

The Comparability of Typographic and Substrate Variables
in Legibility and Readability Research: an Integrative Review

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ABSTRACT

This study focuses on the ability, or inability, to replicate or compare the design of text-related research from the perspective of the independent or dependent variables employed in such designs. Prior text-related research has used variables that were not clearly described or defined, could not be directly compared from one study or time period to the next, or were applied inappropriately. Measurements of typography-related and substrate-related variables may have absolute or relative values, and confusion can arise if the variables are not clearly identified and defined. The study is an integrative review with mixed methods research design investigating 44 books and two websites (part 1); and 83 journal articles, one thesis, and three dissertations (part 2). The integrative review shows that the sources investigated present neither essential information on typographic and substrate characteristics nor consistent definitions of legibility and readability in order to allow comparable replication from one study to another. Findings are displayed in Chapter 4. Discussion and the related details are presented in Chapter 5.

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GENERAL AUDIENCE ABSTRACT

This study focuses on the ability, or inability, to replicate or compare the design of text-related research from the perspective of the independent or dependent variables employed in such designs. Previous text-related research has used variables that were not clearly described or defined, could not be directly compared from one study or time period to the next, or were applied inappropriately. Measurements of typography-related and substrate-related variables may have absolute or relative values, and confusion can arise if the variables are not clearly identified and defined. The study is an integrative review with both qualitative and quantitative research design analyzing 44 books and two websites (part 1); and 83 journal articles, one thesis, and three dissertations (part 2). The integrative review shows that the sources investigated do not present essential information on typographic and substrate characteristics, and consistent definitions of legibility and readability to permit comparable replication from one study to another. Findings are displayed in Chapter 4. Discussion and the related details are presented in Chapter 5.

DEDICATION

Romans 11:36, Philippians 1: 6

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CHAPTER ONE

Introduction

Replication may be defined as the re-creation of results and theoretical concepts of previous studies; this re-creation is an important way to build external validity/credibility of research (Dellinger, 2017). A successful replication supports the conclusion that the results of an original study are not an isolated incident and contributes to the perceived robustness and generalizability of a study (Dellinger, 2017). Furthermore, replication can help verify facts (Schmidt, 2009), reduce misuse of data, and advance science (Novotney, 2014). However, many have argued that a shortage “of replication in the social and behavioral sciences is an important factor limiting the progress of those sciences” (Hargens, 2015, p. 441).

Replications are conducted to reproduce existing studies in order to “retest the same hypotheses, or explore the same issues in the same way (or explore the same issues, in the same way” (Tsang and Kwan, 1999, p. 765). To conduct a robust replication of an original study, requirements need to be set for both the original study and the replication study (Fabrigar & Wegener, 2016, p. 79). For example, an original psychometric study should present “articulation of underlying construction of operationalizations, evaluation of psychometric properties of operationalizations, full report of results of psychometric evaluation of operationalizations, availability of experimental materials, and eventually, report of meta-analytic statistics for key effects across primary experiments to assess robustness to non-replication” (Fabrigar & Wegener, 2016, p. 79). In contrast, the replication study should include “the evaluation of original experimental materials with reference to new context and population, justification of retention/revision of original materials for new context and population, evaluation of psychometric properties of operationalizations in new context and population, comparison of

psychometric properties of new and original experiment to assess invariance, and eventually evaluation of meta-analytic implications of replication experiment” (Fabrigar & Wegener, 2016, p. 79).

More specifically, a replication study is concerned with first, “construct measurement and data analysis,” and second, “the source of data” (Tsang & Kwan, 1999, p. 765). Related to these two dimensions are “reanalysis of data and conceptual extension” (Tsang & Kwan, 1999, pp. 766-767). In the reanalysis of data “the aim is to assess whether and how the results are affected by problems of definition, as well as by the particular techniques of analysis” (Tsang & Kwan, 1999, p.766). The conceptual extension deals with “the employment of the procedure, such as the measurement of the constructs, the structure of construct relationship, and data analysis” (Tsang & Kwan, 1999, p. 767).

Although it is common for replication studies to focus on the outcomes of previous studies’ comparisons and how those previous studies were replicated (Open Science Collaboration, 2015), this study took a different approach. Instead of focusing on comparisons of results, this study examined the ability, or inability, to replicate or compare the designs of original research based on the adequacy of information regarding specific dependent and independent variables employed in such designs. It did this by focusing on several specific types of information that should be provided as part of original studies in order to facilitate subsequent replications of those initial studies. Of special interest in this study was the possibility that prior research has used variables that: were not clearly described or defined, either in the initial studies or in the replication studies; could not be directly compared from one study or time period to the next; or were applied inappropriately.

The examination of the above factors occurred within the context of text-related research and the associated field of message design. Message design has been important for over a thousand years. During this time, messages have been presented in a variety of formats, including audible, visual, tactile, and combinations of these formats. For audible formats, our sense of hearing receives messages that have been delivered orally, e.g. through radio or audio books. For visual formats, messages have been delivered in pictures, drawings, and text (words) to be received and read/perceived by our sights, e.g. paintings, photographs, sketches, and text messages reflected on mobile devices. In tactile format, messages have been delivered through our physical contacts with one another, e.g. handshakes and hugs. However, it is also possible that messages have combined formats, such as audio/visual (e.g. movies) and audio/tactile (e.g. shaking hands and conversing).

Within the areas of text-related research and message design, the focus was on two dependent variables, legibility and readability, and two independent variables, typography and substrates. The designs of text-related research were examined from the perspective of these two dependent and two independent variables employed in such designs. Interest in this specific topic was based on the importance of text-related research and message design to the field of Instructional Design and Technology; and the possibility that prior text-related research has used variables that were not clearly described or defined, could not be directly compared from one study or time period to the next, or were applied inappropriately.

Instructional messages frequently rely on text to reach their audiences and, not surprisingly, the legibility and readability of text are two constructs that are commonly used as dependent variables in text-related research. Legibility and readability (Tracy, 2003) are separate constructs, but both are thought to be influenced by typography. In its simplest form, legibility is

used to describe or discuss the recognizability of single characters resulting from their design (Tracy, 2003). Readability is concerned more with “the quality of visual comfort” (Tracy, 2003, p. 31) which is “an important requirement in the comprehension of long stretches of text” (Tracy, 2003, p. 31). By this, Tracy (2003, p. 31) refers to comfort in reading continuously those long stretches of text, and not “searching for a single item of information.”

In addition to the dependent variables of legibility and readability, text-related research has involved a variety of independent variables. Of interest in this study were independent variables that fell into either of two categories: typography-related and substrate-related variables. Certain conventions associated with typographic elements are thought to influence the effective delivery of messages in textual format and most textual messages are displayed on either reflective or transmissive substrates. Among the typography-related factors discussed in relevant studies are typeface, type size, type font, and type style. Substrate characteristics addressed in this study fell into two categories: reflective and transmissive. Factors associated with reflective substrate in the reviewed articles included paper size, paper color, and paper finish. Transmissive substrate factors mentioned in the studies included screen type, screen resolution, pixels, and screen size.

Need for the Study

Whether or not the results of replication studies support or disagree with the results of original studies means little if those results are based on independent variables that cannot be compared or replicated between studies. In much the same way, results are difficult to compare if the same terms, but different meanings, are attached to the dependent variables employed in the studies. When relevant, the terminology, dimensions, and units of measurement associated with dependent and independent variables should have equivalent meanings across studies in

order for results to be directly comparable. Although this requirement probably seems obvious to most researchers, there is a need to know if the requirement is met in actual practice.

Contribution to the IDT Field

This study is expected to increase the awareness of current and future researchers regarding the importance of selecting, identifying, defining, and describing appropriate variables and providing all necessary information associated with variables and terminology in order to enable legitimate comparisons of the results of original and replication studies.

Purposes of the Study

This study had three major purposes, all of which were explored through the use of legibility and readability studies. The first purpose was to examine the importance of identifying and carefully defining dependent and independent variables used in original and replicated studies. A second purpose was to examine the necessity of defining or describing the dimensions of, and the related units of measurement associated with, the independent and dependent variables used in original and replicated studies. A third purpose was to propose recommendations that would allow researchers to avoid some of the problems identified while addressing the first two purposes.

Research Questions

The purposes of the study were fulfilled through the use of authentic studies and related literature involving text-related research. Responses to the following text-related questions provided the information needed to achieve those purposes:

- 1) Dependent variables: How have legibility and readability been defined and measured?

- 2) Independent variables: What typographic characteristics are associated with legibility and readability and how are they defined and measured? What similarities and differences in definitions or units of measurement exist among variables used to measure typographic characteristics in studies on legibility or readability?
- 3) What substrate characteristics are associated with legibility and readability and how are they defined and measured? What similarities and differences in definitions or units of measurement exist among variables used to measure substrate characteristics in studies on legibility or readability?
- 4) What definitions, dimensions, or units of measurement associated with typographic and substrate characteristics permit comparisons among studies dealing with the effects of typographic and substrate characteristics on legibility or readability?

Organization of the Study

The study comprises five chapters. The first chapter, Introduction, highlights the background of the study, its purpose and need for the study, contribution to the IDT field/significance of the study, research questions, and organization of the study. Unlike many research studies, the second chapter, Research Methodology, covers the definition of the integrative research reviews, rigor of the study, philosophical assumptions and researcher role, scope and rationale of the study, phases in conducting integrative research reviews (including search strategies, databases used, and coding sheet format), limitations of the study, and research ethics. The third and fourth chapters consist of integrated research reviews. The third chapter contains the first of these integrated research reviews and focuses on the content of professional books and websites to answer research questions dealing with how legibility and readability as dependent variables have been defined in relation to typography and substrates (reflective and

transmissive). The values involved in the units of measurement are included in the discussion. Also, how typographic elements and substrate characteristics have been compared with one another and some examples of the comparisons by the studies are provided. The fourth chapter reports the findings of a second integrated research review from journal articles and dissertations, one that focuses on the elaboration of how the variables and units of measurement have been used in research studies dealing with legibility and readability. The fifth chapter discusses the findings from the fourth chapter, including practical implications, and contribution to the field of IDT.

CHAPTER 2

Methodology

Definition of Integrative Review

The research methodology used in this study involved conducting two integrative research reviews. Integrative research review can be defined as the “reviewing, critiquing, and synthesizing of a set of literature on a mature or new topic” (Torraco, 2005, p. 357). Integrative research review, as defined by Whitemore & Knapfl (2005):

...allows for the simultaneous inclusion of experimental and non-experimental research in order to more fully understand a phenomenon of concern – to define concepts, to review theories, to review evidence and to analyze methodological issues of a particular topic. (pp. 547-548)

In this study, the integrative research reviews were focused on the examination of how independent variables – typographic and substrate characteristics and their units of measurement – in previous studies were defined and applied in relation to the dependent variables of legibility and readability. The independent variables used in the previous studies were examined to see if their designs would provide enough information to allow comparisons with these same variables in future studies dealing with legibility and readability. To achieve this comparability, the definitions and units of measurement of the terminologies used in the variables were analyzed to determine if they were used in a consistent and measurable manner. Since the integrative reviews in the study were based on historical reviews (Cooper, 2015), resources selected were derived from both formal and secondary sources (Cooper, 1998). A variety of resources were

selected until the existence of issues that could contribute to or complicate comparison or replication problems was established.

Rigor of the Study

To ensure rigor in the integrative reviews, the following stages were taken in the analysis (Soares et al., 2014, p. 335).

