Calibrating Luminosity Contrast: Measuring the Difference it Makes

Terra A. Minolli

Middlebury Institute of International Studies

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Dr. Kathleen M. Bailey

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Abstract

With increasing use of PowerPoint (PPT) presentations in classroom lessons, few consider how luminosity contrast in presentation slides can impact learners. Using a counter-balancing for an ordering effect, this study investigated the effect of high- and low-luminosity contrast in PowerPoint presentations on adults' abilities to retain information. Fifty-six subjects participated in the study. Each subject viewed one high-luminosity contrast PowerPoint presentation, one low-luminosity contrast PowerPoint presentation and took a 10 question, closed notebook quiz after each presentation. Luminosity contrast was defined as the ratio of relative luminance between the lighter and darker of two colors (Caldwell, Cooper, Reid, & Vanderheiden, 2008). A Wilcoxon Signed Rank Test was used to determine if there was a statistically significant difference in adults' abilities to retain information from high-luminosity contrast presentations and low-luminosity contrast presentations. The results indicated no significant difference between high- and low-luminosity contrast presentations on adults' abilities to retain information. This study's results do not conform to previous studies' findings. Thus, further investigation and a study repeat is recommended.

Calibrating Luminosity Contrast: Measuring the Difference it Makes

With the increasing popularity of technology in the classroom, teachers are no longer restricted to using white chalk on a black chalkboard or colored makers on whiteboards. With PowerPoint presentations, teachers have access to any color of the spectrum in designing their presentations. Nowadays, teachers can routinely make presentations available for students to study from, rather than studying from one's own handwritten notes. However, the effects of color in digital media on students are still under debate and are being investigated in research. This study addressed one part of digital media problems by looking at luminosity contrast in PowerPoint presentations.

Background and Literature Review

This section reviews current research literature in the areas of digital media in classrooms; color in digital media, and their effects on student performance.

Attitudes and Preferences Toward PowerPoint in Classrooms

Student preferences in PowerPoint slide structure and color can help teachers design slides to benefit student learning. Apperson, Laws, and Scepansky (2008) surveyed 275 psychology students on their preferences in PowerPoint designs using a questionnaire on (a) background color preference, (b) the use of pictures, (c) the use of graphs and (d) style. Their results showed that students preferred colored background PowerPoint slides built line-by-line using key phrases and bullet points, and preferred colored backgrounds, ideally with high contrast between background and foreground colors. Students also preferred slides that contained pictures and graphs.

Oommen (2012) researched student perceptions about teachers using PowerPoint presentations in English language classrooms through action research and a questionnaire survey.

The results indicated that students preferred classes that used PowerPoint presentations and were more positive towards instructors who used them. While students may prefer instructors who use PowerPoint presentations, PowerPoint presentations do not necessarily benefit student-learning outcomes. In a study by Szabo and Hastings (2000), students believed PowerPoint lectures assisted learning; however, their grades did not match their perceptions. Szabo and Hastings (2000) compared student test results from a course taught by the same professor in two different years to examine if there was a difference between overhead instruction and PowerPoint instruction on student grades. Test results did not indicate a significant difference between overhead instruction and PowerPoint instruction on student grades (Szabo & Hastings, 2000). Despite student belief that PowerPoint lectures facilitate learning, the test results did not support this assertion.

Perceived Effectiveness of PowerPoint Presentations in Classrooms

Other researchers have explored the effects technology has had on student motivation and learning. Bartsch (2003) examined student preference for PowerPoint presentations relative to overhead transparencies in classroom instruction. Their results were inconclusive as the end of term ratings strongly indicated that students preferred PowerPoint presentations, but ratings immediately following class indicated no preference. Bartsch (2003) additionally researched the effect of PowerPoint slides that included irrelevant pictures on university student learning. Their results indicated that unrelated graphics in PowerPoint presentations negatively affected student-learning enjoyment. However, PowerPoint slides with relevant pictures neither increased nor decreased student enjoyment.

Based on Bartsch's (2003) study, the question still remains as to whether or not PowerPoint presentations are effective for student learning. A study conducted by Lari (2014)

examined the effectiveness of using technology in classrooms versus teaching without

technology in an English foreign language (EFL) context. The results showed, through a pre-

test/post-test design, that students taught using a PowerPoint presentation outperformed students

who were taught only using the blackboard and textbook. The study by Oommen (2012)

additionally found students taught using a PowerPoint presentation performed better on tests than

students taught through oral lectures and a whiteboard.

Both of these studies support the integration of PowerPoint presentations into classrooms

as they have been shown to be effective tools for student learning. However, the findings from

these studies do not align with those of Rankin and Hoaas (2001) or Ahmed's (1998) findings.

Rankin and Hoaas (2001) analyzed test results from four introductory economics classes, of

which two classes were taught using PowerPoint slides and the other two were taught without

slides. Their results indicated no significant difference in student test performance. Likewise, the

study by Ahmed (1998) found little difference in student test scores between lessons taught with

PowerPoint slides and lessons taught with overhead projectors. There is little evidence

supporting the idea that "teaching with PowerPoint leads to significantly better learning and

significantly better grades than teaching by conventional methods" (Craig & Amernic, 2006, p.

150).

