect of the text presentation style implementing the PI illusion to text legibility as expected. The researcher concluded that the phantom illumination illusion was unable to improve text legibility in augmented reality applications on a smartphone. However, the data from the experiment suggested that, in some cases, people have to spend a lot more time to find a text presented with the standard text presentation style than the standard text presentation style enhanced with the PI illusion. Due to too small a number of participants from some groups of majors, the study cannot statistically conclude which people from which specific majors felt that was the case. Nevertheless, the data suggested that people from the group of agriculture, environment, and ecology majors and the group of communication, teaching, education, and liberal art majors may have problems in finding texts presented with the standard text presentation style, solid white text on a 50% transparent black billboard. The use of the PI text presentation style, the standard text presentation style with the decoration of black-white shading PI illusion at the internal edge, could reduce this problem.

Moreover, the study applied only one implementation of the PI illusion on text presentation style, the decoration of black-white shading PI illusion at the internal edge. The PI illusion can be implemented to enhance text presentation in many different ways. Other implementation of the illusion could yield different results.

After the analysis, the researcher found that the low internal validity of the study could cause an error to the result. The original idea of the experimental interaction design was to measure the effect of the text presentation styles in the environment that was close to the real application of text in augmented reality applications. Text appeared to provide information on the real-world video scenes, and a user tapped on the text to access more information. The different appearances of text presentation styles should affect the speed in the application usage. However, from the experiment, the time in physical movement of hands to provide response to the experimental application was relatively large in comparison to the time in text recognition. Consequently, the design of the interaction in the experiment caused low internal validity because the study cannot clearly measure the time in text recognition.

5.5 Summary

This chapter introduced the analysis of data and the conclusion from the study. The researcher analyzed the RTs in detail and applied the mixed model for the ANOVA for the statistical analysis. SAS Glimmix procedure was used as a tool for the analysis. The analysis demonstrated no significant difference in text presentation styles, the standard style and the style implemented the phantom illumination illusion, for text representation in augmented reality applications on a smartphone. The study concluded that the phantom illumination illusion was unable to improve legibility of text representation in augmented reality applications on a smartphone. However, the study showed that people, especially in some specific major groups, have difficulties in reading text when the text is presented using the standard text presentation style, solid white text on a 50% transparent black billboard.

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APPENDICES

Appendix A IRB Approval and Consent Form

PURDUE
UNIVERSITY

HUMAN RESEARCH PROTECTION PROGRAM
INSTITUTIONAL REVIEW BOARDS

To:	DAVID WHITTINGHILL KNOY
From:	JEANNIE DICLEMENTI, Chair Social Science IRB
Date:	09/28/2012
Committee Action:	**Approval**
IRB Action Date	09/27/2012
IRB Protocol #	1209012629
Study Title	An Examination of Presentation Strategies for Textual Data in Augmented Reality
Expiration Date	09/26/2013

Following review by the Institutional Review Board (IRB), the above-referenced protocol has been approved. This approval permits you to recruit subjects up to the number indicated on the application form and to conduct the research as it is approved. The IRB-stamped and dated consent, assent, and/or information form(s) approved for this protocol are enclosed. Please make copies from these document(s) both for subjects to sign should they choose to enroll in your study and for subjects to keep for their records. Information forms should not be signed. Researchers should keep all consent/assent forms for a period no less than three (3) years following closure of the protocol.

Revisions/Amendments: If you wish to change any aspect of this study, please submit the requested changes to the IRB using the appropriate form. IRB approval must be obtained before implementing any changes unless the change is to remove an immediate hazard to subjects in which case the IRB should be immediately informed following the change.

Continuing Review: It is the Principal Investigator's responsibility to obtain continuing review and approval for this protocol prior to the expiration date noted above. Please allow sufficient time for continued review and approval. No research activity of any sort may continue beyond the expiration date. Failure to receive approval for continuation before the expiration date will result in the approval's expiration on the expiration date. Data collected following the expiration date is unapproved research and cannot be used for research purposes including reporting or publishing as research data.