- 1) The first stage involved establishing the research key words, and other related details of “databases, publication years, reference managers” and research “key concepts.”
- 2) The second stage involved “analyzing, presenting, and synthesizing” the results departing from “the identification and the categorization” of the themes including the verification of their validity and authenticity.
- 3) The last stage was maintaining “critical attitude” from the beginning to the end of the writing process through careful examination of “primary concepts or ideas, origin and history of the issue, research methods and applications, and their interactions.”

Philosophical Assumptions

The interpretive framework used in this study was pragmatism. With pragmatism, the focus of the research is not on the methods used. Instead, the focus is on “the problem being studied” and “the questions asked about this problem” (Creswell, 2013, p. 49). To solve problems, the researcher, keeping in mind that “research always occurs in social, historical, political and other contexts,” employs “multiple methods of data collection” (Creswell, 2013, p. 51) to “best answer the research problems/questions.” (Creswell, 2013, p. 50). Thus, this study

worked with applications of “what works” and how to solve problems (Creswell, 2013, p. 49). To identify the strengths and the weaknesses for a variety of studies, the philosophical assumptions and the researcher role held an essential place in the success of this integrative review.

Researcher Role

In interpreting the variety of studies in this integrative review, I had my own worldview which may have affected the interpretation of those studies. This is despite the fact that I had been brought up to be highly critical from a young age through reading activities of different genres. I am able to appreciate different thoughts and opinions from different cultural backgrounds and regard them as equal to my own. However, I may be prone to biases in viewing and solving problems because of my cultural values/ backgrounds and upbringing. In addition, I may also be vulnerable towards preconceptions which may precede or cloud my judgment in analyzing the data and drawing conclusions. Realizing this shortcoming guards me from jeopardizing my research writing. I am responsible for minimizing these personal shortcomings through reasoning, and justifying facts using published written theories and ideas. In this way, I make every effort to not rely solely on my own reasoning.

Scope and Rationale of the Study

Based on the literature reviewed, this study employed two integrative reviews of historical data since it focused on how the typographic and substrate variables were used, viewed, and defined in their units of measurement throughout time in relation to legibility and readability.

The study also employed basic mathematical calculations, descriptive statistics, and qualitative analysis of the referential sources (mixed methods research). The mixed methods

research was selected with the ultimate goal of eventually producing simple mathematical calculations or descriptive statistics related to the possible recommendations dealing with comparable units of measurement. The production of these calculations will be a practical and pragmatic knowledge (Creswell, 2013) contribution to the field of IDT, allowing researchers to identify and possibly “re-conceptualize” (Torraco, 2005, p. 357) the units of measurement used in typographic and substrate characteristics.

Types of Literature in the Study

Formal channels (Cooper, 1998) were the principal sources for the literature used in the integrative research reviews. Formal channels (Cooper, 1998) comprise “professional conference paper presentations, personal journal libraries, electronic journals, and research report reference lists” (p. 51). Secondary channels (Cooper, 1998) comprise “research bibliographies, prospective research registers, reference databases, and citation indexes” (p. 58). Professional books and websites (46 sources) were used in conducting the first integrative research review while journal articles and dissertations (87 sources) provided materials for the second integrative research review. These formal and secondary types of literature were used to answer the research questions.

Information Retrieval Techniques, Search Strategies, and Search Databases

The primary information retrieval techniques used to conduct integrative research reviews and to collect data in this study were the ancestry approach and the on-line computer search. The ancestry approach was done through tracking the citations from one study to another (Cooper, 1998). The on-line computer search involved exhaustive scans or browsing of abstracting services and citation indexes (Cooper, 1998) to achieve and increase validity.

In order to optimize the literature search, a variety of keywords or phrases were used inclusive of, but not limited to:

- (the effects of) screen size on learning/reading,
- typography and screen,
- typography and paper,
- (the effects of) screen (size) and typography (line spacing, typeface, type size, etc.) on legibility,
- (the effects of) screen (size) and typography (line spacing, typeface, type size, etc.) on readability

The word “screen” was sometimes replaced with “CRT,” “LCD,” “laptop,” “smart phones,” “tablets,” “mobile devices,” “reflective substrate,” or “transmissive substrate.” The results of the search were expected to yield a variety of independent and dependent variables. The foci of the independent variables in the study were typography and substrates in their association with legibility and readability.

The referential sources were collected through a search of digital collections and on-line computer resources via <https://www.lib.vt.edu> from Virginia Polytechnic Institute and State University, Blacksburg, Virginia. Some of the referential databases used were EBSCOhost, JSTOR, Networked Digital Library of Theses and Dissertation, ProQuest, Safari Books Online, ScienceDirect, Addison the Virginia Library Catalog, SpringerLink, IEEE Explore Digital Library, and Google Scholar. Simultaneously, the ancestry approach was conducted by tracking citations from one study to another. This was followed by on-line computer searches to obtain the articles needed. Sources selected focused on English typography from the publication years with no limit on publication time period specified for this study.

To be able to analyze the aggregate data from the literature reviewed, a coding form was constructed with all details needed to categorize the data from the literature, including Title Number; Title; Term; Definition; Category; Variable; Value; Unit of Measurement; Apparatus; Display Type; Media; Author's Keyword; and User's Keyword. These terms were used to analyze and classify the reviewed studies with respect to the definitions and the units of measurement of typography and substrate characteristics on legibility and readability. I placed the terms in a spreadsheet format and uploaded them in Google Drive to accountably generate the needed results based on the research questions asked. The access to coding processes and results on Google Drive was also shared with the researcher's advisor.

Details of the Literature or Sources Used in the Study

133 sources used in the two integrative reviews were composed of journal articles, dissertations, professional books and websites. The 44 professional books and two websites were used in the first integrative review (Chapter 3). Meanwhile, 83 journal articles, one thesis, and three dissertations were used in the second integrative review (Chapter 4). The professional books and websites were selected to see if generic or standard definitions, instruments, and units of measurement of legibility, readability, as well as typographic and substrate characteristics were present. In the same way, the journal articles and dissertations were selected to see if these sources contained the same type of information that could be used for replication purposes.

The characteristics of the variables were input manually and from this input, the results were calculated based on the two dependent variables and the two independent variables. The frequencies in the coding tables in the findings of each variable signified whether the terminologies were either identified but not defined or described; defined; or described in the literature. When a terminology was defined, it meant that the terminology had "a statement of the

meaning of a word or word group” (<https://www.merriam-webster.com/dictionary/definition>).

On the other hand, when a terminology was described, it meant that the terminology contained “a written or spoken report of how something is done or of what someone or something is like”

(<https://dictionary.cambridge.org/us/dictionary/english/describe>).

Phases in the Integrative Review

Table 1 illustrates the phases involved in this study, and the actions taken in each phase:

Table 1

Phases in the Integrative Review

Phase	IRR 1	IRR 2
1. Problem Formulation and Literature Search: The problem formulation stage was initiated as the literature was being reviewed and the problem was identified. Next, purposes/objectives for the study, as well as research questions, were formulated.	<p>Conducted thorough literature review focused on professional books and websites (Chapter 3) with the following stages:</p> <p>a. Definitions and units of measurement associated with legibility and readability.</p> <p>b. Typographic characteristics that had been thought to affect legibility and readability by looking at what they were and how they had been measured.</p> <p>c. Substrate characteristics that had been thought to affect legibility and readability by looking at what they were and how they had been measured.</p>	<p>Conducted thorough literature review focused on journal articles and dissertations (Chapter 4) with the following stages:</p> <p>a. Definitions and units of measurement associated with legibility and readability.</p> <p>b. Typographic characteristics that had been thought to affect legibility and readability by looking at what they were and how they had been measured.</p> <p>c. Substrate characteristics that had been thought to affect legibility and readability by looking at what they were and how they had been measured.</p>
2. Data Evaluation/ The Evaluation of Data Points (data points in this study: typography and substrate in relations to legibility and readability as	<p>The first integrative review focused on professional books and websites (Chapter 3) with the following stages:</p> <p>a. Identified variables and</p>	<p>The second integrative review focused on journal articles and dissertations (Chapter 4) with the following stages:</p> <p>a. Identified variables</p>

dependent variables or also called Chapter 3 and Chapter 4 respectively)

- units of measurement associated with legibility and readability.
 - b. Identified variables and units of measurement associated with typographic characteristics that had been thought to affect legibility and readability by looking at what they were and how they had been measured.
 - c. Identified variables and units of measurement associated with substrate characteristics that had been thought to affect legibility or readability by looking at what they were and how they had been measured.
- and units of measurement associated with legibility and readability.
 - b. Identified variables and units of measurement associated with typographic characteristics that had been thought to affect legibility and readability by looking at what they were and how they had been measured.
 - c. Identified variables and units of measurement associated with substrate characteristics that had been thought to affect legibility or readability by looking at what they were and how they had been measured.

3. Discussion (Chapter 5)

- a. Analyzed the potential comparability of variables and units of measurement associated with legibility and readability by looking at units of measurement associated with the variables to determine if they were nominal, ordinal, interval, or ratio and if they had absolute or relative values.
- b. Analyzed the potential comparability of variables and units of measurement associated with typographic characteristics that had been thought to affect legibility or readability by looking at units of measurement associated with the variables to determine if they were nominal, ordinal, interval, or ratio and if they had absolute or relative values.
- c. Analyzed the potential comparability of variables and units of measurement associated with substrate characteristics that had been thought to affect legibility and readability. This was done by looking at units of measurement associated with the variables to determine if they were

- nominal, ordinal, interval, or ratio and if they had absolute or relative values.
- d. Determined which variables and units of measurement associated with legibility and readability could be compared by examining results of the Analysis phase to select variables and units of measurement that had the same meaning and values across studies and whether or not they were able to stand alone.
 - e. Determined which variables and units of measurement associated with typography characteristics could be compared by examining results of the Analysis phase to select variables and units of measurement that had the same meaning and values across studies and whether or not they were able to stand alone.
 - f. Determined which variables and units of measurement associated with substrate characteristics could be compared by examining results of the Analysis phase to select variables and units of measurement that had the same meaning and values across studies and whether or not they were able to stand alone.
 - g. Made comparisons and critiqued existing studies.
 - h. Made observations regarding what variables and units of measurement to use and what issues to avoid.
 - i. Provided practical implications of the study and its contribution to the field of IDT.
-

Limitations of the Study

The study may also have been hampered by my unfamiliarity with the topic due to my previous academic experience. To overcome this, I was willing to devote more time to delving into the topic and exploring more sources. Thus, my advisor played a very important role as the critic, evaluator, and supervisor of my written work to guide me in the whole writing process. Through my advisor's feedback, my bias was then minimized.

In addition, the observations made in this study may become obsolete in the future and thus, new studies may need to be undertaken.

Research Ethics

The study only involved literature related to the study, and no other methods of data collection such as interviews, questionnaires, or surveys were required. Thus, no personal information was dealt with or risked within the study. The Virginia Tech Institutional Review Board (IRB) granted permission to conduct the integrative review on October 24, 2016 with the IRB number 16-931.

Summary

A total of 133 sources were used in the two integrative reviews and they were composed of professional books, websites, journal articles, and dissertations. The 44 professional books and two websites were used in the first integrative review (Chapter 3). The 83 journal articles, one thesis, and three dissertations were used in the second integrative review (Chapter 4). The details of the sources were digitally stored and coded using the coding form with supervision from the researcher's advisor to avoid potential biases. The results of the coding are presented in Chapter 3 and Chapter 4.

CHAPTER THREE

Integrative Research Review 1: Professional Books and Websites

Two integrative research reviews dealing with issues related to replication were conducted in this study. This first integrative review involved 44 professional books and two websites and focused on definitions, dimensions, units of measurement, and instruments that could play important roles in replication studies. In broad terms, the purpose of this initial review was to determine if dependent and independent variables, dimensions, units of measurement, and instruments that are likely to be employed in authentic studies in a specific area of study have single, commonly agreed upon meanings and uses or if some of these items have multiple meanings and uses.

