Health Literacy and Measurement of Text Difficulty

by

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M.S. in Speech-Language Pathology, University of Pittsburgh, 2019

Submitted to the Graduate Faculty of

University of Pittsburgh in partial fulfillment

of the requirements for the degree of

Masters of Science

University of Pittsburgh

2019

UNIVERSITY OF PITTSBURGH

School of Health and Rehab Sciences

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March 1, 2019

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Health literacy is an important determinant of health outcomes. Comprehension of written health materials (i.e. patient information brochures) is one aspect of health literacy. Measures currently being used to assess the difficulty of materials may not include all relevant text variables, leading to patients receiving written materials that are more difficult to understand than their health care providers realize. Cohesion refers to how explicit the text is about relationships between concepts and previous research indicates that cohesion contributes to text difficulty. One study by Liu and colleagues (2009), indicated that text cohesion was related to comprehension of written health information for some but not all older adults. There is no evidence to date about the role cohesion may play in comprehension of written health information in readers of a wider age range. This study examined the relationship between cohesion and comprehension of written health information. A within-subject design was used. Subjects read two health-related texts varying in cohesion (high or low), on different topics counter balanced across participants. Readers answered comprehension questions about the texts, and the data was analyzed with respect to the effect of cohesion on text comprehension. Results indicate that text cohesion and readers' familiarity with the topic interact to affect comprehension of written health information.

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1.0 INTRODUCTION

This paper will review the importance and impact of understanding health related materials for patients. It will also examine the construct of health literacy, current practices in the measurement of text complexity, and the intersection of the two. With this foundational information in mind, the researchers conducted a study to evaluate the impact of cohesion on readers' comprehension of written health information.

With the demands of health literacy skills increasing, there might be greater confusion, thus yielding a more significant impact on health outcomes. Naturally, then, the health literacy of the patient is more important as the language being comprehended becomes more complex. Individuals who are "low literate" have few of the skills required for basic literacy and these patients are at the greatest risk of not understanding health related materials presented to them.

2.0 SIGNIFICANCE

To effectively seek out and receive medical care, the ability to consume health information is paramount. An individual may believe she is suffering from a condition and may begin by launching an online search. She would then try to interpret and understand a slew of articles and webpages about her symptoms. After, she may schedule an appointment with a physician, and will need to understand the diagnoses and instructions provided by her doctor. At the pharmacist, she will need to effectively comprehend further instructions and be able to read any written information on her prescription. Considering the above anecdote, it is not at all surprising that health literacy is strongly related to outcomes across multiple health conditions.

The current literature in the field of health literacy focuses on altering texts to match an optimal 'grade level' (often grade six). However, the metrics used in analyzing written health information do not consider all the variables that affect text complexity. This study will contribute to the literature on health literacy by establishing if text cohesion affects text comprehension of written health materials in adults. If so, then this would suggest that metrics which include cohesion should be considered as best practice.

3.0 HEALTH LITERACY

3.1.1 Conceptual Framework for Health Literacy

According to The National Action Plan to Improve Health Literacy, health literacy can be defined as "the degree to which individuals have the capacity to obtain, process, and understand basic health information and services needed to make appropriate health decisions" (U.S., 2010). Thus health literacy is very broadly defined and includes a wide set of skills necessary to effectively use medical information; individuals must be able to recognize medical vocabulary, read complex medical information, connect concepts to real life situations, and use inferencing skills along with a variety of other literacy skills.

In light of the broad definition of health literacy, a conceptual framework will provide clearer context for the remainder of this paper. As described by Nielsen-Bohlman, Panzer, and Kindig (2004) in *Health Literacy: A Prescription to End Confusion*, health literacy acts as the "mediator between individuals and health contexts" (Nielsen-Bohlman, Panzer, & Kindig, 2004). In this framework an individual's health literacy allows them to engage with health contexts. Figure 1. provides a visual to the conceptual framework.

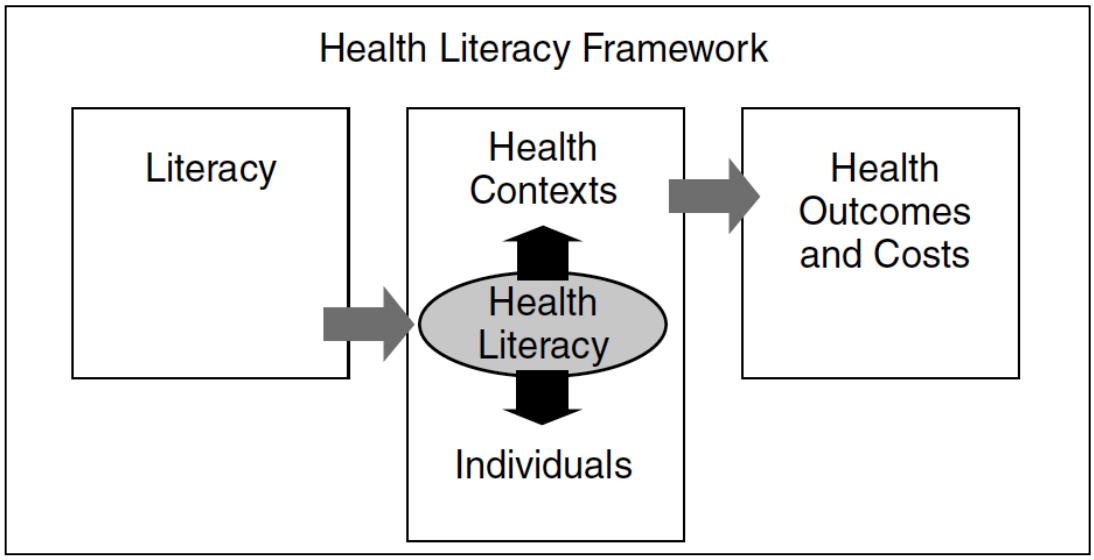

Figure 1: Chart from Nielsen-Bohlman, Panzer, & Kindig, 2004

Nielsen-Bohlman, Panzer, and Kindig, 2004 propose a health literacy framework involving multiple entities with responsibility for health literacy. The entities are as follows: culture and society, the health system, and the educational system. These three entities have a strong influence in the foundation of health literacy skills and thus represent the areas that could be targeted to change the impact of someone's health literacy (Nielsen-Bohlman, Panzer, & Kindig, 2004). In this paper, the focus will be on the impact of the health system entity (e.g. hospitals, physicians, clinicians, insurance companies) in the framework.

Health literacy spans a number of functional areas, including oral, written, and numerical components. According to Nielsen-Bohlman, Panzer, and Kindig, (2004) spoken language production and comprehension compose oral literacy while reading and writing are the primary elements of written literacy. The ability to function in the modern healthcare environment requires competency in all areas of health literacy, including the verbal types (both consuming and producing oral and written language) as well as numerical literacy. For any patient, there may be a need to listen to instructions from a doctor, read a brochure about a new diagnosis or procedure,

speak with their pharmacist, read prescription bottle directions, understand dosage involved in their medications, and a number of other tasks falling within the scope of oral, written, and numerical health literacy. All literacy serves a function and the patient must exhibit different literacy skills based on the task at hand. As the demands of the challenge/function increase, the demands on the literacy skills increase as well (Nielsen-Bohlman, Panzer, & Kindig, 2004). Because patients receive a substantial amount of information regarding their health in the form of written materials, often too complex for the patient's reading level, which encourages the study of written literacy in particular is important. (Liu, Kemper & Bovaird, 2009). This thesis thus focuses primarily on the written aspect of health literacy, but a comprehensive literature review would not be complete without an acknowledgment of the other subtypes of health literacy.