Unanticipated Problems/Adverse Events: Researchers must report unanticipated problems and/or adverse events to the IRB. If the problem/adverse event is serious, or is expected but occurs with unexpected severity or frequency, or the problem/even is unanticipated, it must be reported to the IRB within 48 hours of learning of the event and a written report submitted within five (5) business days. All other problems/events should be reported at the time of Continuing Review.

We wish you good luck with your work. Please retain copy of this letter for your records.

Ernest C. Young Hall, 10th Floor · 155 S. Grant St. · West Lafayette, IN 47907-2114 · (765) 494-5942 · Fax: (765) 494-9911

Research Project Number __________

For IRB Office Use Only

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SEP 27 2012
EXPIRES 9-26-13
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INSTITUTIONAL REVIEW BOARD

RESEARCH PARTICIPANT CONSENT FORM
An Examination of Presentation Strategies for
Textual Data in Augmented Reality

Principal Investigator: David M Whittinghill, Assistant Professor
Student Researcher: Kanrawi Kitkhachonkunlaphat, Graduate student
Purdue University
Computer Graphics Technology, College of Technology

Purpose of Research

The goal of this study is to improve the representation of text in augmented reality applying knowledge in visual perception. The study aims to generate a suggestion for efficiently representation of text-based information in augmented reality applications.

You are invited to participate in a research study in order to examine how human perceive short text enhanced with a visual illusion comparing to normal text representation.

Specific Procedures

The research study consists of two main parts, short survey and augmented reality application on a smartphone.

First part: A short survey

- You will be asked to fill out a short survey.
- The researcher will collect demographic information from the survey.

Second part: Augmented reality application on a smartphone

- You will be asked to interact with an augmented reality application on a smartphone.
- You will be asked to complete 4 mock trials and 36 experimental trials of the experiment.
- For each trial, you will complete the following steps.

- The researcher will collect response times and errors from your interaction.

Duration of Participation

All activities are expected to take around 20 minutes.

______________________ ______________
Participant's Initial Date

______________________ ______________
Researcher's Initial Date

Research Project Number ___________

Risks

The research is minimal risk, which is no greater than every day activities. However, it is possible for some risks to happen.

There could be a physical risk from the mobile phone signal causing effects such as headache. It is uncommon, but it is possible. The researcher minimized the risks by confining the interaction to only seeing and tapping. So, you do not have to put the phone near your head. The Wi-Fi signal of the experimental smartphone will be turned off during the experiment also.

For the psychological risk, some subjects may not have their own smartphone and may have bad feeling that they cannot afford one. The researcher minimized the risks by running the experiment on only one subject at a time. You will not see if other participants have or familiar with smartphones.

Benefits

You may not get direct benefit. The list below shows possible benefits

- You may have new experience of using a smartphone or interacting with augmented reality application from this study.
- You may get new idea of how to apply visual illusions to improve technologies.

Compensation

There are no costs and you will not be paid to be in this study.

Confidentiality

The following procedures will be used to protect the confidentiality of your data.

- The researchers will keep all study records (including the signed consent form and survey) in a secure location. The records will be destroyed after 3 years.
- The digital data will be labeled with an index number which is not associated with your name. The digital data on the other hand will be stored indefinitely. However, all research subjects at the time of the study will be assigned an index number which is not associated with their name. All digital records will use only the de-identified index number and therefore maintain subject anonymity.
- At the conclusion of this study, the researchers may publish the findings. Information will be presented in summary format and you will not be identified in any publications or presentations.
- We will do our best to protect the confidentiality of the information we gather from you but we cannot guarantee 100% confidentiality.
- The project's research records may be reviewed by departments at Purdue University responsible for regulatory and research oversight.

Voluntary Nature of Participation

You do not have to participate in this research project. If you agree to participate you can withdraw your participation at any time without penalty.

____ __________________________

Participant’s Initial Date

____ ___________________________

Researcher’s Initial Date

Research Project Number ________

Contact Information:

If you have any questions about this research project, you can contact the following people.

- David M Whittinghill, the principal investigator, (765) 494-1353
- Kanrawi Kitkhachonkunlaphat, Student researcher, (765) 337-4094

If you have concerns about the treatment of research participants, you can contact the Institutional Review Board at Purdue University, Ernest C. Young Hall, Room 1032, 155 S. Grant St., West Lafayette, IN 47907-2114. The phone number for the Board is (765) 494-5942. The email address is irb@purdue.edu.