Colors and Legibility

Digital media color combinations can affect webpage and computer user's readability and

legibility. *Readability* is the ability to distinguish between letters and word forms, while *legibility*

is the ease with which a form is recognized (Fukuzumi, Yamazaki, Kamijo, & Hayashi, 1998).

Greco, Stucchi, Zavagno, and Marino (2008) analyzed the effect of text-background color

combinations on text legibility, as displayed on a computer screen or wider surface. Their results

showed that dark text on a light background was the most legible and pleasant to read (Greco et al., 2008). These findings are in accordance with studies by Hall and Hanna (2004) and Humar, Gradisar, Turk, and Erjavec (2014), who also found higher contrast between background and foreground (text) colors to be more legible to the eye.

Technology, Color and Memory

With the development of technology and its increasing use in classrooms, the effects of color in digital media on memory are now being more closely analyzed. McConnohie (1999) and Hajnalka (2014) examined the effects of color in presentation software on memory. McConnohie (1999) showed 6th and 7th graders slideshows of alphanumeric characters using black text on white, green and blue backgrounds. The results indicated higher short- and long-term retention rates when using a white background and black foreground compared to a green or blue background and black foreground. Hajnalka (2014) used a variety of background colors to determine which color would enhance recalling words from online texts. The results showed subjects recalled the most words from orange and yellow backgrounds, while not recalling many words with blue or indigo (Hajnalka, 2014). These findings partially support McConnohie's (1999) results.

Hall and Hanna (2004) looked at the effect of website color combinations with high color contrast and low color contrast on retention. They gave 100 participants a 10-question quiz based on information presented on a webpage. There were four different color conditions, which were counterbalanced by reversing the order in which students viewed the color combinations (Hall & Hanna, 2004). Their results showed highest retention scores for black text on white background and lowest scores with white text on black background. Students retained more information from

low contrast color combinations than they did from a white text and black background webpage (Hall & Hanna, 2004).

Humans are surrounded by color every day. Colors can affect moods; increase motivation, and possibly even memory (Huchendorf, 2007; Spence, Wong, Rusan, & Rastegar, 2006). In a study by Huchendorf (2007) one hundred and fifteen students received a packet filled with either warm-colored, cool-colored or white-colored sheets of paper. They defined warm-colored as red and yellow, and cool-colored as green and blue. Students had 1 minute to memorize words from a provided word list, one minute to complete a math task and two minutes to write down as many words from the word list they could recall respectively. The results showed that there was not a statistically significant difference in the amount of words remembered based on packet color.

With paper handouts becoming obsolete, it is equally important to investigate the effect color in digital media and technology have on website color preference and information recall. Out of a spectrum of 23 different colored homepages, all of which were from the same website, Bonnardel, Piolat, and Le Bigot's (2011) study found blue, orange and grey most appealing. Based on these three colors, participants extracted more information from the orange website than the blue or grey website. These results might have implications for language teachers using digital media in the classroom; however, luminosity contrast between background and foreground colors needs further investigation.

Savoy, Proctor, and Salvendy (2009) analyzed the effect of PowerPoint and student retention based on auditory, graphic, and alphanumeric scores of 62 subjects. Their results showed using PowerPoint negatively affected subjects' ability to recall auditory information that was not present on the PowerPoint slides during a lecture. Using slides was reported as a

distraction in retaining oral information. Additionally, test scores did not indicate a difference in student's ability to recall information in a class that used PowerPoint slides to display graphics and alphanumeric characters versus a class that used only a chalkboard and oral lecture.

The study by Savoy et al. (2009) aligns with the findings from Nouri and Shahid (2005) and Buchko, Buchko, and Meyer (2012). Their results neither indicated that PowerPoint presentations enhanced student ability to recall information. While Nouri and Shahid (2005) distinguished between long-term and short-term memory results were inconclusive. There was no significant difference in test scores on long-term or short-term memory in classes taught using a PowerPoint.

According to Mahmoudzadeh (2014), using PowerPoint presentations in a language classroom helped students retain abstract vocabulary words compared to traditional classroom lecture without technology. There were 120 Iranian students divided into two equal sized groups: advanced and intermediate. Mean test scores between advanced and intermediate language learners additionally showed that PowerPoint presentations affected intermediate learners more than advanced learners (Mahmoudzadeh, 2014).

If using PowerPoint in classrooms can help students retain abstract vocabulary words, then it is possible it could also help students across all language related courses. Rajabi and Ketabi (2012) found that using PowerPoint helped students with academic writing; however, it did not aid learning grammar according to the study by Corbeil (2007).

Even though many of these study's findings contradict each other, they provide rich information for teachers to consider when designing and incorporating PowerPoint presentations into lessons. The following literature provides further information on PowerPoint presentations based on the effects of measuring color and luminosity.

Measuring Color and Luminosity

In order to analyze contrast it must be measurable. The World Wide Web Consortium (W3C) recommends the metric of luminosity contrast, which is a measured ratio of light to dark in digital media (Caldwell et al., 2008). It is measured on a scale from 1:1 to 21:1. A ratio below 4.5:1 is considered low luminosity contrast and a ratio above 4.5:1 is considered high luminosity contrast. Although the metric is intended for webpage designers and professors, teachers might also use it as a reference for building high or low contrast PowerPoint presentations. The 4.5:1 threshold accounts for the "loss in contrast that results from moderately low visual acuity" (Caldwell et al., 2008). Webpages that provide enough contrast between foreground and background colors allow people with different degrees of color blindness and vision impairments to read webpages (Caldwell et al., 2008). In designing this study, the contrast in the PowerPoint slides will be measured using an online contrast checker (Color Contrast Checker [Web-based Software], 2014).