3.1.2 Relationship Between Health Literacy and Health Outcomes

Multiple studies provide evidence of a strong association between health literacy and health outcomes. Patients with low health literacy have been found to be hospitalized more frequently (Baker et. al, 1997), have lower glycemic control and retinopathy (Schillinger et al., 2002), and were less likely to properly follow discharge instructions (Swartz et al., 2018).

Low health literacy can also impact a patient's ability to read and comprehend prescriptions. In a study conducted by Davis and colleagues (2006), those who were categorized as having low health literacy skills were "3.4 times less likely to interpret prescription medication labels correctly" (Davis et al., 2006, p.847) which may have an impact on a person's overall health. More broadly, Berkman and colleagues reviewed the current literature on health literacy and its relation to health outcomes finding that low health knowledge is associated with "increased

incidence of chronic illness, poorer intermediate disease markers, and less than optimal use of preventative health services" (Berkman et al., 2004, p. vi).

While these studies establish the correlation between low health literacy and health outcomes, various other studies go further to identify an independent association between lower health literacy skills and poorer health outcomes. Wolf and colleagues (2005), conducted a large scale study with 2,500 older adults. The researchers in this study controlled for chronic medical conditions, health risks, and sociodemographic characteristics and concluded that "health literacy was independently associated with poorer physical and mental health" (Wolf et al., 2005). Another study obtained health information, health literacy skills, and background information (including level of education) from over 300 patients with diabetes. From this population, Schillinger and colleagues concluded that health literacy mediated the relationship between glycemic control (health) and education (Schillinger et al., 2006). Thus, there is support for the idea that health literacy acts as a causal factor in health outcomes.

Limited health literacy is a widespread problem. The National Assessment of Adult Literacy (NAAL) reported that "only 12 percent [of patients] demonstrated *Proficient* health literacy" (U.S., 2010). Naturally, some groups have even lower proficiency levels: the groups most at risk for low health literacy include adults over 65, non-white ethnic groups, immigrants and recent refugees, lower educated individuals (less than a high school degree/GED), people whose incomes are below poverty level, and non-native English speakers (U.S., 2010). According to the U.S. Department of Health and Human Services, 14% of adults or nearly 30 million Americans are categorized as having "*Below Basic"* health literacy skills, and may have difficulty reading charts and understanding simple instructions (U.S., 2010).

Thus health literacy is a significant issue in this country, with a high prevalence of low health literacy, and a demonstrated effect of low health literacy on health outcomes.

3.1.3 Effective Interventions for Health Literacy

Given that low health literacy is a widespread problem, it is important to consider strategies that could address this concern.

One strategy involves identifying people with low health literacy, and providing them with additional support. Two measures commonly used to assess a patient's health literacy are the Test of Functional Health Literacy in Adults (TOFHLA) and the Rapid Estimate of Adult Literacy in Medicine (REALM) (Dumenci et al. 2013). Both assessments are quick screeners targeting information found in the medical setting such as medical terms, numerical descriptions, etc. (Parker et al., 1995). Although the above tests are widely used, they are not thought to comprehensively measure a patient's abilities but rather skim the surface of a patient's overall capacity (Nutbeam, 2009). While screening is a quick means of roughly assessing a patient's health literacy, there are a number of challenges associated. First it is hard to conduct screenings in an efficient and consistent way (McCormack et al., 2013; Kronzer, 2016), screenings may create a stigma and deter patients from utilizing the health care system (Kronzer, 2016), and they do not necessarily cause health care professionals to interact with their patients in a different manner (Seligram et al., 2005).

Another option is to view universal precautions as a response to poor health literacy. Universal precautions structure healthcare services for all patients to ultimately minimize the risks for everyone involved (DeWalt et al., 2016). Because health literacy may not be widely recognized by health care providers, universal precautions may be a good way to make sure all patients receive

information in a way that is beneficial for them. This was the rationale behind the development of the Health Literacy Universal Precautions (HLUP) toolkit by the Agency for Healthcare Research and Quality (AHRQ) (DeWalt et al., 2016). The HLUP focuses on four different categories important for those with low health literacy: "improving spoken communication, improving written communication, improving self-management and empowerment, and improving supportive systems" (DeWalt et al., 2016). The biggest hurdle when implementing a tool kit such as the HLUP is that high levels of time and commitment from the staff and patients is necessary in order for many of the goals to be effective. However it is feasible to make changes to written documents that affect communication with multiple patients. In contrast changes to oral communication styles (such as reducing linguistic complexity of the input), can be difficult for a health care professional to implement and monitor (Safeer & Keenan, 2005). Similarly, changing the fundamental skills that individual patients have with respect to oral language skills or numeracy may require extensive time and resources.

This paper will focus on written health literacy, specifically comprehension of printed health information. It is evident that appropriately written healthcare literature could have a significant impact on the health of patients. In a study by Jacobson and colleagues (1999), elderly patients who received a handout about a certain immunization that was more appropriately geared toward the medical issue at hand were four times more likely to ask their doctor about the immunization and five times more likely to actually receive it (Jacobson, et al. 1999). With this in mind, it makes sense to turn our attention towards methods by which the informational delivery of written health information can be improved.

3.2 MEASURES OF THE COMPLEXITY OF WRITTEN HEALTH MATERIALS

3.2.1 Variables Affecting Text Complexity

The reader must perform several cognitive processes in order to move from visual input to text comprehension: word identification, lexical access, and word to text integration. Figure 2. provides a visual schematic of the "Reading Systems Framework" outlined by Perfetti and Stafura (2013). Within the reading systems framework in order to comprehend a written document, one must have knowledge of three overarching systems: orthographic, linguistic, and general knowledge, and conduct three inter-related processes, namely word identification, lexical access, and word to text integration (higher level comprehension processes).

One would therefore expect that multiple aspects of the text could affect how complex it may be. For example, the word identification process can be affected by word length, orthographic regularity of the words, and word frequency.

In terms of the lexicon, aspects of the text that could make it more or less complex could include word frequency, semantic complexity of the words, morphological complexity of the words, in the case of verbs, argument structure and thematic roles. The higher level comprehension process will be affected by syntactic complexity, the extent to which background information is explicit therefore how easy inferences can be made, and the amount of structure provided in the text. Cohesion is one aspect of text complexity that can be related to these higher level comprehension processes.

Cohesion can be defined as "the degree to which the concepts, ideas, and relations within a text are explicit" according to Graesser and colleagues (2004).

One would naturally think that increased cohesion would allow a reader to more effectively comprehend written material. However, in previous years, studies have demonstrated somewhat of a "reverse cohesion effect"; individuals lacking the background knowledge benefited from more cohesive texts, but individuals with strong pre-existing knowledge on the topic at hand were found to learn more from texts with *less* cohesion (McNamara et al., 1996). The reverse cohesion effect may be attributed to reader's level of engagement and processing while reading texts. McNamara and colleagues (1996) proposed that less cohesive texts allow readers to have greater active processing skills and more engagement while reading a text (McNamara et al., 1996). This reverse cohesion effect has inspired more investigation into cohesion's impact on comprehension.