The purpose of the initial integrative research review was operationalized by focusing on professional books and websites containing information related to the legibility and readability of textual messages. The principal topics examined included similarities and differences among definitions of legibility and readability, typography elements commonly associated with legibility and readability of textual messages, substrates upon which textual messages commonly appear, and dimensions, units of measurement, and instruments associated with legibility, readability, typography and substrates.

Although textual messages may serve a wide variety of purposes, this review concentrated on literature and studies dealing with visual textual messages used for instructional purposes. The actual contents of textual messages and the results associated with the dependent variables were not examined but the physical features of the relevant independent variables, i.e., text and the substrates (the surfaces on which the text was displayed) were examined. These physical features included typographic variables, such as typeface, type style, type size, and line

spacing, as well as substrate variables, such as background color and the manner in which light interacts with the surface.

Legibility and Definitions

As part of this first integrative review, an attempt was made to determine if authors defining legibility and readability adhered to a single, common theme or if some authors deviated from the common theme. If all authors' definitions adhered to a common theme, there might be less concern if research studies addressing legibility or readability failed to define their meaning of the term, relying instead on the premise that the definitions of legibility or readability were common knowledge and required no definition in these studies. However, if the reviewed materials provided multiple definitions of legibility or readability, it would be important to define how the terms were treated in individual research studies. Based on the integrative review of professional books conducted in this study, it is apparent that legibility is a construct that is easier to describe than it is to define, and the results of the review demonstrated that legibility of text has been defined or described in various ways by different authors.

In its most basic form, legibility is defined at the level of a single character (Tracy, 2003). Consistent with this theme, Haley et al. (2012) defined legibility, as “the measure of how easy or difficult it is to distinguish one letter of a typeface from another” (p. 330).

The integrated review of literature examined whether or not legibility and readability studies deviated from this basic theme of the definition either by using a different definition or by failing to state what definition was used.

As part of the first integrative review, an attempt was made to determine if authors defining legibility adhered to the basic theme mentioned above or if some authors deviated from the basic theme. If all authors adhered to the basic definition, there might be less concern if

research studies addressing legibility failed to define their meaning of the term, relying instead on the premise that the definition of legibility was common knowledge and required no definition in these studies. However, if the reviewed books provided multiple definitions of legibility, it would be important to define how the term was treated in individual research studies.

Based on the integrative literature review of professional books conducted in this study, it is apparent that legibility is a construct that is easier to describe than it is to define. Tracy indicated the term means the quality of being decipherable and recognizable but quickly followed this observation by identifying when the term should be used rather than clearly defining its meaning: legibility is the term to use when discussing the clarity of single characters (Tracy, 2003). Tracy's approach has been shown to be quite popular and has been cited in at least 120 studies. His treatment of the term focuses on the recognizability of single characters resulting from their design (Tracy, 2003).

The definition of legibility from Willen and Strals (2009), similar to Tracy's (2003) is defined as "the individual character recognizability" (p. 127). This definition also focuses on single or individual characters. Other definitions of legibility dwell on "the distinguishing characteristics of each letterform with others" (White, 2011, p. 558) and the "distinguishability of letters" Coleman (1968, p. 168). The two sources from White (2011) and Coleman (1968) focus on a more specific form of character, i.e. letterform and letters. All these three sources, however, do not indicate any further involvement of other typographic factors in their definitions.

Concentrating on the "character" theme makes it easy to see how various authors have adopted expanded views of legibility when compared to Tracy's perspective (2003). One area of

elaboration involves identifying what constitutes a character. Authors of works involving legibility have described the term character as “any letter, numeral, punctuation mark, figure” (White, 2011, p. 202), “individual letterforms, numerals, punctuation marks, and other units that are part of a font” (Evans & Thomas, 2012, p. 307), “individual letters, figures, punctuation of the alphabet” (Craig & Scala, 2006, p. 103), or “an elemental unit of written language, such as an alphabet letter” (Willen & Strals, 2009, p. 126), or “a letter, a number, a punctuation mark, or other symbol” (Coles, 2012, p. 247).

The focus on the character theme when describing legibility inevitably leads to the involvement of other typographic factors. One description focuses on the clarity of the typefaces using “all parts of a character and all the styles within a font family” (Bosler, 2012, p. 411). Legibility is also interpreted as an interest in the “distinctiveness of the characters from one another,” and that “highly modular or geometric typefaces may be less legible than those with more organic and individualized forms” (Lupton, 2014, p. 20). The parts of a character in Bosler (2012) and Lupton (2014) have been further dissected into “a typeface design ... related to the actual design, including its x-height, character shapes, size of its counters, stroke contrast, serifs or lack thereof, and weight” in Strizver’s glossary (2010). The terminology which is, “a function of typeface design which is an informal measure of how easy it is to distinguish one letter from another in a particular typeface” should be “transparent, of big features, and restrained” (Haley, n.d.). With the transparency, the typefaces should not bring “undue attention to themselves” (Haley, n.d.). Clarity of typefaces also needs to be delivered through the typeface “big features” where there is high recognizability of “large, open counters, ample lowercase x-heights, and character shapes” (Haley, n.d.). The restraint of typefaces is also essential in ensuring the typefaces’ degrees of lightness or boldness to remain legible for readers. Here, the description of

legibility from Haley (n.d.) is similar to that of Strizver (2010), Bosler (2012) and Lupton (2014) with emphasis on the details of typeface or character shapes.

Legibility and Measurement

Table 2 includes the list of measurements found in the professional books.

Table 2

Details of Measurement of Legibility from Professional Books

Author	Measurement
Walter (2003)	Speed of recognition
Sherr (1993)	Number of correct identifications
Tinker (1963)	Speed of perception, perceptability at a distance , perceptability in peripheral vision, visibility, reflex blink technique, rate of work, eye movements, fatigue in reading
Craig (2006)	The speed of perception
Daniel & Reinking (1987)	Visual fatigue, reading speed and comprehension

Readability and Definitions

Based on the perspective employed in this study, the construct of readability is referred to as “comprehension, and the measure of that is the length of time that a reader can give to a stretch of text without strain” (Tracy, 2003, p. 31). In contrast to legibility, readability concerns itself with text (Tracy, 2003) where text is considered as “the main body of written or printed material, as opposed to display matter, footnotes, appendices, etc” (Carter, Meggs, Day, Maxa, & Sanders, 2015, p. 330), or “the main portion of a story” (White, 2005, p. 206). A text may also be comprised of letters, words, and paragraphs to deliver messages to its readers (Strizver, 2010). Readability as a construct has also been classified into three parts of “words, phrases, and blocks of text” in “books, magazines, newspapers, and websites, or electronic books found on the Kindle or iPad” (Tselentis, 2011, p. 122).

Only definitions where readability was associated with text-related factors were included in this review. However, there are other perspectives from which readability may be viewed. An example of one of these perspectives is where the definition of readability avoids text-related factors and is described as relating to “the emotional impact of a design (or lack thereof) with the amount of effort it presumably takes to read” (Maria, 2014, p. 12). Another description of readability referred to text as the “total reading environment” in Sinclair (1999, p. 7) and White (2005).

Merged Descriptions of Legibility and Readability

In the reviewed sources, some definitions or descriptions of legibility and readability occasionally merge since their authors may see both constructs as inseparable from one another. Legibility is described first, and is then extended to readability. The first description focuses on characters and then, groups of characters. The description of the terminologies refers to the understandability, distinguishability, or ease of reading of characters or groups of characters (Sinclair, 1999; Marshall & Meachem, 2012). A second merged definition expands from characters/letters to words Gilliland (1976, p. 28). Gilliland (1976, p. 28) stresses on “visual perception of letter shapes, isolated words and words in context and those factors of type construction and setting, which affect the ability to identify letters and words, therefore fluency.” A third description of legibility highlights letters, words, and then entire text. Legibility is viewed as “perceptions of letters and words and the reading of continuous text material” by taking into account, i.e. “distinguishable shapes of letters, perception of characteristic word forms, and accurate, rapid, easy, and understandable reading of continuous text” (Tinker, 1963, pp.7-8). Optimal legibility of print (Tinker, 1963) is the result of collaboration and coordination of typographical factors such as shapes of letters, type size, line width, and leading. Tinker’s

description has also been adopted by Schriver (1997) as “features of typography that make it easy for people to read text quickly, effortlessly and with understanding” (pp. 251-252). In referring to legibility, Klare (1963, p. 1) used readability to indicate three things: “handwriting or typography, ease of reading, and ease of understanding or comprehension.” Here, Tinker (1963), Schriver (1997), and Klare (1963) employed extended definitions of legibility. A fourth type of legibility description focuses on text (Baudin, 1988; Lohr, 2008) and especially on the ease of reading of a text (Baudin, 1988).

Typographic Characteristics: Definitions and Measurement

As explained previously, the description of legibility inevitably leads to the involvement of other typographic factors. One description focuses on the clarity of the typefaces using “all parts of a character and all the styles within a font family” (Bosler, 2012, p. 411). Another description focuses on an interest in the “distinctiveness of the characters from one another,” and that “highly modular or geometric typefaces may be less legible than those with more organic and individualized forms.” (Lupton, 2014, p. 20). The details from Bosler (2012) and Lupton (2014) have been examined more thoroughly as “a typeface design ... related to the actual design, including its x-height, character shapes, size of its counters, stroke contrast, serifs or lack thereof, and weight” in Strizver’s glossary (2010). To improve legibility, “typeface design which is an informal measure of how easy it is to distinguish one letter from another in a particular typeface” should be “transparent, of big features, and restrained” (Haley, n.d.). The “transparent” typefaces should bring proper and reasonable “attention to themselves” (Haley, n.d.). The typeface “big features” should bring high recognizability of “large, open counters, ample lowercase x-heights, and character shapes” (Haley, n.d.). The “restrain” of typefaces can

be done by setting their appropriate levels of lightness or boldness in order that they are legible for readers.

Several authors, e.g. White (2005 and 2011), Cullen (2007), and Strizver (2010), have also related their definitions for readability to typographic arrangements by including factors such as spacing and/or alignment. Readability is viewed as “the quality of reading, determined by letter spacing, line spacing, paper-and-ink contrast, among other factors” (White, 2011, p. 562). Readability definition has also focused on “the recognition of how typography is presented as words, lines, and paragraphs and influenced by the typographic arrangement, including such factors as line length, leading, and spacing” (Cullen, 2007, p. 235). Readability is also referred to as ‘the ease with which a type setting can be read related to how the type is arranged, including size, leading, line length, alignment, letter spacing, and word spacing’ (Strizver, 2010).

Regardless of the definitions of legibility and readability used in the books that were reviewed in the integrative review, legibility and readability, as dependent variables, have often been associated with typography-related features functioning as independent variables. Please note that features of printed text are frequently described using a special vocabulary that has evolved along with the evolution of printed type.

Major typographical factors that were described as influencing legibility and readability include typefaces, fonts, sizes and styles and letter, word, and line spacing. A brief discussion of these factors is presented below.

Typefaces and type fonts determine and produce the appearance of text-related characters in visual text. Although a type face or font is often presented as a single word, each type font contains a multitude of design features that determine the appearance of characters, words, and lines of type. An example of some of the features that are incorporated within a type font are shown in the graphic depicting the basic anatomy of printed type in Figure 1. Unique combinations of the features identified in the graphic are automatically activated whenever a specific type font is selected.