Non-standardized descriptions of colors can seriously reduce a study's reliability. One screen may display the colors of a document differently than another screen, depending on the manufacturer's configurations. For example, the blue sky in two identical images may display slightly darker or lighter on a user's tablet than it does on his or her desktop monitor from a different manufacturer. The sRGB (*standardized* red, green, blue) color space is a standardized system for describing colors across different displays (Michael, Anderson, Chandrasekar, & Motta, 1996). Following the color-contrast guidelines suggested by the W3C, this study used sRGB descriptions of colors in order to make its findings reliable and reproducible.

Rationale

The literature provided the grounds and rationale for this research study. While some studies have investigated topics similar to that of this study (background-foreground colors in webpages and PowerPoint presentations, and luminosity contrast in webpages), no research that the researcher is aware of has investigated the effect of luminosity contrast in PowerPoint presentations on an adult's ability to retain information. Therefore, as there is a research gap, the purpose of this study was to analyze whether there is a statistically significant difference in adults' abilities to retain information from high-luminosity contrast and low-luminosity contrast presentations. Both teachers and students can benefit from this study; teachers can design PowerPoint presentations to better help students retain lesson information. The topic was explored by examining the question; does luminosity contrast in PowerPoint presentations affect retention of information?

Method

This section outlines the subjects, materials and procedures for conducting this study. For conciseness, Table 1 provides a list of key terms used in the following sections of the paper.

Table 1

Key Terms

Contrast:	The difference in relative luminance between background and foreground (text) colors in digital media (e.g., PowerPoint presentations), measured as luminosity contrast using the W3C guidelines (Caldwell et al., 2008). A contrast ratio below 4.5:1 (Caldwell et al., 2008) will be defined as low-contrast. High-contrast is defined as having a contrast ratio higher than 4.5:1(Caldwell et al., 2008).
PowerPoint presentation:	A static, non-animated, structured visual presentation, as seen on one's own computer.
Lesson:	An online, non-verbal PowerPoint presentation on a single subject followed by an online quiz over the same material.
Retention of information:	Subjects' ability to recall information immediately following a lesson, as measured by a 10-point quiz.

Subjects

Fifty-six adults, both male and female, between the ages of 18 and 69 years old participated in this study. They had at least a high school diploma or General Equivalency Diploma (GED) and were native English speakers. As a condition of participation, none of the subjects spoke Italian or had lived in Italy. They also had no previous experience or knowledge about Braille. To control for visual acuity, subjects did not have any known serious visual impairment that affected their ability to view the PowerPoint. All subjects had experience navigating and reading on a computer, and had to access a computer and Internet to complete the study's tasks. Since this study was not bound to a physical location, subjects could participate from a place of their choosing.

Materials

Each subject read two lessons. Each lesson included a PowerPoint presentation covering one of two topics: Italy and Italian (Appendix A) or Braille (Appendix B). For each lesson there was a high-contrast and low-contrast version of the associated PowerPoint presentation. The presentation of these materials was counter-balanced to control for an ordering effect. Subjects in Track A received a high-contrast lesson on Italy and Italian followed by a low-contrast lesson on Braille. Subjects in Track B received a high-contrast lesson on Braille followed by a low-contrast lesson on Italy and Italian. Subjects in Track C received a low-contrast lesson on Italy and Italian followed by a high-contrast lesson on Braille. Subjects in Track D received a low-contrast lesson on Braille followed by a high-contrast lesson on Italy and Italian. Table 2 illustrates the topic matter and contrast level for the PowerPoint presentations used in Lesson 1 and 2, ordered by Track.

Table 2

PowerPoint Presentations Divided by Track, Lesson, Topic and Contrast

	Lesson 1		Lesson 2	
	Topic	Contrast	Topic	Contrast
Track A	Italy/Italian	High	Braille	Low
Track B	Braille	High	Italy/Italian	Low
Track C	Italy/Italian	Low	Braille	High
Track D	Braille	Low	Italy/Italian	High

The PowerPoint presentation in each lesson contained a title page, 8 slides and 1 image. All slides used a sans-serif font with no italicized or bolded words and had the same background-foreground color combination, and consequently the same luminosity contrast. Additionally, the

Flesch-Kincaid reading ease score indicated that both texts were comparable in difficulty

(Braille=100, Italian=80).

Both high- and low-luminosity contrast PowerPoint presentations had the same *light-blue*

background, defined by the red, green, blue triplet (218, 235, 243). The low-contrast

presentations had a *mid-blue* foreground color, or text, color, defined by the sRGB triplet (51,

181, 246) (see Appendix C for a low contrast sample). They had a contrast ratio of 1.89:1, and

were thus low-contrast (Color Contrast Checker [Web-based Software], 2014). The high contrast

presentations had a *dark-blue* foreground, or text, color, defined as the red, green, blue triplet (5,

75, 109), in the sRGB color space (see Appendix D for a high contrast sample). They had a color

ratio of 7.68:1, and were thus high-contrast (Color Contrast Checker [Web-based Software],

2014).