O'Reilly and McNamara (2007) dug deeper into this effect, introducing existing comprehension skills into their analysis. Their work showed that low-comprehension high-knowledge readers benefited from low cohesion texts while high-comprehension high-knowledge readers benefited from high cohesion texts. But, interestingly, for low-knowledge readers, increased cohesion only improved performance on inference-based questions (O'Reilly & Mcnamara, 2007). Based on this, cohesion is clearly a more complex and nuanced aspect of written material that can affect different readers in different ways. To truly utilize cohesion modification to improve comprehension, one must not simply increase or decrease cohesion but better understand its impact on the overall text and the targeted audience.

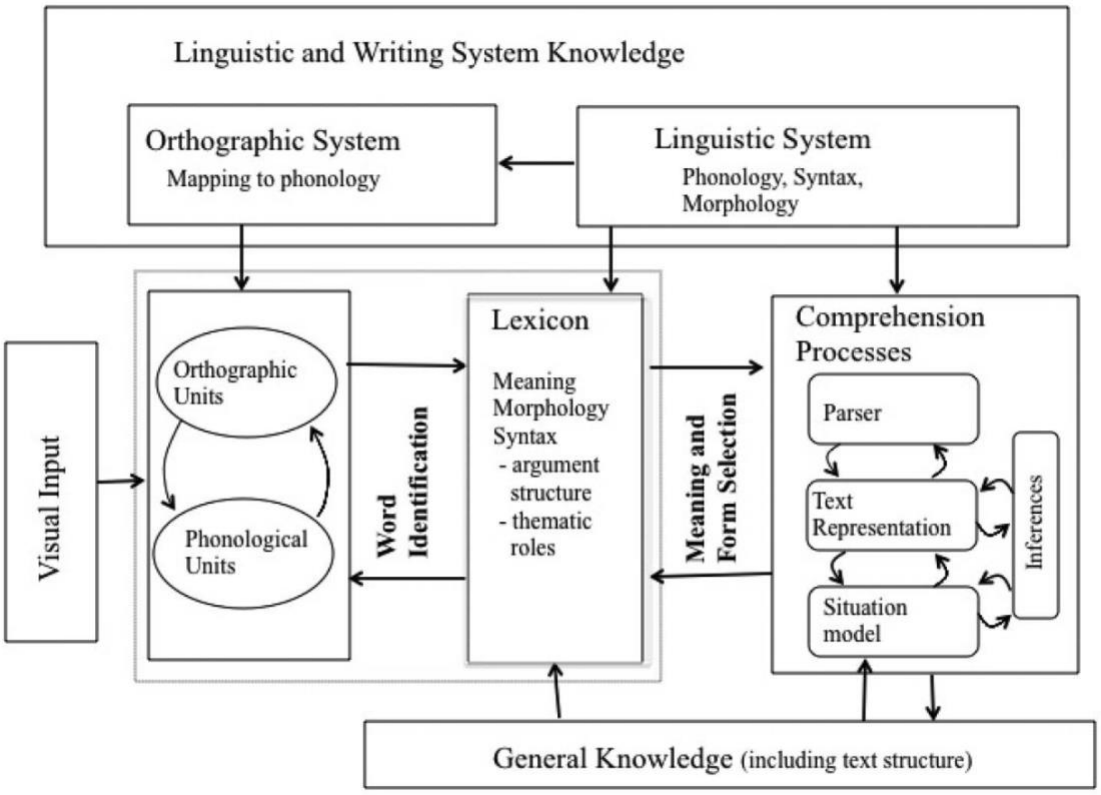

Figure 2. "Reading Systems Framework" (Perfetti & Stafura, 2013).

Many commonly used text analysis systems include variables such as word frequency, sentence length, and word length. (Nelson et al., 2012). Different readability formulas will therefore tap into different aspects of the reading process as described. For example, word length would be related to the word identification process and word length is probably a correlate of word frequency in the lexicon. Sentence length is expected to correlate with syntactic complexity but may not be not equivalent. Notably, most commonly used readability formulas do not consider the text variables related to higher level comprehension processes.

In a landmark study, Nelson and colleagues (2012) investigated the validity and reliability of multiple commonly used text analysis tools relative to expert evaluations of text difficulty in school aged children. Most of the measures that Nelson and colleagues analyzed were found to

successfully predict grade level and students' performance. These measures can be used by publishers and schools in order to meet the curriculum required for each grade. A core question they sought to answer was whether "additional features of text, such as vocabulary and cohesion features, can be measured to yield practical and predictive information about text beyond sentence length and word difficulty" (Nelson et al., 2012). For example, Coh-Metrix provides multiple indices of complexity and includes more sophisticated features than other tools, such as cohesion. The authors found that generally, metrics utilizing a wider set of measures yielded higher correlations with the reference measures, indicating the potential addition of multi-dimensional indices of text complexity.

3.2.2 Measures Currently Used to Assess Written Health Materials

A variety of measures are available to writers of written health information to use to assess text complexity. There are a number of studies that report the readability of written health information about specific health topics e.g. (Cherla et al. 2012; Eberlin et al., 2014; Ibrahim et al., 2016; Misra et al., 2012a; Misra et al., 2012b; Patel et al., 2011; Seth et al., 2016; Storino et al., 2016; Vargas et al., 2014a; Vargas et al., 2014b; and Vargas et al., 2014c). Appendix A provides an overview of which measures were used in this sample of reports from the literature.

In a review of a range of studies of health literacy, it was found that the following measures were most commonly used to measure text complexity: SMOG, FORCAST formula, Flesch-Kincaid Grade Level, Coleman Liau Index, Gunning Fog Index, New Fog Count Formula, Fry Readability Graph, Raygor Readability Estimate Graph, and the New-Dale Chall Readability Formula. (Cherla et al. 2012; Eberlin et al., 2014; Ibrahim et al., 2016; Misra et al., 2012a; Misra

et al., 2012b; Patel et al., 2011; Seth et al., 2016; Storino et al., 2016; Vargas et al., 2014a; Vargas et al., 2014b; and Vargus et al., 2014c).

A few of the studies averaged the measures to gather a mean grade level, but a significant body of literature reports each measure separately. Thus, most frequently, multiple measures are reported, and no authors used any measure in isolation. This suggests that there is no broad alignment within the field on the most useful metric of text complexity. This research investigation is motivated by the need to identify the most helpful metrics of text complexity for written health materials.

3.2.3 Aspects of Text Complexity Considered in Currently Used Measures

It is notable that a majority of the measures reported take into account syllables, word length, number of words per sentence, etc. Table 1. provides an overview.

	Word Length	Sentence Length	Word Complexity	Word Familiarity	Text Variables Considered
Flesch-Kincaide grade level (FKGL)		X	X		Avg. # of words/sentence, avg. # of syllables/word
Coleman-Liau index	X	X			Avg. # of letters/100 words, avg # of sentences/100 words
SMOG grading					# of polysyllables, 30/number of sentences
Gunning-Fog index		X	X		Avg. # of words/sentence, avg. # of 3+ syllable words (excluding proper nouns, hyphenated words-compound words, 2 syllable words with /es/ or /ed/ at the end)
New Fog count formula (NFC)		X	X		# of easy words, 3x# of complex words, # of sentences
Fry readability graph		X	X		Avg # of sentences and syllables / 100 words
Raygor readability estimate graph (RRE)	X	X			Avg # of sentences and long words / 100 words
New Dale-Chall readability formula (NDC)		X		X	Avg # of words, % of unfamiliar words (familiar words are compiled from a list of 3,000 words a 4th grader would likely be familiar with)
FORCAST formula			X		Single syllable words in a 150 word sample
Flesch reading ease score (FRES)		X	X		Avg. # of words/sentence, avg. # of syllables/word
SMOG		X	X		% of words with 3+ syllables (avg polysyllabic words per sentence)

Table 1. Variables Used in Each Measure

From the table it is clear that many formulas use word length and sentence length to approximate text complexity, but they do not account for cohesion. Considering the "Reading Systems Framework" (Perfetti & Stafura, 2013), a number of additional variables may affect text comprehension, one being cohesion. While the measures are composed of a number of statistics about the text, none factor in cohesion, and this current study addresses this need.