Documentation of Informed Consent

I have had the opportunity to read this consent form and have the research study explained. I have had the opportunity to ask questions about the research project and my questions have been answered. I am prepared to participate in the research project described above. I will receive a copy of this consent form after I sign it.

________________________ ________________
Participant's Signature Date

____
Participant's Name

________________________ ________________
Researcher's Signature Date

Appendix B Paper-Based Survey

Research Survey

Principal Investigator: **David M Whittinghill, Assistant Professor**
Student Researcher: **Kanrawi Kitkhachonkunlaphat, Graduate student**
Study Title: **An Examination of Presentation Strategies for Textual Data in Augmented Reality**

Demographic Information

1. Gender
   □ Male □ Female

2. Age Range
   □ 0-15 □ 16-20 □ 21-25 □ 26-30 □ 31-35 □ 36-40 □ 41 and up

3. Role
   □ Undergraduate student □ Graduate student □ Faculties and staff

4. Major (Please choose the one that is the closest to your area)
   □ Engineering, technology
   □ Computer science, information system
   □ Health, human science, pharmacy, veterinary Medicine
   □ Agriculture, environment, ecology
   □ Business, management, finance, marketing
   □ Performing art, visual art, design
   □ Communication, teaching, education, liberal art
   □ Law, politic, religion, entrepreneurship

5. In the last 24 hours, approximately how much time did you spend on smartphones?
   □ 0-1 hr. □ 2-3 hrs. □ 4-5 hrs. □ 6-7 hrs. □ 8 hrs. or more

6. Have you ever use an augmented reality application on a mobile phone?
   □ Yes □ No

7. Vision
   □ Normal
   □ Corrected-to-normal (eye glasses, contact lens, etc.)
   □ Vision deficiency (uncorrected vision, color blindness, etc.)

8. Are you familiar with words in “Word Bank of 1200 High-Frequency Writing Words” (See the attachment)
   □ Yes □ No

Appendix C Word Bank of 1200 High-Frequency Writing Words

The document below was the list of words with six characters in the Rebecca Sitton's List of 1200 High Frequency Words (The SUU Teacher Education Programs, Southern Utah University, 2009, October 27). The words were implemented in the experimental mobile application for the study. The researcher also showed the document below as an attachment to the participants in the survey part of the experiment.

Word Bank of 1200 High-Frequency Writing Words

The words in this word bank are listed in the order of their frequency of use in everyday writing. Since the is the most frequently used word in our language, its number is one in the word bank. The first 25 words are used in 33% of everyday writing, the first 100 words appear in 50% of adult and student writing, and the first 1,000 words are used in 89% of everyday writing.

The 182 words listed below are the words with six characters in the Rebecca Sitton's List of 1200 High Frequency Words.

little	doctor	within
people	indeed	simple
around	motion	center
number	myself	itself
always	church	friend
should	divide	spring
enough	supply	travel
mother	string	window
school	sister	circle
father	hungry	listen
almost	entire	bottom
second	twenty	single
animal	flower	energy
toward	finger	caught
better	expect	rather
across	wooden	length
during	breath	street
change	danger	reason
answer	member	except
family	twelve	figure
United	season	square
inside	proper	middle
States	valley	moment
ground	double	bright
really	market	record
though	oxygen	choose
plants	liquid	forest

before	stream	famous
living	accept	beside
course	police	object
become	future	modern
behind	finish	minute
cannot	rubber	yellow
letter	symbol	amount
notice	silent	garden
strong	remain	result
person	height	region
matter	belong	period
longer	bottle	weight
winter	design	corner
either	forget	island
common	secret	broken
follow	escape	return
summer	charge	chance
system	planet	decide
office	leader	cattle
nature	review	pretty
dinner	nobody	anyone
narrow	coffee	engine
mental	pencil	afraid
useful	repeat	spread
public	tongue	bought
speech	avenue	method
report	garage	action
column	author	beyond
farmer	couple	silver
nation	affect	happen
appear	rhythm	please
unless	cancel	cotton
effect	social	wonder
desert	frozen	