Each Track had one online Braille quiz (Appendix E) and one online Italy/Italian quiz

(Appendix F), formatted using Google Forms, an online application that allows users to design

private or public anonymous quizzes (Google Inc., 2015). The Braille and Italy/Italian quizzes

were the same for all Tracks. The quizzes contained 10 questions each: 1 multiple-choice

question and 9 open-ended questions. Each question, regardless of type, was worth 1 point.

Subjects were not scored on spelling, and open-ended questions were each graded as 0 or 1, with

no partial points given.

Procedures

The researcher randomly assigned subjects to one of the four tracks, denoted as Track A,

B, C and D. There were 14 subjects in Track A, 12 in B, 14 in C and 13 in D. After subjects

submitted their online consent to participate in the study (Appendix G), there were six

demographic questions regarding their age, gender, highest education degree and background

knowledge on Italy/Italian and Braille (Appendix H). If subjects had prior Italian or Braille

knowledge, the study immediately notified them and prevented them from continuing.

Furthermore, to adhere to the Institutional Review Board (IRB) guidelines for conducting

research (Appendix I), subjects had the option to participate in the study ("Middlebury

International Review Board," 2015).

To account for computer-to-computer font incompatibilities, the PowerPoint

presentations were distributed in Portable Document Format (PDF). Subjects received one of the

four Tracks aforementioned via an email hyperlink to Google Forms. Upon clicking the

hyperlink and agreeing to participate in the study, subjects encountered directions and a

hyperlink on how to proceed with the study. The first hyperlink channeled subjects to the first

appropriate PowerPoint presentation. After subjects read through the PowerPoint presentation,

the final slide had directions with a hyperlink to the corresponding quiz. At the end of the first

quiz there was a hyperlink that channeled the subjects to the second PowerPoint presentation.

After subjects read through the second PowerPoint presentation, the final slide of the PowerPoint

presentation had a hyperlink to the corresponding quiz. The order of hyperlinks in Google Forms

and on the PowerPoint presentations corresponded to the subjects' Track. The PowerPoint

presentations were stored on DropBox and accessed via hyperlink on Google Forms.

Subjects recorded their time and completed all tasks individually, without the help of

others or Internet searches. They had a maximum of 5 minutes to read the information in the first

lesson and a maximum of 5 minutes to complete the corresponding anonymous quiz. Subjects

also had a maximum of 5 minutes to read the information in the second PowerPoint lesson and a

maximum of 5 minutes to complete the corresponding anonymous quiz. The tasks took subjects

no more than twenty minutes to complete.

Analysis

To determine statistical difference, the subjects' high-contrast and low-contrast quiz scores were analyzed using a Wilcoxon Signed Rank statistic. The Wilcoxon Signed Rank Statistic was the most appropriate statistic for this study's design because there were matched scores. Each of the 56 subjects' high-luminosity contrast scores matched their low-luminosity contrast scores.

The assumptions for a Signed Rank test were met for the research question. The independent variable, ± *high luminosity,* was nominal and had two levels, which were represented by the same subjects in the control condition (+ high luminosity) and experimental condition (- high luminosity). The scores for the dependent variable, *retention of information*, were not normally distributed but were measured on an interval scale and were rankable. The histograms in Figure 1 and Shapiro-Wilk Tests verified this. The *p-values* from the high-luminosity and low-luminosity contrast Shapiro-Wilk Tests were less than 0.05. Thus, there is 95% certainty that the data is not normally distributed. Furthermore, since visual acuity and background knowledge of Braille or Italian could have affected the study's outcome, the researcher created the following control variables: visual impairments, Braille background knowledge and Italian background knowledge. Each of these three control variables was represented by one level. Only subjects who did not have severe visual acuity, Italian background knowledge or Braille background knowledge could participate in the study.
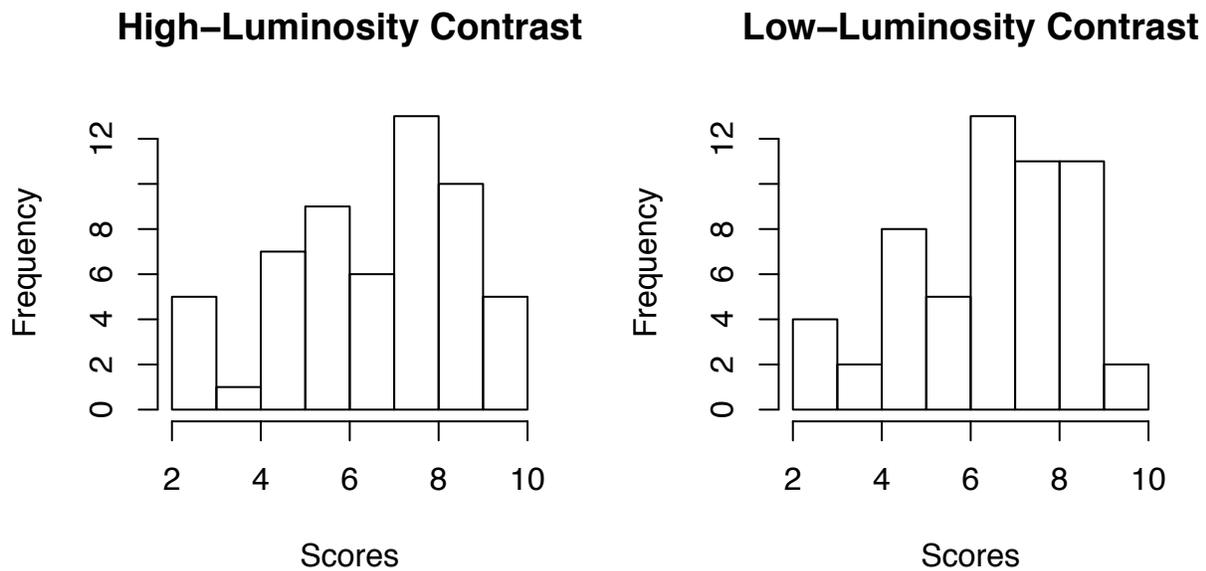
High–Luminosity Contrast   **Low–Luminosity Contrast**