3.2.4 Text Cohesion

Given the theoretical perspective (Perfetti & Stafura, 2013) and empirical evidence (Nelson et al., 2012) described earlier, these measures may give incomplete information about text complexity. Current metrics fail to include all possible text features and may therefore provide authors of written health materials with misleading or incomplete information about the complexity of the text.

3.3 TEXT COMPLEXITY AND WRITTEN HEALTH MATERIALS

3.3.1 Cohesion and Health Literacy

Within the research literature on health literacy, there is one study that addresses the effect of text cohesion on comprehension of health texts. Texts were collected that varied in both Flesch Reading Ease (FRE) and text cohesion. Participants read a selection of texts ranging in FRE and cohesion, answered comprehension questions, and took tests to measure working memory and verbal ability, and prior knowledge of the topic (Liu, Kemper, & Bovaird, 2009).

Liu and colleagues (2009) concluded that changing FRE had no significant impact on comprehension for older adults with high working memory, but increased FRE (meaning texts were assumed to be easier) decreased average comprehension for adults with low working memory (Liu, Kemper, & Bovaird, 2009). The authors hypothesized that increasing FRE may strip the text of important connecting words and causal/temporal phrases, thereby taxing the cognitive resources of those with low working memory.

The authors also found that when FRE was high (meaning texts were assumed to be easier), increasing cohesion benefited all adults. However, when FRE was low (meaning texts were assumed more difficult), increased cohesion negatively impacted comprehension (Liu, Kemper, & Bovaird, 2009). The results are difficult to interpret, but it may be that using easier words and shorter sentences can allow older adults to take advantage of more cohesive text, but in more difficult texts, individuals may already struggle with complex words/sentences, and higher cohesion may not support comprehension.

3.4 RESEARCH QUESTION

3.4.1 Aim

This study will determine the impact of text cohesion, an often-overlooked aspect of text complexity, on adults' comprehension of written health texts that are written at target grade levels, using traditional readability formulas. The study will involve adults, but not specifically older

adults. Results from this investigation will inform methods for more appropriate evaluation of written health information from clinicians and medical professionals.

This research study will specifically target one variable, text cohesion, and aim to identify its impact on the comprehension of written health materials, holding other text variables constant. Cohesion refers to how explicit the text is about relationships between the concepts presented. It is expected that results from this study will lead to more specific guidance for clinicians who produce health literacy materials, particularly informing what measures warrant the most attention.

Aim 1: To determine the effect of text cohesion on readers' comprehension of written health materials, holding educational attainment and topic-specific background knowledge constant.

Hypothesis: The hypothesis is that readers will demonstrate better comprehension of texts that have high cohesion (Liu et al., 2009).

Aim 2: To determine if text cohesion interacts with either educational attainment or text familiarity, with respect to readers' comprehension of written health materials.

Hypothesis: The hypothesis is that cohesion and education will interact, such that readers with lower education will experience greater increases in comprehension as a result of high cohesion. Similarly it is hypothesized that text familiarity will interact with cohesion such that readers with high familiarity will not significantly benefit from an increase in cohesion.

4.0 METHODS

A within-subject design was used. Participants read two health-related texts on different topics, with two levels of cohesion. The texts, differed in subject matter (topic), preventing carryover effects (participants were not be able to use information learned from the first text and apply it to the second set of text and comprehension questions). Topics of texts were counter balanced across participants via random assignment of the texts. Table 2. provides an example of how the health-related brochures were randomly assigned to the participants.

Group A	**Group B**
Topic 1: Atherosclerosis	Topic 1: Atherosclerosis
Text cohesion level: Low	Text cohesion level: High
Topic 2: Hernia	Topic 2: Hernia
Text cohesion level: High	Text cohesion level: Low

Table 2: Example Assignment to Participants

4.1 PARTICIPANTS

Participants were recruited from an online crowdsourcing marketplace, Amazon Mechanical Turk (MTurk). All participants were U.S. residents, English speakers, and over eighteen years of age. Information was collected regarding years of education; however, it was not

used as an exclusionary criterion. Responses were collected using a secure Qualtrics survey site, and no identifying information was collected. This protocol was reviewed by The University of Pittsburgh Institutional Review Board and was granted exempt status. Participants received $5 for the completion of the study via MTurk. Pilot study data was collected from ten participants whose data was used to develop the coding criteria. Information about education attainment was not collected for these initial participants. Analysis of pilot data (n=20), indicated a trend towards an effect of cohesion on comprehension scores that was not significant. It was judged that the originally proposed sample size (n = 115) would be adequate in this case, and the full experiment was run. During the main data collection period, 26 participants were excluded because responses appeared to use sources other than the texts provided. This impression was confirmed through an internet search by the researchers, meaning that participants answers matched essentially word for word when the internet search was conducted. After data had been collected from 83 participants, instructions were made more explicit (Figure 4) for the remaining participants to increase the proportion of responses that could be included. After this change, the rate of usable participant data (e.g. not excluded due to use of outside sources) rose from 71% to 91%. The final sample size for analysis was n = 98. Descriptive information about educational attainment for participants whose data was included vs. excluded is shown in Figure 3. Educational attainment was categorized on a zero-five scale; 0 = none of these apply, 1 = middle school, 2 = high school / GED, 3 = greater than high school diploma, 4 = college degree, and 5 = more than one college degree.

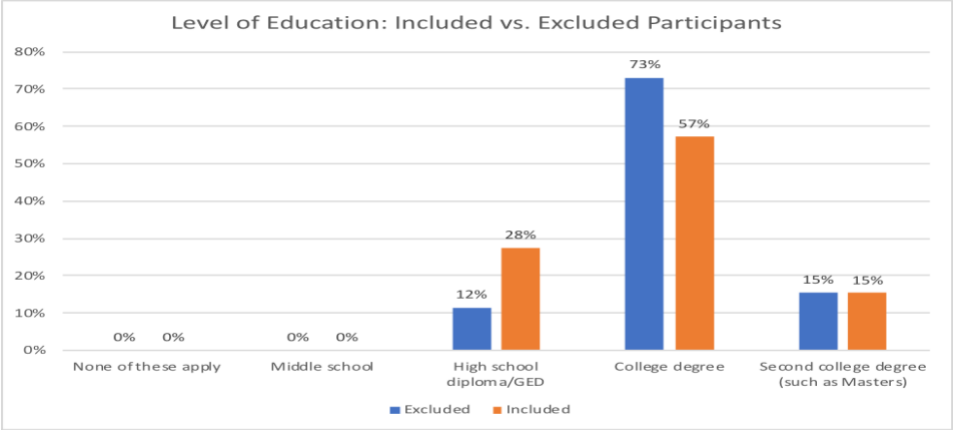

Figure 3. Level of Education: Included vs. Excluded Participants

Thank you for participating in this study. You will have up to one hour to complete this study.