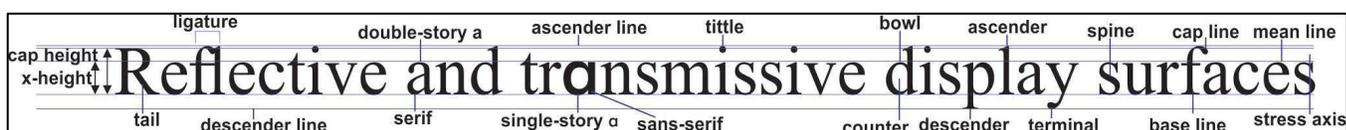


Figure 1. The terminology of types

In addition to these automatically activated features, other decisions must be made when determining the appearance of textual material. The size and style of the type must be specified, either by default or by choice. The size of the type is typically expressed in units of measurement known as points and the style choice include options such as regular, bold, italics, and upper or lower case.

Another factor that influences the appearance of textual material is the alignment and spacing of the letters, words and lines of type.

Spacing. Textual spacing takes three kinds of formats, i.e. letter spacing, word spacing, and line spacing/leading.

Letter spacing. Letters are arranged together to form meanings through words and the spacing of letters within a word affects the legibility and readability of both the characters and the words formed by the characters. Inter-letter spacing decisions “determine proper spatial relationships” within words (between letters), while inter-word spacing decisions determine the

distance between words within a line of text (Carter et al., 2015, p. 53). Inter-letter or inter-word spacing that is too narrow can cause either the letters or the words to be unreadable since “the narrow letter- and word-spacing causes words to merge together visually” (Carter et al., 2015, p. 53). On the other hand the “extremely wide letter spacing” is annoying for the readers (Carter et al., 2015, p. 53). Figure 2 provides examples of three different letter spacing possibilities.

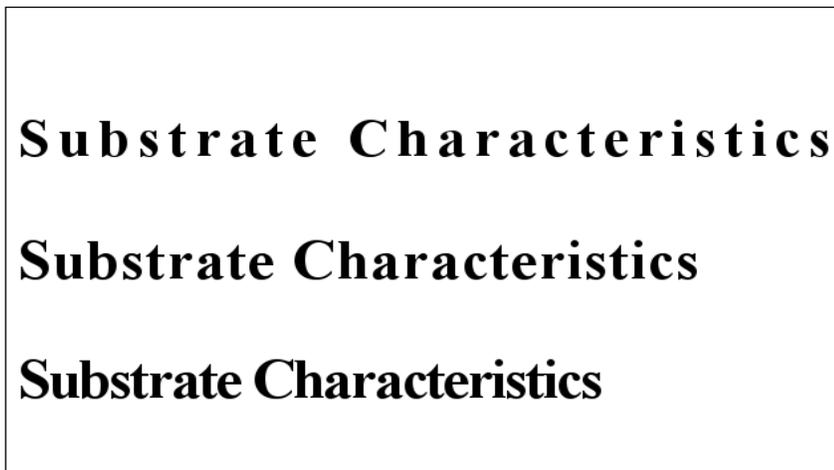


Figure 2. Letter-spacing

In Figure 2, we can see how the inter-letter spacing of S, u, b, s, t, r, a, t, e, C, h, a, r, a, c, t, e, r, i, s, t, i, c, s, is set differently from one another. In the first line, there is a space between letters (sans serifs). In the second line, there is tighter space between letters. In the third line, the result is all the letters touch one another and no space is left. In the first and the second lines, the word “Substrate Characteristics” is still readable. However, in the third line, the letters seem to blend/crash into one another which may make it difficult for readers to read (Harkins, 2010). On the other hand, when the letter spacing is too much between one another, words will not be in good unity (Harkins, 2010) and therefore, may also become unreadable.

Word spacing. While letter spacing or tracking deals with adjusting the average distance between letters in a word or other block of text, word spacing deals with adjusting the average distance between words to improve readability or to fit a block of text into a given amount of space (McCormick, 2013). The amount of letter spacing and word spacing both depend on typeface, typestyle, and type size (Carter et al., 2015). The way they are spaced can produce normal, tight, very tight, or open settings.

Line spacing (leading). Line spacing, which is often referred to as leading, typically depends on three elements: the choice of typeface, the type size, and the line length (Harkins, 2010). In the days of metal type leading, this referred to the insertion of horizontal strips of lead of given point sizes (or depths) between lines of type to adjust a text's vertical spacing. The objective of this adjustment was "to allow for visual evenness of the type composition" (Harkins, 2010, p. 128). In modern typesetting, leading is simply another term that is used to express the amount of vertical space between lines of type, i.e., line spacing. In addition to letter-, word-, and line-spacing, line length and alignment are also other factors which affect readability.

Similarities and Differences in Definitions or Measurement of Typographic Characteristics in Studies of Legibility and Readability

Although the above discussion focuses on legibility of single characters or a small group of characters, numerous researchers have gone beyond the association of legibility with a single character, and have employed an expanded view of legibility that is closely associated with reading. For example, according to Tinker (1963) legibility is concerned with "perceiving letters and words," and with, "the reading of continuous textual material." Thus, "the shapes of letters must be discriminated, the characteristic word forms, and continuous text read accurately,

rapidly, easily, and with understanding” (Tinker, 1963, pp. 7-8). In order to achieve this, typographic factors must be considered to “foster ease and speed of reading” (Tinker, 1963, p. 8). Carter et al. (2015, p. 49) also mention that legibility should have “those qualities and attributes inherent in typography that make type readable and make it possible for a reader to comprehend typographic forms with the least amount of difficulty.”

All the features of single text characters discussed so far are essential to defining legibility of printed type. When considering the legibility of a group or groups of text characters, spatial intervals associated with the text also play a role. Three major intervals are relevant here: inter-letter (letter) spacing, inter-word (word) spacing, and inter-line spacing (leading).

As with legibility, regardless of the definitions of readability used in the books that were reviewed in the integrative literature review, readability, as a dependent variable, is often associated with typography-related features functioning as independent variables. Because legibility and readability are closely related, it is important to bear in mind that “some of the factors that can make typography illegible will also have an effect on how readable it will be” (Harkins, 2010, p. 115). If a legible single letter is placed with other letters to form word(s), sentence(s), paragraph(s), and eventually, text(s) in accordance with the mechanics of typographic conventions, readability can be enhanced. If the conventions are ignored, readability can be diminished.

Substrate Characteristics: Definitions and Measurement

The previous sections of this chapter have dealt with the typographic aspects of letters and words that contribute to their legibility and readability. In order for letters and words to be read by a reader, they must be displayed via some medium. Typically, the medium consists primarily of either a reflective substrate or a transmissive substrate.

Reflection. Reflection is characterized by the illumination of an object to reveal its presence, shape, and color of the object (Bigelow, n.d. ; Flammer et al., 2013). Reflection occurs when light falls on a material and that light is sent back. Reflection can be either specular or diffuse. Specular reflection occurs when the light comes in a straight beam and is reflected back in a straight beam. It normally occurs on a smooth surface (e.g., a glossy paper or mirror). Diffuse reflection occurs when light falls on a non-smooth surface (e.g. textured paper, painted wall, leaf or skin) and is reflected back in many directions. Sometimes some of the light is absorbed.

Transmission. Transmission is characterized with the transfer of wavelengths of light composition through a transparent object that allows the light to pass through (Bigelow, n.d.; Flammer et al., 2013). For a medium to be able to transmit light it has to be transparent (e.g., glass, water, corneas, crystalline lenses, and air). The level of transparency of a transmissive medium determines how much of the light is absorbed (absorptive) by the medium and how much light the medium allow to pass through.

Absorption. Absorption occurs when a material absorbs, or swallows, some or all of the colors of light that falls upon it. Varying amounts of absorption occur with most reflection and transmission processes (Flammer et al., 2013).

When paper is the substrate material, the color and texture of the paper determines what light is absorbed or reflected. Both the color of the substrate and the color of the type (Carter et al., 2015) play very essential roles in determining whether characters shown are clearly legible for readers. When the color of both the type used and the background are of similar hues, the message delivered can be barely legible.

Most reading substrates are not completely reflective or transmissive. Instead they are combination of reflective and absorptive or transmissive and absorptive and the characteristics of the combinations of reflective/absorptive or transmissive/absorptive substrates impact on the legibility and readability of the text. Paper as the type of reflective/absorptive substrate examined in this study submits to factors such as paper “roughness, whiteness, and gloss” which are essential in ensuring high quality print (Ataeefard, 2014, p. 529). These paper substrate characteristics contribute to the complexity of how to best print the printer dpi of the typographical characteristics. Screens or displays as the type of transmissive substrate in the study depend on factors such as screen size and screen resolution to display typographic characteristics.

Similarities and Differences in Definitions or Measurement of Substrate Characteristics in Studies of Legibility or Readability

Although definitions of legibility and readability provide one possible basis for comparisons of legibility and readability studies, they are not the only basis upon which comparisons can be made. Comparisons of the design of studies dealing with legibility and readability rely on the presence of clearly identified and properly measured independent variables that permit replication or comparison from one study to another. Problems in replication of studies and interpretation of study results arise when incomplete information regarding the independent variables involved is provided or when units of measurement employed in the studies cannot be compared from one study to the next.

Typographic and Substrate Characteristics Permitting Comparisons Drawn from Books and Websites on Legibility or Readability

In Table 3, the terminologies encountered in Integrative Research Review 1 from professional books and websites were presented to provide detailed information regarding how the terminologies were used, what substrate category the terminologies were associated with, the definitions required in the study, their sample values, and examples.

Table 3

Terms Encountered in Integrative Research Review #1

Terms encountered in Integrative Research Review #1	How was the term used?	Sample values	Associated with what substrate category	Definition required in study
Dependent Variables				
Legibility	Dependent variable / construct		Reflective and Transmissive	Yes, multiple definitions
Readability	Dependent variable / construct		Reflective and Transmissive	Yes, multiple definitions
Typography	How was the term used?	Sample values	Associated with what substrate category	Definition required in study
Typeface	Independent Variable	Helvetica	Reflective and Transmissive	No, standard meaning
Type Font	Independent Variable	Helvetica 12 point bold	Reflective and Transmissive	No, standard meaning
Type Size	Independent Variable	6, 8, 10 points	Reflective and Transmissive	No, standard meaning
Type Style	Independent Variable	Bold, italics, etc.	Reflective and Transmissive	No, standard meaning
Type Alignment	Independent Variable	Left, right, etc.	Reflective and Transmissive	No, standard meaning

Line Spacing / Leading	Unit of measurement		12 point	Reflective and Transmissive	No, standard meaning
Line Length	Independent Variable		42 picas (7 inches)	Reflective and Transmissive	No, standard meaning
Units of measurement	How was the term used?	Fixed or variable value	Sample values	Associated with what substrate category	Definition required in study
Pica	Describe line length	Fixed	1/6 inch	Reflective and Transmissive	No, standard meaning
Point	Describe type size	Fixed	1/12 pica; 1/72 inch	Reflective and Transmissive	No, standard meaning
Em	Describe point size of type	Variable	1 em in a 10-point typeface is 10 points	Reflective and Transmissive	No, standard meaning
Associated terms	How was the term used?	Associated with	Example	Associated with what substrate category	Definition required in study
Ascender	Design feature	Typeface / type font	Ascender of upper case letter <i>h</i>	Reflective and Transmissive	No, standard meaning
Descender	Design feature	Typeface / type font	Descender of lower case letter <i>g</i>	Reflective and Transmissive	No, standard meaning
Letter space	Design feature	Typeface / type font	Letter space of the word: <i>display</i>	Reflective and Transmissive	No, standard meaning
Substrates	How was the term used?		Sample values	Associated with what substrate category	Definition required in study
Paper Size	Independent Variable	Print display medium	8.5 x 11 inches	Reflective	No, standard meaning
Paper surface - texture	Independent Variable	Print display medium	Smooth, glossy	Reflective	No, standard meaning
Paper surface - White space	Independent Variable	Print display medium	1 inch margin, all sides	Reflective	No, standard meaning
Paper - print resolution	Independent Variable	Print display medium	300 dpi	Reflective	Yes, multiple definitions

Screen dimensions	Independent Variable	Screen display medium	13.3 inch	Transmissive	No, standard meaning
Screen resolution	Independent Variable	Screen display medium	2560 x 1440	Transmissive	Yes, multiple definitions
Screen - white space	Independent Variable	Screen display medium	Normal margin, all sides	Transmissive	No, standard meaning

Summary

This first integrative review showed that both dependent variables, legibility and readability, were defined in multiple ways. The existence of multiple definitions indicates that definitions for, and descriptions of, both of these dependent variables should be provided when conducting studies involving these constructs in order to eliminate an important obstacle to replications of the studies. Also, given the changing nature of instruments or procedures used to measure these variables, complete descriptions of the measurement instruments used should be provided in all new studies if replication is to be promoted.