Figure 1. High-Luminosity and Low-Luminosity Contrast Histograms

The null hypothesis and two alternative hypotheses are as follows. Null hypothesis 1: There is no statistically significant difference in retention of information, as measured by Italy/Italian and Braille quiz scores, between subjects who read from a high contrast presentation and subjects who read from a low contrast presentation. Alternative hypothesis 1: There is statistically significant difference in retention of information, as measured by Italy/Italian and Braille quiz scores, between subjects who read from a high contrast presentation and subjects who read from a low contrast presentation, with subjects who read from a high contrast presentation performing better than subjects who read from a low contrast presentation. Alternative hypothesis 2: There is statistically significant difference in retention of information, as measured by Italy/Italian and Braille quiz scores, between subjects who read from a high contrast presentation and subjects who read from a low contrast presentation, with subjects who

read from a high contrast presentation performing more poorly than subjects who read from a

low contrast presentation.

Alpha was set at 0.05 as no critical decisions about people or resources were made on the

basis of this study, as it was conducted solely for exploratory purposes. The effect size was

further calculated, because there were more than 30 subjects per control and experimental

condition.

Results

In order address the research question "does luminosity contrast in PowerPoint

presentations affect retention of information?" descriptive statistics were calculated for high-

luminosity contrast scores and low-luminosity contrast scores (Table 3). The mean, median and

mode indicated that the high-luminosity contrast and low-luminosity contrast scores were

similar. In other words, luminosity contrast had a small effect on students' ability to recall

information. The high-luminosity contrast mean score ($\bar{x} = 7.018$) and low-luminosity contrast

mean score ($\bar{x} = 6.893$) indicated subjects scored higher when reading from a high-luminosity

contrast PowerPoint than from a low-luminosity contrast PowerPoint. However, this is not

significant because the two mean scores are nearly equal in value. The standard deviations

showed that scores were more concentrated near the low-luminosity contrast mean than the high-

luminosity contrast mean. The score distributions for both high-luminosity contrast and low-

luminosity contrast were negatively skewed. Furthermore, all scores ranged between 2-10 points

for both high-luminosity contrast and low-luminosity contrast quizzes. Since descriptive

statistics do not indicate significant difference, the exact probability was calculated using the

Wilcoxon Signed Rank statistic.

Table 3

Descriptive Statistics for High- and Low-Luminosity Contrast Scores

	High-Luminosity Contrast	Low-Luminosity Contrast
Mean	7.018	6.893
Median	7.5	7
Mode	8	7
Range	2 – 10 (8 points)	2 – 10 (8 points)
Standard deviation	2.058	1.951

The results from the Wilcoxon Signed Rank Statistic indicated that there is no statistically significant difference in retention of information, as measured by Italy/Italian and Braille quiz scores, between subjects who read from a high contrast presentation and subjects who read from a low contrast presentation. As the study did not exhibit any significant difference at the 0.05, .0.01 or 0.001 probability level, the null hypothesis was accepted. Therefore, on the basis of this small-scale study, the researcher can be 95% certain that there is no statistically significant difference in retention of information, as measured by Italy/Italian and Braille quiz scores, between subjects who read from a high-luminosity contrast presentation and subjects who read from a low-luminosity contrast presentation ($V = 631.5$; $p = 0.9573$). The effect size (0.007) further indicated a weak impact on subjects' ability to recall information between high-luminosity contrast PowerPoint presentations and low-luminosity contrast PowerPoint presentations.

Discussion

The researcher checked several sources to best characterize this research design, however, none contained a counter-balanced design for matched pairs. Thus, it can be argued that this research study is of either experimental or quasi-experimental design. According to

Shavelson (1981) this study can be characterized as post-test only control group design in the experimental class. It contained (a) an experimental treatment and (b) random subject assignment (Shavelson, 1981). Other researchers might say this study is not experimental because it had matched-pairs and lacked random selection. Subjects were not randomly selected as they voluntarily participated in the study using a convenient sampling feature. The researcher asked friends and family as a first tier, who then asked their friends and family as a second tier.

According to Turner (2014) and Sowell (2001) this study can be characterized as a quasi-experimental counter-balanced time-series design. There was (a) an experimental treatment, (b) a single group which was interrupted by the intervention/treatment, (c) random assignment and (d) legitimate comparison groups, determined by the demographic questions at the beginning of the study. The two levels of the independent variable, ± *high luminosity contrast*, defined the treatment.