You will be reading two passages and answering some questions. Please read the first passage and answer the questions about it.

Once you are finished with the first passage, please read the second passage and answer the questions about it.

We expect that some questions will be harder than others, and that's fine. It's okay if you're not sure about the answers- you can guess if you need to.

We want to know what people remember from reading these texts. Please don't look on the internet or in books to answer these questions. If your answers come from websites, you will not be paid.

Participants will only be able to complete this survey one time.

Thank you for your time! Upon completion you will be rewarded with $5.

Figure 4. Survey Instructions

4.2 STIMULI

4.2.1 Texts

Two written health texts were identified via an online search to roughly simulate how a patient may find their own health related materials. One of these texts was about hernias, and the other was about atherosclerosis. These two texts were altered so they had approximately a 6th grade reading level, as measured by a widely available, traditional reading formula (Flesch Kincaid). This was done by adding/eliminating words, using higher frequency lexical items, and reducing sentence length.

These texts were then adapted so there were two versions, one with high cohesion and one with low cohesion, using the guidelines in O'Reilley & McNamara (2007). The three cohesion measures used by O'Reilley & McNamara (2007) were used as benchmarks, and texts were iteratively adapted until low and high cohesion texts roughly corresponded to the O'Reilley & McNamara (2007) values. Characteristics of the final texts are shown in Table 3: ratio of causal verbs to causal particles (causal cohesion), proportion of grammatical connectives (grammatical connectives), and LSA (latent semantic analysis) measures of global cohesion (lexical cohesion). The LSA measure compares the semantic relatedness of adjacent utterances, using a multidimensional semantic space based on large text corpora (O'Reilley & McNamara, 2007). Each of these measures reflects a different aspect of cohesion: causal cohesion is the ratio of causal particles (i.e., to) to causal verbs (i.e. make, cause, help) which is an index of the ratio of causal to noncausal verbs; connectives are words such as 'because', 'in other words', 'after', or 'when', which explicitly signal the relationships between ideas in a text; LSA global cohesion is a measure

of similarity in meaning/conceptual relatedness words, sentences, or paragraphs (McNamara & O'Reilly, 2007).

	O'Reilley & McNamara (2007) Low	**Hernia Text** Low	**Atherosclerosis Text** Low	**O'Reilley & McNamara (2007)** High	**Hernia Text** High	**Atherosclerosis Text** High
Causal Cohesion	0.182	0.143	0.179	0.326	0.28	0.395
Connectives	52.795	60.325	54.852	63.687	78.3	98.232
LSA Global Cohesion	0.315	0.254	0.239	0.369	0.385	0.356
Flesch-Kincaid Reading Grade Level	_____	5.912	5.718	_____	6.835	6.694

Table 3. Cohesion Targets

The combination of these three metrics was considered to be an index of cohesion, namely how explicit ideas, concepts, and relations are within a text. Using an online text analysis tool called CohMetrix, scores for the above three measures were first gathered for the two modified written health texts described above. To create a low cohesion version of the texts, the scores of

the three measures were iteratively adjusted in a variety of ways. For example, LSA global cohesion was reduced by altering sentence organization and omitting topic headers. Causal cohesion was altered by either reducing the causal verbs or increasing the use of noncausal verbs. Grammatical connectives were reduced by eliminating sentence connectives. To create a high cohesion version, the opposite alterations were made to produce high scores for each of the three metrics (i.e. add topic headers, replace pronouns with noun phrases, and add connectives). After modifications were made, the scores of the three measures were again estimated using CohMetrix, to establish that these metrics are in the target range for high and low cohesion texts, using O'Reilly & McNamara (2007) as guidelines. In addition, CohMetrix was used to establish that the two high-cohesion texts have similar scores and the two low-cohesion texts have similar scores across all three metrics.

The texts were originally matched with traditional readability formulas and for length. Table 3 shows the new Flesch-Kincaid Reading Grade Level and cohesion scores after cohesion adjustments were made. The adjusted versions were all +/- one grade level from a 6.0 grade level. However, the trend was for low cohesion texts to have lower grade level scores using Flesch-Kincaid. In a study by Beck et al. (1984) texts were revised to improve coherence in order to study the effects of improved coherence on children's comprehension. After the revisions, the authors found that grade-level scores increased. The findings by Beck et al. (1984) are similar to this study in that revisions related to coherence led to increased grade-level scores which by traditional simplification measures would deem the texts harder. In the case of the Beck et al texts, comprehension actually improved.

An example of the text that participants viewed can be found in Figure 5. A side by side comparison of low versus high cohesion as well as full versions of all the texts can be found in Appendix B.

Information on Hernias

A hernia happens because of tissue from inside the belly cavity pushing through the muscles of the belly wall.

Hernias typically happen in areas of the body where there is weakness. Common areas are the groin and umbilical areas.

Hernias of the groin are most common in men. Men have weakness where the testicles pass from the inside of the belly through muscles in the groin and down into the scrotum. Groin hernias are up to 12 times more common in men. A groin hernia can also be called an inguinal hernia.

The second groin hernia that can occur is the femoral hernia. Weakness can be caused by the blood vessels of the leg passing out of the abdomen and into the thigh.

Umbilical hernias occur in or near the belly button. Weakness can be caused because the muscles of the belly wall have opened. The opening lets the umbilical cord pass through and connects the baby to the mother.

Hernia Repairs

Because small umbilical hernias are less than 2-3 cm, they can be fixed using stitches to repair the hole.

The larger umbilical and groin hernias are fixed by using surgical mesh and not stiches. Pulling the muscles tightly together with stiches to close the hole can make the muscles tear open with time which can create another hernia.

The mesh can be placed over the hernia from the outside and is called an open repair. An open repair can be done under general or local anesthesia.

Today doctors can use laparoscopes to put the mesh on the hernia from the inside out. Laparoscopic repair is performed under general anesthesia. These repairs need a little less time to recover when compared to open mesh repairs.

Studies show that open mesh repairs are as good, if not even better, than laparoscopic repairs. Open mesh repairs have less risk of hernias coming back. Open mesh repairs also have less risk of major complications.

A method of open mesh repair of groin hernias is the Lichtenstein technique. Patients will be put under sedation and have local anesthetic put around the hernia to make it numb. The skin and the first layer of the belly muscle are divided to get to the hernia. The hernia is then uncovered and pushed back into the belly cavity. Then, the mesh is stitched in place.

The wound is then stitched closed. Next, a special tape is placed over the skin. The wound is then covered with a padded pressure dressing.

Some swelling, bruising, and pain may happen. An area of numbness in the groin skin can occur.

Go back to the doctors 7 days after the procedure for a checkup.

Figure 5. Example Text

4.2.2 Comprehension Questions

Following each text, participants were asked to respond, in writing, to twelve open ended comprehension questions. Questions included ten text specific questions (half implicit and half explicit), and two questions that could not be answered from the text alone. The purpose of these text-independent questions was to provide researchers with a measure of participant's preexisting knowledge of the topic. Following the pilot study, comprehension question data was reviewed, and all twelve comprehension questions were deemed appropriate to include in the collection of the main data. The complete list of comprehension questions and acceptable answers can be found in Appendix C. The grading criteria given to the additional raters can be found in Appendix D.