Multiple descriptions were also found when examining some independent variables. Because the nature of reflective and transmissive substrates has changed in the past, and very likely will continue to change considerably in the future, replication of studies involving these substrates would be difficult without the inclusion of detailed descriptions in the original studies. However, typography-related features, the other category of independent variables examined in this integrative review, had the opposite results. The professional books and the websites presented commonly accepted standard meanings of variables such as type style, type size, type alignment, and type spacing. With respect to these variables, studies should present dimensional

information along with the units of measurement employed but definitions of these terms would not be needed in order for replication to occur.

Definitions also are not needed for the variables of type face and type font. However, because new versions of type faces are possible and new technologies may be incorporated into type fonts, future researchers should provide information concerning the version name, number, date, or other information that would alert future researchers to possible differences between their type faces and type fonts and those used in prior research.

Using authentic dependent and independent variables and information from professional books and websites, this integrative review identified conditions in which replication-related problems are likely to occur. The review reported in this chapter examined literature to determine what conditions could prevent, or present, obstacles to replication of studies. The next chapter provides the results of the second integrative review in which journal articles and dissertations were reviewed to determine if those conditions were absent or present in actual studies.

CHAPTER FOUR

Integrative Research Review 2: Journal Articles and Dissertations

Two integrative research reviews dealing with issues related to replication were conducted in this study. The first integrative review included 44 professional books and two websites and focused on definitions, dimensions, units of measurement, and instruments that could play important roles in replication studies. In broad terms, the purpose of this initial review was to determine if dependent and independent variables, dimensions, units of measurement, and instruments that are likely to be employed in authentic studies in a specific area of study have single, commonly agreed upon meanings and uses or if some of these items have multiple meanings and uses.

The second integrative review included 83 journal articles, one thesis, and three dissertations to determine the extent to which these studies adhered to the findings of the first integrative review. These earlier findings emphasized the importance of including definitions of variables when multiple meanings have been attached to those variables. The findings also demonstrated the importance of providing adequate descriptions of dimensions, units of measurement, and instruments associated with variables even though the variables might have commonly understood meanings.

The purpose of the second integrative research review was operationalized by focusing on journal articles and dissertations that dealt with issues related to the legibility and readability of textual messages. The principal topics examined included the presence or absence, within each study, of the following items: definitions of the dependent variables of legibility and readability, identification of the instruments used to measure values associated with legibility and readability, the completeness of descriptions of independent variables regarding typography,

and the completeness of descriptions of independent variables associated with substrates. Indicators of the completeness of the descriptions of the independent variables included dimensions, units of measurement, and, where relevant, instruments associated with those variables.

The first part of this chapter focuses on the constructs of legibility and readability, including their definitions and their measurements, across the 87 journal articles and dissertations. The second part of the chapter focuses on typographic elements and substrate characteristics, including their definitions and units of measurement across the two types of sources. In this chapter, the two types of sources were abbreviated as follows: JAs for the journal articles and DSs for the dissertations.

Findings on Legibility: Definitions and Measurement

The findings regarding legibility across the sources examined are presented in Table 4. The legibility term was identified, but not defined or described, in 51 of 83 sources, all of which were in the journal articles. Definitions of legibility were found in 13 journal articles and 4 dissertations, and descriptions of the legibility were observed in 5 journal articles. The measurement of legibility (using a variety of instruments or measures for reading elements) was covered in 24 of 87 sources, 20 of which were found in the journal articles. The remaining 14 sources did not identify, define, or describe legibility.

Table 4

Legibility in Sources

Type of sources	Legibility (identified)	Legibility (defined)	Legibility (described)	Measurement
83 journal articles	51	13	5	20
4 theses/ dissertations	0	4	0	4
Total sources examined: 87	51	17	5	24

There were 17 definitions of legibility found in 13 journal articles and 4 dissertations.

These definitions are listed in Table 5.

Table 5

Details of Definitions of Legibility

Author	Definition
Chaparro, Shaikh, Chaparro, & Merkle (2010, p. 39)	“How well a character can be identified typically measured at the individual character or word level.”
Stone, Fisher, & Eliot (1999, p. 25)	“The ease, accuracy and efficiency of perceiving printed symbols while reading (of continuous text material) with understanding” - from Tinker, 1963, p. 7.
Lee, Shieh, Jeng, & Shen (2008, p. 11)	“The attribute of alphanumeric characters that makes it possible for each to be identifiable from others. It is defined as the visual properties of a character or symbol that determine the ease with which it can be recognized in ISO 9241-3 [11]. Legibility depends on such features as stroke width, form of characters and font size.”
Erdmann & Neal (1968, p. 403).	“The average percentage of correctly identified letters or words; it is recognized as depending on variables in both the stimulus and the observer; typically, stimulus material may vary in respect to

- character size, type style, height-width ratio of characters, stroke width, color, paper surface, and contrast; Variables which include the user are, for example, viewing angle and distance, visual exposure duration, illumination, and visual acuity.”
- Hodges
(2011, pp. 56, 59)
“1). Features of the characters in a text that make physically seeing and distinguishing letters and words possible; 2). Ease or difficulty of physically seeing, interpreting, and understanding a text.”
- Loomis
(1990, p. 106)
“Overall recognition performance (measured in percentage correct) of a given character set under some set of conditions; recognition refers to the process by which a given character within a set is selected in response to presentation of a stimulus from the set.”
- Humar, Gradišar, & Turk (2008, p. 886).
“A group of visual properties of a character or symbol that determine the ease with which it can be recognized, with respect to ANSI/ HFS 100-1988 standard. In principle, legibility is affected only by observer’s spatial vision abilities. Up to some asymptotic level, legibility is enhanced by high luminance and color contrast, larger targets, and increased inter- and intra-target spacing” from Sanders and McCormick (1993).
- Woods, Davis, & Scharff
(2005, p. 87).
Distinguishability of letters.
“The ability of an individual to distinguish characters.”
- Coleman (1968)
Van Nes
(1986, p. 100)
“The legibility of text is defined here, following for instance Tinker (1964) and Klare (1969), as the effect of all relevant text properties, such as type face and colour, on the visual processes involved in reading.”
- Buckley & Shepherd
(1993, p. 18)
Droulers & Amar
(2015, p. 1060)
“The ease with which characters and symbols can be detected and discriminated from one another.”
“Legibility is the ability to clearly define letter or overall word form in order to read quickly and precisely the characters of continuous text.”
- Roethlein (1912, p. 38)
“The product of six factors: 1. The form of the letter; 2. The size of the letter; 3. the heaviness of the face of the letter (the thickness of the lines which constitute the letter); 4. The width of the white margin which surrounds the letter; 5. the position of the letter in the letter-group; 6. The shape and size of the adjacent letters.”

Chandler (2001, p. 17)	“The relative ease with which individual letterforms, words and paragraphs may be read. Speed of reading has historically been used as one method to ascertain the legibility of different size and styles of type.”
Baker (2010, p. 7)	“Whether you can identify individual letters or characters.”
Yeaman (1984, p. 13)	“Degree of ease and efficiency with which a text may be read; can be operationalized as speed of reading and comprehension; may be prescribed for in print by a safety zone formulation.”
Zhang (2006, p. 7)	“The ease with which we can recognize a character or distinguish it from another similar character.”

In Table 6, it is shown that the measurements of legibility were performed using instruments and measures, where only four sources used the instrument from Chapman Cook Speed of Reading Test, and seven sources used reading speed as measures.

Table 6

Details of Legibility Measurement (Instruments or Measures)

Author	Measurement
Lee, Shieh, Jeng, & Shen (2008, p. 13)	“The subject’s total search time and accuracy, where accuracy was defined as the number of searched targets divided by the number of total targets.”
Erdmann & Neal (1968, p. 403)	“The average percentage of correctly identified letters or words.”
Chaparro, Merkle, Fox, & Chaparro (2011)	Visual acuity
Soar (1951)	Reading speed
Loomis (1990, p. 106)	“Overall recognition performance (measured in percentage correct) of a given character set under some set of conditions.”
Dyson & Haselgrove (2001)	Reading rate
Humar, Gradišar, & Turk (2008)	Visual performance task
Woods, Davis, & Scharff (2005, p. 91)	“Discrimination task and pair-letter identification”

Kak (1981, p. 137)	“Scanning for target letters in a random-letter noise field”
Ali, Wahid, Samsudin, & Idris, (2013)	Reading speed
Salcedo, Read, Evans, & Kong, (1972)	Reading speed
Paterson & Tinker (1931)	Chapman-Cook Speed of Reading Tests
Tinker (1936)	Eye movement
Webster & Tinker (1935)	Chapman-Cook Speed of Reading Test
Tinker & Paterson (1932)	Chapman Cook Speed of Reading Tests
Paterson & Tinker (1932)	Rearranged Chapman Cook Test
Droulers & Amar (2015, p. 1060)	“1). Distance method which is based on assessing the distance from which the subject accurately perceives the text; 2). The rate of involuntary blinking, which is assumed to be inversely proportional to legibility; 3). The rate of work, which is based on the amount of work accomplished in a given time, e.g. the number of words read, 4). Reading speed, which measures the time taken to read a text, 5). Reading accuracy, which measures the amount of read data correctly” –from Tinker (1966).
Siegenthaler, Wurtz, Bergamin, & Groner (2011)	Eye tracking
Boyarski, Neuwirth, Forlizzi, & Regli (1998)	The Tinker’s Speed of Reading Test
Bix, Lockhart, Selke, Cardoso, & Olejnik (2003)	Lockhart Legibility Instrument
Chandler (2001)	Reading speed
Baker (2010)	Identification of individual letters or characters
Yeaman (1984)	Reading speed
Zhang (2006, p. 18)	“String matching algorithm – the Levenshtein distance algorithm.”

Findings on Readability: Definitions and Measurement

The next section covered the findings of readability across the sources examined (Table 7). Of the 87 sources, readability was identified in 28 sources; defined in 13 sources; and described in 6 sources. The measurement of readability was found in 15 sources, 13 of which were observed in the journal articles.

Table 7
Readability in the Sources

Type of sources	Readability (identified)	Readability (defined)	Readability (described)	Measurement
83 journal articles	28	9	6	13
4 theses/ dissertations	0	4	0	2
Total sources examined: 87	28	13	6	15

Readability was defined in only 13 of the 87 journal articles and theses/dissertations as detailed in the following Table 8.