Therefore, based on Shavelson (1981), Turner (2014) and Sowell's (2001) definitions for research designs, this study can best be characterized as a counter-balanced repeated measures design in the quasi-experimental class. The study exhibited characteristics from the *controlling* quadrant of van Lier's (1988) model. The study measured adults' ability to retain information from PowerPoint presentations of different luminosity contrasts through quantitative data collection and quantitative analytical procedures (Allwright & Bailey, 1991). According to Grotjahn's (1987) framework for classifying research, this study is a pure form; it is a quasi-experimental design, consisting of quantitative data and a statistical analysis.

Opposite from belief, the results indicated no significant difference between high- and low-luminosity contrasts on subjects' ability retain information. These results do not align with previous research. A possible explanation for this inconsistency is that this research study was

conducted solely online using DropBox to display PowerPoint lessons. In other words, no other

studies, that the researcher is aware of, have researched the effects of luminosity contrast on

retaining information from PowerPoint presentations not accompanied by a lecture. For example,

some studies have researched classroom lectures aided by PowerPoint and lectures not aided by

PowerPoint to determine the effectiveness of PowerPoint on student retention (Buchko et al.,

2012; Mahmoudzadeh, 2014; Nouri & Shahid, 2005). However, these studies did not analyze the

effect of PowerPoint luminosity contrast on student retention.

Furthermore, other research studies, such as Hall and Hanna (2004), used webpages for

determining which luminosity contrast would return highest test scores. Their study found that

students retained more information from low contrast color combinations than they did from a

white text and black background webpage (Hall & Hanna, 2004). However, Hall and Hanna's

(2004) study neither aligns with the current research study because they used webpages, rather

than PowerPoint presentations, as a medium for determining significant differences for high- and

low-luminosity contrast on student retention.

Limitations

This study had several internal threats to validity. Although colors and luminosity

contrasts were clearly defined using the sRGB triplets, the amount of ambient light present in a

room may have altered subjects' perceptions of the foreground and background colors (Keithley,

2008). This threat was beyond the researcher's control, as the amount of light in a room may

have varied from each subjects' setting.

In addition, the researcher could not control the amount of time subjects took to complete

tasks, as the study was conducted entirely over email and online. Unfortunately many subjects

did not honor the 5-minute time limit for viewing lessons and taking quizzes. Subjects' time-

stamps on the Google Forms results sheet disclosed this information. Deleting the results of subjects who violated the rules was unrealistic as there was a small sample-size to begin with.

Since this study did not differentiate for kinesthetic or auditory learners, the results may not have been a representation of retention inasmuch as of subjects' abilities to learn solely from PowerPoint presentations. In addition, the lesson on Braille could be categorized as more problem solving than the Italian lesson, so those who are more analytical learners might have scored higher on the Braille quiz than the Italian quiz. Creating a moderator variable based on "learning style" might have eliminated these threats; though, it was impractical since there was such a small group of participants.

Due to subjects not following directions, the number of subjects in each track is not perfectly balanced. In Track A there were 14 subjects, 12 in Track B, 14 in Track C and 13 in Track D. The researcher had to eliminate results for subjects who completed only part of the study. In order to use a Wilcoxon Signed Rank Statistic, subjects high-luminosity contrast scores needed to match their low-luminosity contrast scores. Therefore, the results for subjects who did not complete the study or whose results could not be matched were discarded. Although the number of subjects in each Track slightly varied in number, it is possible that the imperfect counter-balanced numbers affected the study's findings.

Lastly, there was not a pre-test to ensure subjects' skills were comparable from the outset. The background knowledge questions prior to the study's commencement ensured that subjects had not studied Italian or Braille. However, the questions were not specific enough to guarantee subjects did not have knowledge about Braille or Italian history and geography. For example, someone who had never studied either of the two languages, but studied history, might have received higher Italy/Italian quiz scores due to their background history and geography

knowledge. This is an internal threat to validity because it could have skewed the study's findings.

A major threat to the external validity is the generalizability. Since there were a small number of subjects, 56 adults, it is unlikely they would appropriately represent the greater population. Furthermore, studies with high internal validity tend to have lower external validity (Nunan & Bailey, 2008; Turner, 2014). By controlling for visual impairments and background Italian and Braille knowledge, this study had high internal validity, but lacked high external validity. Thus, a threat to this study is its generalizability.

A significant threat to both the internal and external validity is that subjects were not tested for colorblindness or visual impairments. Testing each subject for colorblindness and vision impairments at the end of the study may have possibly reduced this threat, as it would have been fast and not pre-disclose the study's purpose. However, subjects were not tested because it was not practical to exclude anyone, as there were a small number of participants. To control for this, the researcher, as best as possible, did not contact anyone with color blindness or visual impairments, as it would have affected subjects' ability to read slides. It is still possible, however, that some subjects may have had a visual deficiency, but were unaware of it. As a result, subjects' quiz scores are not really generalizable to the greater population because they may not have truly reflected their "retention" of information.

Recommendations for Future Research

Despite these threats to validity, this study should be repeated with more participants and in a more controlled environment. The researcher could find that with more subjects, the gap between high-luminosity and low-luminosity contrast scores may increase, indicating a significant difference. This study was also not consistent with other research studies. However,

with a larger sample size, it is possible that the results may align with the findings of other studies. Additionally, rather than conducting the research entirely online, it might be best to conduct the research in a classroom where lighting and timing can both be controlled.