4.3 PROCEDURE

Participants were recruited using MTurk. Information about the study was given to participants prior to the beginning of the study. Participants were asked to read two health-related texts. The texts varied in cohesion but were broadly controlled for reading grade, specifically Flesh-Kincaid scores, and length. Following the reading, participants responded to a series of comprehension questions specific to each text. Responses were typed and recorded on a secure Qualtrics site. In addition, participants were asked to describe their number of years of education and highest level of educational attainment. Participants were asked to rate their familiarity with each health topic prior to this study on a scale of 1-5. Upon completion of the study, participants received $5.

4.4 RELIABILITY

Responses to comprehension questions were coded using a 2-point scale (0 = incorrect, 1 = correct), using general principles used in other related research (Keenan, Betjemann, & Olson, 2008; Duff, 2015), and with item specific criteria. These principles are defined as: either a correct or incorrect response, correct responses to explicit questions must come from information found in the passage, and the answer to implicit questions need to be taken from clues in the text (Duff, 2015).

The pilot study data was used to establish item specific coding criteria for the comprehension questions. Initially the primary researcher created a code for the questions which were then given to a second rater. Following the pilot study data, interrater reliability was 93%. Coded answers were then compared, and the grading criteria were altered to include more detail on acceptable answers. Using the main study data, two additional raters were used to establish interrater reliability with the altered grading criteria. The raters were given a random sample of ten participants from the main study data, to match the number of participants from the pilot study. Interrater reliability for the main study was 98%.

4.5 DATA ANALYSIS

The overall analysis was a mixed effects logistic regression model, with response accuracy on comprehension questions as the outcome variable. The model in each case was as follow:

Aim 1 was to determine the effect of text cohesion on readers' comprehension of written health materials, without educational attainment and topic-specific background knowledge. The

hypothesis was that readers would demonstrate better comprehension of texts that have high cohesion. The prediction was that cohesion would be a significant effect in the model. The outcomes of interest for this aim was whether cohesion had a significant effect in the model and the size of the parameter estimate for cohesion.

Aim 2 was to determine if text cohesion interacts with either educational attainment or text familiarity, with respect to readers' comprehension of written health materials. The hypothesis was that cohesion and education would interact, such that cohesion would have a greater facilitative effect on comprehension for lower education readers. In addition, it was hypothesized that text familiarity would interact with cohesion in a way that readers with high familiarity will more significantly benefit from an increase in cohesion. The prediction was that both the interaction between cohesion and education as well as the interaction between cohesion and text familiarity would have significant effects in the model. To address both of these aims and their interactions, a single linear mixed model was fit with three fixed effects: cohesion, educational attainment, and topic familiarity.

5.0 RESULTS

The data was initially fit with a logistic mixed effects model with cohesion, familiarity, and education as fixed effects and participant, item, and text as random effects. The variables of familiarity and education were centered. This allowed the model to converge and facilitated interpretation of results. Cohesion was contrast coded, meaning that the reference point within the model was midpoint between low and high cohesion. The initial model did not converge. The random effects of text and item had very high correlation indicating that the variance that was explained by item and text topic substantially overlapped. Therefore, text topic was removed from the analysis and the resulting model converged. This model included all three fixed effects and all interactions between them. The R code for this model was as follows: glmer(Score ~ 1 + Cohesion*FAmTotal.cen*EdScore.cen + (1|Item) + (1|Subject), data=Main_Data_Final_Jan18, family=binomial). The AIC of this model was 2434.4 and the BIC was 2490.2. It's noted that this model is preferred to other simpler models because it explains more of the variance in the data, based on AIC and BIC. The parameter estimates were converted from log odds to odds which are reported below in Table 5. The intercept represents the base likelihood of a correct response. A summary of statistics for the random effects can be found in Table 4. Table 5 shows the model output for the fixed effects.

There is no significant simple effect of cohesion in the model ($p=0.13608$, $\beta=0.15766$). On average high cohesion increases the odds of a correct response by 1.17 times. There was a marginal simple effect of educational attainment in the model ($p=0.09432$, $\beta= -0.24129$). On average an increase of one unit of edscore increases the odds of a correct response by 0.785. There was not a significant simple effect of topic familiarity in the model ($p=0.18332$, $\beta=0.06303$). On average an

increase of one unit of familiarity increase the odds of a correct response by 1.06. Thus, cohesion, educational attainment, and familiarity were not significant simple effects in the model. The sign of the parameter estimates indicated the following direction of effects: increasing text cohesion increased the likelihood of the correct response; increased familiarity with the topic increased the probability of a correct response; increased education score decreased the probability of a correct response. This is reported to facilitate interpretation of significant interactions.

The interaction between cohesion and familiarity was highly significant ($p=0.00666$, $\beta= -0.14904$), indicating that the cohesion effect (increased cohesion resulted in higher comprehension scores) gets larger in the presence of low topic familiarity. The interaction between familiarity and educational attainment was also significant ($p=0.0.00898$, $\beta= -0.17745$) indicating that higher educational attainment reduces the effect of familiarity (increased familiarity corresponded to higher comprehension scores) on comprehension scores. There was no significant interaction between cohesion and educational attainment. The three-way interaction between cohesion, familiarity, and education score was not significant.

Group Name	**Variance**	**Standard Deviation**
Subject (Intercept)	0.5068	0.7119
Item (Intercept)	0.6804	0.8249
Number of obs: 1960, groups: Subject, 98; Item, 20		

Table 4. Random Effects

	Estimate	Standard Error	z value	Pr(>|z|)	Odds
(Intercept)	0.33527	0.20613	1.626	0.10385	1.39
Cohesion	0.15766	0.10577	1.491	0.13608	1.17
FamTotal.cen	0.06303	0.04737	1.331	0.18332	1.06
EdScore.cen	-0.24129	0.14422	-1.673	0.09432	0.785
Cohesion1:FamTotal.cen	-0.14904	0.05493	-2.713	0.00666	0.8615
Cohesion1:EdScore.cen	0.10521	0.16744	0.628	0.53007	1.19
FamTotal.cen:EdScore.cen	-0.17745	0.06791	-2.613	0.00898	0.837
Cohesion1:FamTotal.cen:EdScore.cen	0.05171	0.08035	0.644	0.51984	____

Table 5. Fixed Effects

MEAN SCORES FOR HIGH AND LOW COHESION	
Cohesion	**Mean Score**
0 (low cohesion)	0.541
1 (high cohesion)	0.572

Table 6. Mean Scores – Cohesion

MEAN SCORES FOR DIFFERENT LEVELS OF FAMILIARITY	
Familiarity	**Mean Score**
0	0.600
1	0.500
2	0.546
3	0.577
4	0.617
5	0.555
6	0.568
7	0.517
8	0.483
9	NA
10	0.525

Table 7. Mean Scores – Familiarity

MEAN LEVELS FOR DIFFERENT LEVELS OF COHESION AND FAMILIARITY		
Familiarity	**Mean Score (low cohesion)**	**Mean Score (high cohesion)**
0	0.5	0.7
1	0.414	0.586
2	0.518	0.574
3	0.546	0.608
4	0.617	0.617
5	0.573	0.536
6	0.600	0.536
7	0.500	0.533
8	0.467	0.500
9	NA	NA
10	0.60	0.45

Table 8. Mean Scores - Cohesion and Familiarity

MEAN LEVELS FOR DIFFERENT LEVELS OF EDSCORE	
EdScore	**Mean Score**
2 (high school degree)	0.572
3 (college degree)	0.569
4 (greater than college degree)	0.480