Table 8
Details of Definitions of Readability

Author	Definition
Friedman (2006, p. 353)	“The sum total (including the interactions) of all those elements within a given piece of printed material that affects the success a group of readers have with it; it is measured with the readability formulas” – from Dale & Chall (1949, p. 23).
Kuzu & Ceylan (2010, p. 882)	“A factor that is impressed by the font size, the color, and all other criteria mentioned above. It is also impressed by where the text is published.”
Hodges (2011, pp. 56)	“The logicity of a text that makes complete words, sentences, and paragraphs comprehensible.”

- Shieh & Hosei
(2008, p. 75) “The degree of understandability of written text; in other words, it is an indication of reading ease and it can be assessed with more than 40 different formulas.”
- Humar, Gradišar, & Turk
(2008, p. 886) “Readability is the ability to recognize the form of a word or a group of words for contextual purposes (ANSI/HFS 100-1988). It is the property that permits an individual to read sentences from the stimulus material easily irrespective of their meanings (Fukuzumi et al., 1998). Normally it is concerned with continuous texts. Common measures of readability include reading rate, identification of misspelled words, searching for pre-specified letters/words within word lists or passages, etc. However, as readability is considered to be a psychological response, there are several factors influencing its performance. It is difficult to isolate these factors when measuring readability performance (Gradišar et al., 2005). One of principal requirements for efficient readability is the legibility of presented information (Legge et al., 1987; Sanders and McCormick, 1993).”
- Woods, Davis, & Scharff
(2005, p. 87) “The ease (speed and comfort) with which an individual reads and comprehends text and encompasses other factors such as leading and page layout.”
- Ali, Wahid, Samsudin, & Idris
(2013, pp. 27-28) “Generally, readability refers to the speed and comfort of reading and the understanding of its meaning (Woods, Davis & Scharff, 2005; Mills & Weldon, 1987). In particular, the legibility of words, sentences, and paragraphs defines the level of readability (Mills & Weldon, 1987; White, 2005). According to Brinck, Gergle, and Wood (2002), readability refers to how many words and sentences can be detected by the reader and the clarity of vocabulary and grammar in words and verses. In addition, readability is also related to features and layout of a text which influence the understanding of the meaning that the writer intended to convey” – Ambrose & Harris, 2006; Barth, 2008; Rabinowitz, 2006.
- Van Nes
(1986, p. 100) “The effect of the style of writing, such as terseness and vocabulary used, on the cognitive processes involved in understanding the text (Klare 1969).”
- Clark & Kaminski (1986, p. 184) “The ease of understanding or comprehension due to the style of writing ” –from Klare (1963, p.1).

Chandler (2001, p. 17)	“The complexity of the words that make up the message being read; used interchangeably with legibility but now has taken on a different and broader meaning.”
Baker (2010, p. 7)	“How easy it is to understand something you are reading and includes the measure of reading comprehension.”
Yeaman (1984, p. 14)	“The difficulty level or comprehensibility of text content; a text may be rated readable at a certain age or grade level based on the number of syllables per word and words per sentence; measured through reading score, reading time, comprehension rate.”
Zhang (2006, p. 7)	“The quality that makes the page easy to read, inviting, and pleasurable to the eye.”

Reading-related measurement approaches or tools were described in 15 of the 87 journal articles and dissertations (Table 9).

Table 9

Details of Readability Measurement (Instruments or Measures)

Author	Measurement
Rello & Baeza-Yates (2016, p. 6)	“Reading time, fixation duration, number of fixations, and preference rating.”
Friedman & Hoffman-Goetz (2006)	Readability formulas
Yazar, Seimyr, Novak, White, & Lidén (2014, p. 235)	“Completion time, recognition rate, eye movements, task load, subjective preference
Shieh & Hosei (2008)	Readability formulas
Soar (1951, p. 64)	“Speed of reading, reader preferences, and economy of presentation”
Brumberger (2003)	Flesch-Kincaid Grade Level, Nelson-Denny Reading Test
Bernard, Chaparro, Mills, & Halcomb (2003)	Reading time, text accuracy, adjusted accuracy measure
Humar, Gradišar, & Turk (2008, p. 886)	“Reading rate, identification of misspelled words, searching for pre-specified letters/words within word lists or passages, etc.”

Kak (1981, p. 137)	“Standardized reading test (Nelson-Denny Reading Test) presented on a CRT and answering comprehension-testing questions with paper and pencil, traditional paper-format version of the Nelson-Denny test.”
Burt (1949, pp. 212-214)	“Photographs of eye movements, speed of reading, short exposure, maximum distance, focal variator, blinking rate, significance of differences in scientific experiments.”
Ali, Wahid, Samsudin, & Idris (2013)	Reading speed and reading accuracy
Salcedo, Read, Evans, & Kong (2012)	Comprehension
Clark & Kaminski (1986) Baker (2010, p. 21)	Readability formula “Paper-based reading comprehension test taken from McCall-Crabbs Standard Test Lessons in Reading, Book F.”
Yeaman (1984)	Measured through reading score, reading time, comprehension rate

The following section contained the findings on typographic and substrate characteristics in relation to legibility and readability. 41 articles related to the paper substrate, 29 to screen/display substrate, and 13 to both paper and screen/display substrates. In addition, one thesis and three dissertations were also on the list, 3 of which focused on screen/display substrate and 1 of which focused on both paper and screen/display substrates.

Findings on Typographic Characteristics: Definitions and Measurement

Because these typographic terms possess commonly assigned meanings or definitions, it was expected that the terms would not be defined in the journal articles. However, it was expected that the terms would be identified or described in the journal articles. As seen in Table 10, only 1 definition of type face was given in a dissertation and 1 definition of type font in a journal article, but 63 sources identified or described type size, 56 sources identified or described

type font, 55 sources identified or described typeface, and 28 sources identified or described type style.

Table 10

Findings on Typeface, Type Font, Type Style, and Type Size

Typographic Characteristics	Identified	Defined	Described	Remaining (not identified, not defined, or not described)
Typeface	5	1	50	31 (36%)
Type font	7	1	49	30 (35%)
Type style	2	0	26	59 (68%)
Type size	7	0	56	28 (32%)

Table 11 lists the findings for typographic units of measurement used in the 87 sources. The units of measurement do not need to be defined since the definitions refer to standard meaning. However, the units of measurement need to be described or explained.

Table 11

Findings on Typographic Measurement

Typographic Measurement	Identified	Defined	Described	Remaining (not identified, not defined, or not described)
Em	0	0	1	86 (99%)
Point (pt)	0	0	52	35 (40%)
Millimeter (mm)	0	0	3	84 (97%)
Pixel	0	0	1	86 (99%)
Degree	0	0	1	86 (99%)
Arcmin	0	0	1	86 (99%)
Inch	0	0	1	86 (99%)

In Table 11, point was the most frequently used units of measurement in typographic measurement occurring in 52 sources. As expected, none of the sources defined the units of measurement. Although no definitions accompanied the units of measurement given in the 87 sources, these units of measurement were defined in the Integrative Research Review I.

Table 12

Findings on Type Anatomy

Typographic Characteristics	Identified	Defined	Described	Remaining (not identified, not defined, or not described)
Lower case	22	0	0	65 (74%)
Upper case	23	0	0	64 (74 %)
Serif	20	2	3	62 (71 %)
Sans serif	22	1	3	61 (70 %)

The most discussed type anatomy factors in Table 12 were Sans Serif (26 sources) and Serif (25 sources). Upper Case and Lower Case were found in 23 and 22 sources respectively.

Multiple studies, as indicated in Table 13, mentioned line length and line spacing, which were found in the highest number of sources (respectively 30 and 27 sources in total). Letter spacing and alignment were in the third place with 14 and in the fourth place 10 sources in total respectively.

Table 13

Findings on Alignment and Spacing

	Identified	Defined	Described	Remaining (not identified, not defined, or not described)
Alignment	0	0	10	77 (88%)
Letter spacing	6	1	7	73 (84%)
Word spacing	5	1	3	78 (90%)
Line spacing/ leading	11	2	14	60 (69%)
Line length/ line width	9	0	21	57 (66%)

Findings on Substrates' Characteristics: Definitions and Measurement

As discussed in Chapter 3 in the first Integrative Research Review, there were two types of substrates used in the study: reflective and transmissive. The reflective substrate drawn from the literature was paper, and the transmissive substrates were computers, laptops, tablets, cellular phones, and other mobile devices. Paper and screen were the two most common substrates and are the foci of the discussion in this review. 41 journal articles focused on paper substrate, 29 on screen substrate, and 13 on paper and screen substrates.

Findings on reflective (paper) substrate: definitions and measurement. Table 14 demonstrates that paper size/dimension, paper material format, and reference to paper are the most dominant characteristics in paper display surface. No definitions were provided from the 41 paper-substrate and 29 paper-and-screen-substrate journal articles.

Table 14

Findings of Paper Substrate Characteristics in the Sources

Paper substrate characteristics	Identified	Described	Remaining (not identified, not defined, or not described)
Paper weight	0	1	86 (99%)
Paper size/ dimension	0	11	76 (87%)
Paper stock/ type	0	9	78 (90%)
Paper texture	1	3	83 (96%)
Paper brand	0	2	85 (98%)
Paper color	0	11	76 (87%)
Paper finish	0	4	83 (95%)
Paper material format (booklets, books, etc.)	0	14	73 (84%)
Reference to paper	0	15	72 (83%)

Findings on transmissive (screen) substrate: definitions and measurement.

Transmissive substrates, based on the literature, can be grouped into (desktop) computers, laptops, tablets, cellular phones, and other mobile devices. The characteristics of the transmissive substrates were classified into screen size/ dimension, screen resolution, computer operating system, and their units of measurement.

Table 15 presents the results of the substrate characteristics used in the transmissive substrates.

Table 15

Findings on Screen Size, Screen Resolution, Screen Type and Computer Operating System

Screen substrate characteristics	Identified	Described	Remaining (not identified, not defined, or not described)
Screen size/ dimension	3	11	73 (84%)
Screen resolution	0	18	69 (79%)
CRT	0	12	75 (86%)
TFT/TFT-	0	6	81 (93%)
Screen type*			
LCD/LCD			
RGB	0	1	86 (99%)
Computer operating system	0	11	76 (87%)

* CRT: Cathode Ray Tube; TFT: Thin-Film Transistor; RGB: Red, Green, Blue; TFT-LCD: Thin-Film-Transistor Liquid-Crystal Display; LCD: Liquid Crystal Display

Screen resolution and screen type were emphasized over all other categories in Table 15. The third place was taken by screen size/dimension. Similarly to typographic units of measurement, the units of measurement in screen substrate do not need to be defined because the definitions of the measurement refers to standard meaning.

In Table 16, pixels were the mostly reported units of measurement for screen resolution. For screen size/dimension, inch was more frequently reported than metric system in the sources.

Table 16

Findings in Units of Measurement of Transmissive Substrates in Sources

Screen substrate measurement		Described	Remaining (not identified, not defined, or not described)
Screen dimension/ size	Inch	12	75 (86%)
	Cm	2	85 (98%)
	Mm	1	86 (99%)
Screen resolution	DPI	5	82 (94%)
	PPI	1	86 (99%)
	Pixels	10	77 (89%)

CHAPTER FIVE

Discussion

Chapter 5 focuses on summary of the study, practical implications, and contribution of the study to the field of Instructional Design and Technology (IDT).

Summary of the Study

Legibility and readability: definitions and measurement. Information regarding the definitions of legibility and readability was obtained primarily from professional books. Of the 42 distinct definitions of legibility, 25 were obtained from books while only 17 came from journal articles (13 instances) or theses/dissertations (4 instances). Of the 33 distinct definitions of readability, 19 were obtained from books and one from a web-based article while 13 of them came from journal articles (9 instances) or dissertations (4 instances).