This study can be expanded on in a number of ways. First, more high-contrast and low-contrast color combinations could be used, instead of strictly adhering to the light-blue and dark-blue color combination. Secondly, the study could use other lesson content combinations other than Braille and Italy/Italian. Using different content combinations could: (a) eliminate the possibility of subjects having content background knowledge prior to participating in the study and (b) help equalize non-comparable lesson content. For example, some might say this study's Braille and Italian lessons are not comparable because Braille could be categorized as more logical than Italian. Therefore, this study could be expanded as a factorial design, in which both content and color combinations are manipulated to gather more valid and reliable high-luminosity and low-luminosity contrast results. Lastly, examining different types of information subjects retain more (e.g., letters, numbers, words, sentences) depending on luminosity contrast would be an interesting and worthwhile investigation.

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Appendix A

The following document is the online Italian lesson

Italy and Italian

Geography

- Italy is divided into 20 regions
  - Northern regions are more developed than the southern regions
- Sicily and Sardinia are the 2 largest islands
  - Sicily is larger than Sardinia
- There are 2 important mountain ranges
  - Apennines: run from the north to south
  - Alps: in the north, running west to east

Language

- ▶ Italian is the descendent of vulgar Latin, based on the Florentine dialect
- ▶ It is the standard language, however, there are numerous dialects
  - ▶ Most of them don't have a written form
- ▶ There are 21 letters in the standard language
  - ▶ J, K, W, X, Y are not part of the alphabet, but appear in loanwords such as "jeans, yogurt," and "trekking"

Pronunciation - 1

- ► C and G have a hard sound before "a, o, u" as in "cat" or "go"
- ► How would you pronounce the following words?
    - ► corto (short)
    - ► camera (room)
    - ► gusto (taste)
    - ► gatto (cat)

Pronunciation - 2

- ▶ C and G have a soft sound before "e, i" as in "church" or "gem"
- ▶ How would you pronounce the following words?
  - ▶ cena (dinner)
  - ▶ cioccolato (chocolate)
  - ▶ gelato (ice cream)
  - ▶ giorno (day)

Pronunciation - 3

- ▶ CH and GH together make a hard sound as in "cat" and "go"
- ▶ How would you pronounce the following words?
  - ▶ anche (also)
  - ▶ perchè (why)
  - ▶ ghetto (ghetto)

Food

- ▶ Varies from region to region
- ▶ Pesto originated in the region of Liguria
- ▶ Tiramisu, which metaphorically means "cheer me up," is a regional dessert from Veneto
- ▶ A coffee shop is called a "bar" in Italian
  - ▶ Italians don't usually sit down at them

Quiz Time

- Click the arrow below to take the quiz
- Rules:
    - Closed book, closed notes.
    - 5 minutes
- Take quiz ➲

Appendix B

The following document is the online Braille lesson

# An Introduction to Braille

History

- ▶ Braille is a writing system that lets blind and visually impaired people read by touch
- ▶ Frenchman Louise Braille designed it in 1821
- ▶ Originally designed for the French alphabet system
- ▶ A Perkins Brailler is a Braille typewriter for the visually impaired

The System

▸ Braille consists of raised dots arranged in cells

▸ A cell is made of 6 dots arranged in 2 columns
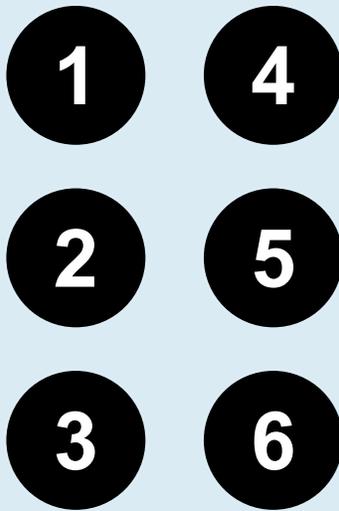
The Cell

▶ Each cell represents a single letter or space

C　　O　　D　　E

Alphabet: First Row

▶ The first 10 letters of the English alphabet are formed using the top 4 dots (1, 2, 4, 5)

A	B	C	D	E	F	G	H	I	J
⠁	⠃	⠉	⠙	⠑	⠋	⠛	⠓	⠊	⠚

▶ How would you write "bed" in Braille?

Alphabet: Second Row

► The second 10 letters are formed by adding a dot 3:

	A	B	C	D	E	F	G	H	I	J
add	K	L	M	N	O	P	Q	R	S	T

► How would you write "panda" in Braille?

Alphabet: All Rows

► The remaining 6 letters, except for "W," are formed by adding a dot 6

	A	B	C	D	E	F	G	H	I	J
	⠁	⠃	⠉	⠙	⠑	⠋	⠛	⠓	⠊	⠚
add	K	L	M	N	O	P	Q	R	S	T
	⠅	⠇	⠍	⠝	⠕	⠏	⠟	⠗	⠎	⠞
add	U	V	X	Y	Z				W	
	⠥	⠧	⠭	⠽	⠵				⠺	

► "W" does not follow the code because it wasn't used much in the French language at the time Louis Braille invented it

Quiz Time

- ► Click the arrow below to take the quiz
- ► Rules:
  - ► Closed book, closed notes.
  - ► 5 minutes
- ► Take quiz ➡