Table 9. Mean Scores – EdScore

MEAN LEVELS FOR DIFFERENT LEVELS OF EDSCORE AND FAMILIARITY			
Familiarity	**Mean Scores (High School Diploma- EdScore =2)**	**Mean Scores (College Degree- EdScore =3)**	**Mean Scores (Greater than College Degree- EdScore =4)**
0	0.45	NA	0.75
1	0.650	0.367	0.45
2	0.523	0.545	0.675
3	0.640	0.542	0.525
4	0.567	0.680	0.600
5	NA	0.600	0.433
6	NA	0.617	0.350
7	0.70	0.80	0.05
8	NA	0.525	0.400
9	NA	NA	NA
10	NA	0.50	0.55

Table 10. Mean Scores - EdScore and Familiarity

The mean score overall was 0.56. To aid in the interpretation of the findings from the mixed effect model, tables were constructed showing overall means for the comprehension scores across conditions. These are reported in Table 6, Table 7, Table 8, Table 9, and Table 10. These data are broadly consistent with the conclusions based on the interaction terms for the model. Specifically,

mean comprehension scores were larger in the high cohesion condition, compared to the low cohesion condition, which is consistent with the direction of the (nonsignificant) simple effect in the model. The means across familiarity and cohesion conditions show that when familiarity is between low (0-3) the mean comprehension scores are higher in the high cohesion condition. Conversely, when the familiarity is very high (10), scores were higher in the low cohesion condition. They were equivalent at a familiarity score of 4, with a mixed pattern between 5 and 8. Again, this overall pattern is consistent with the interpretation of the cohesion-familiarity interaction in the mixed effect model.

Table 9 shows the mean scores for educational attainment independently. The mean scores for lower education is higher than the mean score for the higher education, consistent with the direction of the (nonsignificant) simple effect in the model. Table 10 shows means across 3 levels of educational attainment and 10 levels of familiarity. The pattern in this case seems to be complex, and somewhat difficult to interpret. However, it is perhaps notable that at the very lowest familiarity level (0), mean comprehension scores were higher for readers with greater than college education, compared to those with only a high school education. This instance is consistent with the interpretation of the model.

6.0 DISCUSSION

Overall, this study makes a meaningful contribution to an important body of literature. The field of health literacy, as a subset of a broader field of literature, has a meaningful and tangible impact on society through its link to overall health. Researchers have put significant effort into understanding the comprehension of medical texts, but this is the first study to include all adults rather than only older adults. With this expanded population in mind, this study has the potential to generalize to a broader population.

The model did not show a significant simple effect of cohesion on comprehension scores. However, this may be due to shared variance with the cohesion-familiarity interaction.

In the model it was found that cohesion did have a significant interaction with familiarity. Specifically, cohesion mattered more to text comprehension when the reader's familiarity was low. This is because in a mixed effects model, each effect is considered when all other effects are zero. In other words, the less an individual knows about a topic, the more important cohesion becomes to comprehension. This result is consistent with the findings of O'Reilly and McNamara (2007). It can be assumed that most individuals reading written health information will not be well versed on that particular topic. The results indicate that cohesion matters, and it matters most for the people who are in most need of the information. If cohesion is not considered when developing written health information, there may be a critical aspect of text complexity missing.

The results with regards to educational attainment also warrant some discussion. It is notable that educational level did not affect comprehension scores, either as a simple effect or in interaction with cohesion. However, there was a marginal effect of educational attainment, such that higher education was associated with lower comprehension scores. We also observed that

more individuals with high education (college degree) had to be excluded from the study based on the similarity of their responses to online sources. These individuals seem to have been more likely to utilize external information than other participants. It may be that participants with more education used different strategies when reading or may have had different level of motivation on the task.

Moreover, the results of this study may impact the future composition of written health information. Today, authors of written health information often aim for about a 6th grade reading level. This study saw a reverse effect of Flesch-Kincaid scores when the text materials were made more cohesive. As we increased cohesion, Flesch-Kincaid scores also increased. This might suggest that Flesh-Kincaid scores may be misguiding people to alter texts in a way that actually decreases comprehension. Conventionally, authors of written health information may target a specific Flesch-Kincaid score. The findings are consistent with the findings by Beck and colleagues (1984) in that revisions related to coherence led to increased grade-level scores which by traditional simplification measures would deem the texts harder. Considering the demonstrated negative relationship between cohesion and Flesch-Kincaid, trying to lower Flesch-Kincaid may actually be making it harder for individuals to comprehend texts. This study suggests that readability measures should include cohesion, because it impacts comprehension of written health information for readers with low familiarity. Now, authors may be able to improve their readers' comprehension by modifying other linguistic features such as cohesion rather than simply targeting a given reading level.

6.1.1 Limitations

Future studies may address certain limitations of this study. Below are some limitations the researchers identified throughout the implementation of this study and some potential future means to test such limitations.

During the study, the researchers were unable to prevent participants from obtaining and using knowledge from outside sources (i.e. Google) which ultimately threatened validity. However, while it was impossible to confidently detect cheating, a number of participants had very similar answers that matched what appeared when questions were typed into Google. When the researchers were sufficiently confident that these participants had used outside sources, data from those participants was discarded.

Secondly, the researchers relied on participant's self-reported education, which may have led individuals to rank their education higher than what it may truly be. Years of education was also requested from participants but did not lead to transparent answers. For example, one individual answered that they received a high school diploma / GED but completed fourteen years of education. This may include part time studies, repeated course work, or partial completion of college studies. It's unclear from that pair of answers how to factor this respondent's education into the analysis. It was not easy to reconcile the years of education with the highest level of education achieved, and as a result, the researchers chose to discard one measure. Highest level of educational attainment was judged to be sufficient for this study, and therefore years of education was not included in the analysis.

Another limitation was the way data was collected. Without a natural setting, participants were required to read health related texts on computer screens with the intent of answering specific unknown questions. One may argue that such a procedure will not accurately capture an

individual's experience when reading texts. Additionally, one could argue that comprehension may vary based on the setting. If patients are reading health related documents due to concerns about their health, the text may be more personally relevant, and thus more attention may be given. Moreover, other factors such as anxiety or stress may affect comprehension in a real-world setting. In this controlled environment online, the researchers could not simulate real-world conditions and may have introduced additional stress through the experimental process.

In addition to the aforementioned limitations, there were also a few restrictions to generalizability. This study only looked at two texts, which leads to the question of if the results of this study could be generalized to other medical texts. Furthermore, apart from education, additional demographic information was not obtained (age, socioeconomic status, race, gender, vocation) which affects our ability to generalize to the entire population.

6.1.2 Future Directions

This study may facilitate additional studies on the impact of text complexity on individual's comprehension of written health materials. Future studies may address the limitations listed through a few adjustments, including focusing on the adaptation of cohesion within particular texts.

As a first step, expert revisions may have greater validity compared to revisions designed to alter cohesion measures. Ideally, an expert will modify texts to improve cohesions which will allow researchers to determine the variables that are affected. By comparing comprehension across multiple modified texts with similar levels of cohesion but different sets of edits from experts, researchers can more accurately assess which particular cohesion variables are most significant for improving comprehension. Ideally, researchers will be able to identify not only which variables to

target, but also understand the thresholds that these measures must cross to influence effective comprehension.