Although many of these definitions were associated with the common theme of character, the manner in which the definitions approached character varied considerably. Approaches ranged from treating character as a single letter to clusters of letters, and from only letters to combinations of letters, numbers, symbols, punctuation marks and various other elements. The lack of agreement on a single definition for legibility in the professional books indicates the need for authors to clearly define the term in research articles in order for replication or comparison to occur. The review of journal articles and dissertations demonstrated that this need for authors to clearly define legibility as a term was frequently overlooked. In fact, only 13 of the total 83 journal articles defined the term (Table 4).

Authors of professional books also failed to agree on a single definition of readability; 19 different definitions were obtained from such books. As with legibility, the review of journal articles and dissertations demonstrated that this need for authors to clearly define readability as a

term was frequently overlooked. Only 9 of the total 83 journal articles and all 4 theses/dissertations defined the term (Table 7).

Although legibility was frequently defined in professional books at the character level, the nature of those definitions varied over time as authors focused on specific features of the characters, what constituted a character, or the role of clusters of characters as they related to legibility. Their definitions also extended to wider features including words and eventually texts. Similar situations occurred in examining readability. The definitions do not always agree with one another since their foci shift from letters to words, sentences, paragraphs, and eventually, to texts.

Just as the definitions of legibility and readability are needed for replications to occur, information concerning measurement of these dependent variables is also necessary. The two integrated reviews found more information regarding measurement in the journal articles and dissertations than they did in professional books. 20 journal articles and four theses/dissertations contained information regarding the measurement of legibility, while 13 journal articles and two dissertations included information regarding the measurement of readability. Legibility was measured in 5 professional books, and all utilized different measures. It is essential to remember that, in order to establish comparability, how the two terms are measured is just as important as having comparable definitions.

Typographic characteristics: definitions and measurement. Definitions of typographic characteristics and their units of measurement were found exclusively in professional books. Substantial differences in definitions for typographic characteristics and their units of measurement were not expected, and were hardly evident, in any of the 87 journal articles and dissertations. On occasion, some sources focused on a strict interpretation of

historical uses of the typographic terms while in other cases, the merging of terms such as type face and type font were evident. Depending on the contexts within which the terms were used and how the terms were used, it was possible to identify and relate comparable terms from one study to another.

The fact that definitions were hardly found in journal articles for typeface, type font, type style, and type size was not a concern because the treatment of these terms in the professional books clearly demonstrated that standard meanings were associated with each of these terms. However, although definitions are hardly provided, the units of measurement need to be provided in order that comparison can be conducted. Other settings for which information should be provided include the case (upper or lower) and the alignment (e.g., left, center, right) of the type. Line spacing, type size (typically expressed in points), type style (e.g., regular, bold, italics), and line length (typically expressed in picas or inches) are other units of measurement that should be provided.

Paper (reflective) substrate characteristics: definitions and measurement. Paper substrate, despite its long history as an educational medium, does not receive adequate attention in the literature in terms of its characteristics. To be able to replicate comparably, paper substrate characteristics such as paper size, paper print resolution, and paper surface, type, color, and brightness are essential information to include. Paper color, for instance, could have an effect on absorption of light. Paper texture could impact the sharpness of the printed text. Dot per inch (dpi) on paper impacts on the crispness of a text since dpi is responsible for “the number of individual dots represented in a line within the span of 1 in or 2.54 cm” (Sikos, 2014, pp. 347) to deliver legible and readable texts to learners.

Screen (transmissive) substrate: definitions and measurement. To conduct a comparable replication, essential information of screen substrate, such as transmissive screen dimension and vertical-horizontal-diagonal transmissive screen resolution (pixels per inch) should be included. Knowing the resolution (vertically, horizontally, and diagonally) and the screen dimension (the diagonal size in inches) provides us with the information of pixel per inch (ppi) of a screen substrate. With this information, we also know how legible and readable the display of the text is.

Dots per inch (dpi) and pixels per inch (ppi) were frequently confused for one another (Sikos, 2014) in the journal articles and professional books. Dpi (dots density) refers to print application, and ppi (pixel density) refers to screen application (Sikos, 2014), whereas pixels or picture elements are defined as “very basic switchable unit of a visual display” with “the electro-optical function to control the light output for emissive and transmissive” substrates (Blankenbach, 2016, p. 10). Theoretically, a 72 ppi screen image has the same physical dimensions as a 72 dpi printed image. However, this theory “is not accurate and has lost its significance” (Sikos, 2014, p. 347).

Practical Implications

The focus of the conclusions chapter is on the need for typographic and substrate information to promote the replicability or comparability of legibility and readability research. Specific types of information are needed in order to replicate prior research. This information includes the identifications of and definitions for dependent and independent variables as well as adequate descriptions for treatments performed in prior studies. An integrative research review of professional books dealing with legibility and readability identified several types of information needed for comparison or replication of prior studies. This initial integrative

research review examined multiple definitions of legibility and readability offered by various authors, and also identified essential typographic and substrate factors associated with legibility and readability. A second integrative research review examined historical research reports to determine whether they presented sufficient information to permit replication or comparison.

Based on the study results, it is recommended that both legibility and readability should be defined so future researchers will have a basis for comparison. If an instrument or a measure is used, details of publication should be included. Typographic and substrate-related terminologies need to have a standard meaning. While the meaning does not always need to be defined, the measurement methods should be provided.

In order to allow for replication of comparable characteristics, a study should, at the very least, include adequate information on typographic elements and substrate characteristics in relation to legibility and readability. The required information associated with typographic and substrate characteristics needed to permit comparisons among studies dealing with the effects of typographic and substrate characteristics on legibility or readability is explained in Table 17.

Table 17

Essential and Supplementary Information in Typographic and Substrate Characteristics

Typographic or Substrate Characteristics	Essential information	Supplementary information
Typographic features and units of measurement (comparable when defined similarly)	Typeface or Type Font Type style (bold, italics, etc.) Type size (expressed in points) Alignment (left, center, right, justified) Line spacing / leading (vertical distance between baselines expressed in points, inches, or equivalent linear units) Line length (picas, inches, or equivalent linear units)	Letter spacing, word spacing, line spacing, line length (information is provided only when one, some or all of these elements is/are manually set) Means of production (lead type, phototypesetting, digital typesetting)
Paper surface and units of measurement (comparable when defined similarly)	Paper size (inch, cm, mm) Paper print resolution (dpi) Paper surface /type/ opacity/color/brightness White space	—
Transmissive screen display and units of measurement (comparable when defined similarly)	Transmissive screen dimension (inch, mm, cm) Vertical, horizontal, and diagonal transmissive screen resolution (ppi) White space	—

Contribution of the Study to the Field of Instructional Design and Technology (IDT)

In the field of Instructional Design, the domains and elements of typographic and substrate characteristics are related to Communications Theory (Richey, Klein, & Tracey, 2011, pp. 428). Typographic characteristics are included in the domain of, “designers and design processes” where text design covers for instance, “page and type size, typeface, spacing, and capitalization” (Richey, Klein, & Tracey, 2011, p. 428). Substrate characteristics are included in

the domain of “media and delivery systems” where the elements focus on “auditory and visual delivery channels, and new technologies and message transmission” (Richey, Klein, & Tracey, 2011, p. 428). Instructional text, as a source in the learning process, is delivered through a channel which can manifest in audio, visual, or audiovisual formats. In delivering this message, noise, such as the wrong choice of typographic-related design, may obstruct the successful delivery of the instruction (Richey, Klein, & Tracey, 2011, pp. 85-87). Thus, careful consideration of typographic and substrate characteristics in replication studies cannot be ignored in order to ensure that replication brings progress to the field of Instructional Design.

Typographic features as part of the text are frequently displayed either in print or on screen (Gagne, 1985). Replicable findings regarding print text are important in the “presentation of textbooks, workbooks, worksheets, and outlines” (Gagne, 1985, p. 12). It is also possible certain types of text display can “aid learning and retention” (Gagne, 1985, p. 12). Replication is not a new discussion in instructional design, and plays a very important role in redefining previous studies, especially when comparison work is involved. In addition, carefully defining and applying the replicable and comparable typographic and substrate characteristics have the potential to provide valuable information that contributes to the progress of instructional design.

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Appendix A: List of References Used in the Integrative Review

No.	83 JOURNAL ARTICLES
1	Comparing the legibility of six ClearType typefaces to Verdana and Times New Roman (Chaparro, Shaikh, Chaparro, & Merkle (2010)
2	The clarity and comfort of printed text (Wilkins, 1987)
3	Chart construction and letter legibility/ readability (McMonnies, 1999)
4	Adults' prior exposure to print as a predictor of the legibility of text on paper and laptop computer (Stone, Fisher, & Eliot, 1999)
5	Effect of character size and lighting on legibility of electronic papers (Lee, Shieh, Jeng, & Shen, 2008)
6	The legibility of type on maps (Phillips & Noyes, 1977)
7	Estimating the legibility of a single letter E viewed at different display angles (Cai, Green, & Kim, 2013)
8	Factors determining the legibility of letters and words derived from elemental printers (Long, Reid, & Queal, 1951)
9	Legibility of letters of the alphabet (No author, 1886)
10	Letter size and legibility (Smith, 1979)
11	Roxane: A study in visual factors affecting legibility (Gluth, 1999)
12	The relative legibility of the small letters (Sanford, 1888)
13	Word legibility as a function of letter legibility, with word size, word familiarity, and resolution as parameters (Erdmann & Neal, 1968)
14	ClearType sub-pixel text rendering: Preference, legibility and reading performance (Sheedy, Tai, Subbaram, Gowrisankaran, & Hayes, 2008)
15	Ergonomic evaluation of electronic paper: Influences of anti-reflection surface treatment, illumination, and curvature on legibility and visual fatigue (Lin, Lin, Hwang, Jeng, & Lin, 2008)
16	Examination of the legibility of isolated characters of onscreen typefaces (Chaparro, Merkle, Fox, & Chaparro, 2011)
17	Studies of display symbol legibility: The effects of brightness, letter spacing, symbol background relation and surround brightness on the legibility of capital letters (Shurtleff, Botha, & Young, 1966)
18	Readability (Betts, 1977)
19	The effect of font type on screen readability by people with dyslexia (Rello & Baeza-Yates, 2016)
20	Typography (Metcalf, 1996)
21	A systematic review of readability and comprehension instruments used for print and web-based cancer information (Friedman & Hoffman-Goetz, 2006)