Appendix C

The following document is an example of a low contrast slide

Alphabet: All Rows

▶ The remaining 6 letters, except for "W," are formed by adding a dot 6

▶ "W" does not follow the code because it wasn't used much in the French language at the time Louis Braille invented it

Appendix D

The following document is an example of a high contrast slide

Alphabet: All Rows

▶ The remaining 6 letters, except for "W," are formed by adding a dot 6

	A	B	C	D	E	F	G	H	I	J
	⠁	⠃	⠉	⠙	⠑	⠋	⠛	⠓	⠊	⠚
add	K	L	M	N	O	P	Q	R	S	T
	⠅	⠇	⠍	⠝	⠕	⠏	⠟	⠗	⠎	⠞
add	U	V	X	Y	Z				W	
	⠥	⠧	⠭	⠽	⠵				⠺	

▶ "W" does not follow the code because it wasn't used much in the French language at the time Louis Braille invented it

Appendix E

The following document is the Braille quiz

Braille Quiz (Part 3 of 3)

Which alphabet system was Braille invented for? *

Who designed Braille? *

Which type of typewriter lets visually impaired people type? *

How many dots is a cell made of? *

How many columns are in a cell? *

The first 10 letters are formed using which dots? *

○ 1, 2, 4, 5

○ 1, 3, 4, 5

○ 1, 2, 5, 6

○ 2, 3, 4, 5

○ 2, 3, 5, 6

The second 10 letters are formed by adding which dot number? *

Which letter of the alphabet does not follow the Braille code? *

The remaining 6 letters, except for "W," are formed by adding which dot number? *

How many cells are there in the the sentence "run fast" ? *

Appendix F

The following document is the Italy/Italian quiz

Italian Quiz (Part 2 of 3)

* Required

How many regions does Italy have? *

[⬍]

What is the name of the second largest island? *

[   ]

How many important mountain ranges are there? *

[⬍]

Which dialect is Italian based on? *

[   ]

How many letters does standard Italian consist of? *

[⬍]

What is 1 English loanword, used by Italians, that has the letter "k" in it? *

[   ]

How do you pronounce the "CH" in "mischiare?" *

○ Like the "sh" in "she"

○ Like the "ch" in "church"

○ Like the "c" in "cat"

What food originated in Liguria? *

[   ]

What does 'tiramisu' metaphorically mean? *

[   ]

What do Italians call a coffee shop? *

[   ]

[Submit]

Never submit passwords through Google Forms.

Appendix G

The following document is the online subjects' agreement to participate in the study form

PowerPoint Research (Part 1 of 3)

I am a graduate student at Middlebury Institute of International Studies at Monterey (MIIS). I am conducting research to learn more on the effects of PowerPoint presentations. The findings from the study will be used to help teachers be more aware of the effects PowerPoint presentations have on their students. I would like to invite you to participate.

If you would like to participate, you will need a maximum of twenty minutes to read 2 PowerPoint presentations and take 2 ten-question mini-quizzes. The quizzes are entirely anonymous and confidential, meaning that there is no way to connect your responses to you. Toward that end, please do not sign your name to the survey or include any information in your responses that makes it easy to identify you. If at any time you would like to discontinue with the study you are more than welcome to exit the screen. Thank you for your time!

If you have any questions about this research before or after you complete it please contact either:

The researcher, Terra Minolli, at tminolli@miis.edu (831.588.3339) or the Middlebury Institutional Review Board Chair, Matthew Kimble, at irb@middlebury.edu (802.443.5402)

*Required

Are you willing to participate in this study? *

◯ Yes

◯ No

Continue »

Appendix H

The following document is the online demographic questions on subjects' age, gender,

highest education degree and lesson content background knowledge form

Demographic Questions

What is your gender? *

[   ]

What is your age? *

[▼]

What is the highest degree or level of school you have completed? *

If currently enrolled, highest degree received.

[▼]

Have you ever studied Braille? *

○ Yes

○ No

Can you read Braille? *

○ Yes

○ No

○ Some

Do you speak Italian? *

○ Yes

○ No

○ Some

Have you ever lived in Italy? *

○ Yes

○ No

Have you ever visited Italy? *

○ Yes

○ No

Appendix I

The following document is the NIH training course certificate of completion and IRB

approval for conducting research

Certificate of Completion

The National Institutes of Health (NIH) Office of Extramural Research certifies that **Terra Minolli** successfully completed the NIH Web-based training course "Protecting Human Research Participants".

Date of completion: 12/17/2014

Certification Number: 1637301

March 30, 2015

Terra Minolli
MIIS

Dear Terra,

Your proposal (15644, Calibrating Luminosity Contrast: Measuring the Difference it Makes) was reviewed by the Middlebury Institutional Review Board (IRB) on March 30, 2015 through the normal process for an exempt proposal. Your proposal is now approved.

Please check http://www.middlebury.edu/academics/resources/irb/deadlines to ensure that you apply for renewal in time to prevent your approval from expiring.

If the project will run for longer than 12 months, you must renew this approval no later than March 30, 2016.

It is important that you inform the committee promptly should you encounter any unanticipated problems involving risks to subjects or others associated with your research. Please inform the committee when the study is completed and forward copies of publications or conference presentations based on this project to Eileen Brunetto, IRB Coordinator, MBH 412, for our institutional records.

Good luck with your research.

Matthew O. Kimble
IRB Chair

c: Dr. Bailey