- 22 Science speaks: Improving readability of texts (Hodges, 2011)
- 23 Readability of product ingredient labels can be improved by simple means: an
experimental study (Yazer, Seimyr, Novak, White, & Liden, 2014)
- 24 Printed health information materials: Evaluation of readability and suitability (Shieh &
Hosei, 2008)
- 25 Readability of typography in psychological journals (Soar, 1951)
- 26 The rhetoric of typography: The persona of typeface and text (Brumberger, 2003)
- 27 Legibility and subjective preference for color: Combinations in text (Pastoor, 1990)
- 28 A new teletext character set with enhanced legibility (Van Nes, 1986)
- 29 A model of character recognition and legibility (Loomis, 1990)
- 30 Letter legibility for signs and other large format applications (Garvey, Zineddin, &
Pietrucha, 2001)
- 31 The effects of text drawing styles, background textures, and natural lighting on text
legibility in outdoor augmented reality (Gabbard, Swan, & Hix, 2006)
- 32 Legibility of words rendered using ClearType (Aten, Gugerty, & Tyrrell, 2002)
- 33 Typography for mobile phone devices: The design of the QUALCOMM Sans Font Family
(Benson, Olewiler, & Broden, 2005)
- 34 CRT versus LCD: A pilot study on visual performance and suitability of two display
technologies for use in office work (Menozzi, Napflin, & Krueger, 1999)
- 35 Comparing reading processes on e-ink displays and print (Siegenthaler, Wurtz, Bergamin,
& Groner, 2011)
- 36 The influence of reading speed and line length on the effectiveness of reading from screen
(Dyson, & Haselgrove, 2001)
- 37 Comparing the effects of text size and format on the readability of computer-displayed
Times New Roman and Arial text (Bernard, Mills, & Halcomb, 2003)
- 38 Reading normal versus rapid, sequential text formats: Effects of text structure and reading
ability (Chen, 1983)
- 39 The impact of color combinations on the legibility of a Web page text presented on CRT
displays (Humar, Gradisar, & Turk, 2008)
- 40 Effects of typeface and font size on legibility for children (Woods, Davis, & Scharff,
2005)
- 41 Relationships between readability of printed and CRT-displayed text (Kak, 1981)
- 42 A study of fonts designed for screen display (Boyarski, Neuwirth, Forlizzi, & Regli,
1998)
- 43 How physical text layout affects reading from screen (Dyson, 2004)
- 44 Print advertising: Type size effects (Pillai, Katsikeas, & Presi, 2012)
- 45 Paper versus CRT - Are reading rate and comprehension affected? (Clausing & Schmitt,
1990)
- 46 A study of print and computer-based reading to measure and compare rates of
comprehension and retention (Young, 2014)

- 47 The impact of mobile phone screen size on user comprehension of health information (Alghamdi, 2013)
- 48 Letter case and text legibility in normal and low vision (Arditi & Cho, 2005)
- 49 Typography and readability (Burtt, 1949)
- 50 Reading electronic text (Alfred Lee, 1996)
- 51 Typographic properties of online learning environments for adults (Kuzu & Ceylan, 2010)
- 52 Reading online or on paper: Which is faster? (Kurniawan & P. Zaphiris, 2001)
- 53 Reading on the computer screen: Does font type have effects on web: Text readability? (Wahid, Samsudin, Idris, & Ali, 2013)
- 54 Optimal line length in reading: A literature review (Bias & Bias, 2005)
- 55 Resolution and legibility: A comparison of TFT-LCDs and CRTs (Wright, Bailey, Tuan, & Wacker, 1999)
- 56 Typography and the screen: A technical chronology of digital typography, 1984-1997 (Loretta Staples, 2000)
- 57 Letter legibility and visual word recognition (Nazir, O'Regan, & Jacobs, 1998)
- 58 Emil Ruder: A future for design principles in screen typography (Kenna, 2011)
- 59 Experimental studies of readability: Part II measures of readability and relevant populations (E. B. Coleman, 1968)
- 60 Experimental studies of readability: Part I stimulus dimensions that affect readability (B. Coleman, 1968)
- 61 Is x-height a better indicator of legibility than type size for drug labels? (Bix, Lockhart, Selke, Cardoso, & Olejnik, 2003)
- 62 Space, colour and typography on visual display terminals (Van Nes, 1986)
- 63 Serif vs. Sans (Haley, 1985)
- 64 Type variation and the problem of cartographic type legibility part one: Cartographic typography as a medium of communication; the cartographic view of legibility (Bartz, 1969)
- 65 Optimal visual characteristics for large screen displays (William Ton, 1969)
- 66 A broader look at legibility (Salcedo, Read, Evans, & Kong, 1972)
- 67 An experimental approach to the improvement of the typographic design of textbooks (Wendt, 1979)
- 68 Studies of typographical factors influencing speed of reading: VI. Black type versus white type (Paterson and Tinker, 1931)
- 69 Ergonomic factors: The clarity of food labels (Buckley & Shepherd, 1993)
- 70 Eye movement, perception, and legibility in reading (Tinker, 1936)
- 71 The influence of typeface in the legibility of print (Webster, & Tinker, 1935)
- 72 Legibility of print for children in the upper grades (Tinker, 1963)
- 73 Readability of marketing principles textbooks: Another look at the data (Clark & Kaminski, 1986)

- 74 Studies of typographical factors influencing speed of reading: IX. Reductions in size of newspaper print (Tinker & Paterson, 1932)
- 75 Studies of typographical factors influencing speed of reading: VIII. Space between lines or leading (Paterson and Tinker, 1932)
- 76 Typographic changes in package leaflets of the European Union based on the example of German versions between 2005 and 2015 (Fuchs, Kraft, Vettermann, & Reiche, 2017)
- 77 Typeface legibility of patient information leaflets intended for community-dwelling seniors (Chubaty, Sadowski, & Carrie, 2009)
- 78 The relative legibility of modern and old style numerals (Tinker, 1930)
- 79 The relative legibility of different faces of printing types (Roethlein, 1912)
- 80 The legibility of food package information in France: An equal challenge for young and elderly consumers? (Droulers & Amar, 2015)
- 81 The effect of variations in color of print and background on legibility (Preston, Schwankl, & Tinker, 1932)
- 82 The legibility of prescription medication labelling in Canada: Moving from pharmacy-centred to patient-centred labels (Leat, Ahrens, Krishnamoorthy, Gold, & Fernandez, 2014)
- 83 A note on the legibility of printed matter: prepared for the information of the committee on typefaces (Legros, 1922)
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FOUR THESES/DISSERTATIONS

- 84 Comparing the readability of text displays on paper, e-book readers, and small screen devices (Chandler, S. B., 2001).
- 85 Electronic books and legibility: A microcomputer simulation (CRT, reading, visual displays) (Yeaman, A. R. J., 1984).
- 86 Comparing the legibility and comprehension of type size, font selection and rendering technology of onscreen type (Baker, R. D., 2010).
- 87 The effect of font design characteristics on font legibility (Zhang, 2006)
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TWO WEB-BASED ARTICLES

- 88 Secret symphony: The ultimate guide to readable web typography (C. Pearson, 2011)
- 89 It's about legibility (Haley, n.d.)
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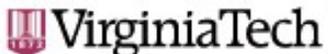
44 PROFESSIONAL BOOKS

- 90 Instructional message design: Principles from the behavioral and cognitive sciences (Editors: Levie & Fleming, 1993):
- Chapter 1 - Motivation principles (Keller & Burkman, 1993)
 - Chapter 2 - Perception principles (Winn, 1993)
- 91 Typography: Getting the hang of web typography (Muller, 2011)
- 8 simple ways to improve typography in your designs (Carusone, 2011)
 - 10 Principles for readable web typography (Cronin, 2011)

- 92 The education of a typographer (Editor: Heller, 2004)
- The list (Fried, 2004)
- What is a letter? (Drucker, 2004)
- 93 Computers and typography 2 (Editors: Lancaster & Warner, 1985)
- Computer screens are not like paper: Typography on the web (Davidow, 1985)
- 94 The Technology of Text Volume 1 (Editor: Jonassen, 1982)
- Displaying text on microcomputers (Merrill, 1982)
- Display problems for teletext (Reynolds, 1982)
- 95 The Technology of Text Volume 2 (Editor: Jonassen, 1985)
- Electronic publication and its impact on the presentation of information (Jonassen, 1985)
- 96 Reading and computers: Issues for theory and practice (Editors: Daniel & Reinking, 1987)
- Chapter 2: The construct of legibility in electronic reading environments (Daniel & Reinking, 1987)
- 97 Design with type (Dair, 1967)
- 98 The measurement of readability (Klare, 1963).
- 99 Letters of credit: A view of type design (Tracy, 2003).
- 100 The Thames and Hudson manual of typography with 188 illustrations (McLean, 1980)
- 101 Creating Graphics for Learning and Performance (Lohr, 2008)
- 102 Dynamics in document design (Schriver, 1997)
- 103 Typographic web design: How to think like a typographer in HTML and CSS (Franz, 2012)
- 104 Designing instructional text (Hartley, 1994)
- 105 On web typography (Maria, 2014)
- 106 Type on screen: A critical guide for designers, writers, developers, & students (Lupton, 2014)
- 107 Type, form, and function: A handbook on the fundamentals of typography (Tselentis, 2011)
- 108 Typography essentials: 100 design principles for working with type (Saltz, 2009)
- 109 Reading letters, designing for legibility (Beier, 2012)
- 110 The practice of typography: A treatise on the processes of type-making: The point system, the names, sizes, styles and prices of plain printing types (De Vinne, 1910)
- 111 Readability (Gilliland, 1976)
- 112 Electronic displays (Sherr, 1993)
- 113 Digital color and type (Carter, 2002)
- Chapter 3: Color and type
- 114 Publication design: A guide to page layout, typography, format and style (Hurlburt, 1976)
- Chapter 3: Typography

- 115 Legibility of print (Tinker, 1963)
- 116 Finer points in the spacing and arrangement of type (Dowding, 1995)
- 117 Type and typefaces: A treasury of typography book (Lieberman, 1978)
- Part 1: Getting to know typefaces, Chapter A: From beginner to designer of type
in one easy step
- 118 Designing with type: The essential guide to typography (Craig, 2006)
- 119 The elements of graphic design: Space, unity, page architecture, and type (White, 2011)
- 120 Mastering type (Bosler, 2012)
- 121 Lettering and type: Creating letters and designing typefaces (Willen & Strals, 2009)
- 122 The fundamentals of typography (Ambrose & Harris, 2011)
- 123 Layout workbook: A real-world guide to building pages in graphic design (Cullen, 2007)
- 124 The complete manual of typography: A guide to setting perfect type (Felici, 2012)
- 125 The fundamentals of graphic design (Ambrose & Harris, 2009)
- 126 Thinking in type: The practical philosophy in typography (White, 2005)
- 127 Typography on the Web (Sinclair, 1999)
- 128 How typography works (and why it is important) (Baudin, 1988)
- 129 Typography, referenced: A comprehensive visual guide to the language, history, and
practice of typography (Tselentis, Haley, Poulin, Seddon, Leonidas, Saltz, Henderson, &
Alterman, 2012)
- 130 How to use type (Marshall & Meachem, 2012)
- 131 Type rules!: The designer's guide to professional typography (Strizver, 2010)
- 132 Playing with type: 50 graphic experiments for exploring typographic
design principles (McCormick, 2013)
- 133 Basics typography 02: Using type (Harkins, 2010)
-

Appendix B: IRB Approval Letter Number 16-931



Office of Research Compliance
 Institutional Review Board
 North End Center, Suite 4120, Virginia Tech
 300 Turner Street NW
 Blacksburg, Virginia 24061
 540/231-4606 Fax 540/231-0959
 email irb@vt.edu
 website <http://www.irb.vt.edu>

MEMORANDUM

DATE: October 24, 2016
TO: Ken Potter, Helen Hendaria Kamandhari
FROM: Virginia Tech Institutional Review Board (FWA00000572, expires January 29, 2021)
PROTOCOL TITLE: Integrative Review of Typography and Display Surface Characteristics on Legibility and Readability
IRB NUMBER: 16-931

Effective October 24, 2016, the Virginia Tech Institution Review Board (IRB) Chair, David M Moore, approved the New Application request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

<http://www.irb.vt.edu/pages/responsibilities.htm>

(Please review responsibilities before the commencement of your research.)

PROTOCOL INFORMATION:

Approved As: **Exempt, under 45 CFR 46.110 category(ies) 4**
 Protocol Approval Date: **October 24, 2016**
 Protocol Expiration Date: **N/A**
 Continuing Review Due Date*: **N/A**

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:

Per federal regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals/work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

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Date*	OSP Number	Sponsor	Grant Comparison Conducted?

* Date this proposal number was compared, assessed as not requiring comparison, or comparison information was revised.

If this IRB protocol is to cover any other grant proposals, please contact the IRB office (irbadmin@vt.edu) immediately.