Another step may be to determine how different methods of simplifications interact with one another and the individual and combined effect on comprehension. In this study, cohesion was altered based on cohesion metrics. Future studies may want to compare the aforementioned way of altering cohesion, to the traditional simplification methods (using shorter words and sentences) of reducing complexity, and the combination of the two. A more robust understanding of the relative effects of these two types of simplifications will further enhance the ability of authors of written health information to improve their readers' comprehension.

APPENDIX A

A.1 MEASURES CURRENTLY USED TO ASSESS WRITTEN HEALTH MATERIALS

Citation	Title	Measures Used	Comments
Misra, Poonam, Kasabwala, Khushabu, Agarwal, Nitin, Eloy, A., Jean, and Liu, K., James. (2012). Readability analysis of internet-based patient information regarding skull base tumors. *Journal of Neuro-Oncology*. 109 (3) 573-580.	"Readability analysis of internet-based patient information regarding skull base tumors"	• Flesch reading ease (FRE) • Flesch-Kincaide grade level (FKGL) • Coleman-Liau index (CLI) • SMOG grading • Gunning-Fog index (GFI) • New Fog count formula (NFC) • Fry readability graph • Raygor readability estimate graph (RRE) • New Dale-Chall readability formula (NDC) • FORCAST formula	• Reported all measures

Cherla, V., Deepa, Sanghvi, Saurin, Choudhry, J., Osamah, Liu, K., James, and Eloy, A., Jean. (2012). Readability assessment of internet-based patient education materials related to endoscopic sinus surgery. *The Laryngoscope.* 122 (8) 1649-1654.	"Readability assessment of internet-based patient education materials related to endoscopic sinus surgery"	• Flesch-Kincaide grade level (FKGL) • Flesch reading ease score (FRES) • SMOG (Simple measure of gobbledygook) • Gunning frequency of gobbledygook (Gunning FOG)	• Reported all measures
Misra, Poonam, Agarwal, Nitin, Kasabwala, Khushabu, Hansberry, R., David, Setzen, Michael, and Eloy, A., Jean. (2012). Readability analysis of healthcare-oriented education resources from the american academy of facial plastic and reconstructive surgery. *The Laryngoscope.* 123 (1) 90-96.	"Readability analysis of healthcare-oriented education resources from the american academy of facial plastic and reconstructive surgery"	• Flesch Reading Ease • FKGL • SMOG grading • Coleman-Liau Index • Gunning-Fog Index • New Fog Count • NDC • FORCAST formula • Raygor Readability Estimate • Fry Graph	• Reported all measures
Vargas, R., Christina, Chuang, J., Danielle, Ganor, Oren, and Lee, T., Bernard. (2014). Readability of online patient resources for the operative treatment of breast cancer. *Surgery.* 156 (2) 311-318.	"Readability of online patient resources for the operative treatment of breast cancer"	• Coleman-Liau • Flesch-Kincaid • FORCAST • Gunning Fog • NDC • New Fog Count • Raygor • SMOG	• Reported all measures
Patel, P., P, Hoppe, C., I, Ahuja, K., N,	"Analysis of Comprehensibility of	• SMOG • Flesch-Kincaid	• Reported all measures

and Ciminello, S., Frank. (2011). Analysis of Comprehensibility of Patient Information Regarding Complex Craniofacial Conditions. *Journal of Craniofacial Surgery.* 22 (4), 1179-1182.	Patient Information Regarding Complex Craniofacial Conditions"	• NDC	
Vargas, R., C, Koolen, G., Pieter, Chuang, J., D, Ganor, O, and Lee, T., B. (2014). Online Patient Resources for Breast Reconstruction: An Analysis of Readability. *Plastic and Reconstructive Surgery.* 134 (3), 406-413.	"Online Patient Resources for Breast Reconstruction: An Analysis of Readability"	• Coleman-Liau • Flesch-Kincaid • FORCAST • Fry • Gunning Fog • NDC • New Fog Count • Raygor Estimate • FOG	• Reported all measures
Seth, K., A, Vargas, R., C, Chuang, J., D, and Lee, T., B. (2016). Readability Assessment of Patient Information about Lymphedema and Its Treatment. *Plastic and Reconstructive Surgery.* 132 (2), 287e-295e.	"Readability Assessment of Patient Information about Lymphedema and Its Treatment"	• Coleman-Liau • Flesch-Kincaid • Flesch Reading Ease Index • FORCAST • Fry Graph • Gunning Fog Index • NDC • New Fog Count • Raygor Readability Estimate • SMOG	• Averaged all measures
Storino, A, Castillo-Angeles, M, Watkins, A., A, et al. (2016). Assessing the Accuracy and Readability of Online	Assessing the Accuracy and Readability of Online Health Information for Patients with Pancreatic Cancer.	• Coleman-Liau Index • Flesch-Kincaid Grade Level • FORCAST	• Median readability level was reported using all 9 measures

Health Information for Patients with Pancreatic Cancer. *Journal of the American Medical Association*. 151 (9), 831-837.		• Fry Readability Graph • Gunning Fog Index • NDC • New Fog Count • Raygor Readability Estimate • SMOG	
Vargas, R., C, Chuang, J., D, and Lee, T., B. (2014). Online patient resources for hernia repair: analysis of readability. *Journal of Surgical Research.* 190 (1), 144-150.	Online patient resources for hernia repair: analysis of readability.	• Coleman-Liau Index • Flesch-Kincaid Grade Level • FORCAST • Fry Graph • Gunning Fog Index • NDC • New Fog Count • Raygor Readability Estimate • SMOG • Flesch Reading Ease	• Analysis was performed using the Readability Studio Professional Edition v2012.1 software
Eberlin, R., Kyle, Vargas, R., C, Chuang, J., D, and Lee, T., Bernard. (2014). Patient education for carpal tunnel syndrome: analysis of readability. *HAND.* 10 (3), 374-380.	Patient education for carpal tunnel syndrome: analysis of readability.	• Coleman-Lieu • Flesch-Kincaid • Flesch Reading Ease • FORCAST • Fry Graph • Gunning Fog • NDC • New Fog Count • Raygor Estimate • SMOG	• Reported all measures
Ibrahim, Ahmed, Vargas, R., C, Koolen, G.L., Pieter, Chuang, J., D, Lin, J., S, and Lee, T., B. (2016). Readability of online patient resources for	Readability of online patient resources for melanoma.	• Coleman-Liau • Flesch-Kincaid Grade Level • FORCAST • Fry Graph • Gunning Fog Index	• Reported all measures • Reported a mean reading level for the 10

melanoma. *Melanoma Research.* 26 (1), 58-65.		• NDC • NFC • Raygor Readability Estimate • SMOG • FRE index	measures used

APPENDIX B

B.1 LOW VS. HIGH COHESION COMPARISON

Low Cohesion	High Cohesion
"These types of hernias are up to 12 times more common in **that population.** **It** can also be called an inguinal hernia. The second groin hernia that can occur is the femoral hernia. **It** is an area of weakness. They can be caused by blood vessels of the leg passing out of the abdomen or the thigh. The muscles of the belly wall have opened. Umbilical hernias occur in or near the belly button."	"Groin hernias are up to 12 times more common in **men**. A groin hernia can also be called an inguinal hernia. The second groin hernia that can occur is the femoral hernia. Weakness can be caused by the blood vessels of the leg passing out of the abdomen and into the thigh. Umbilical hernias occur in or near the belly button. **Weakness** can be caused because the muscles of the belly wall have opened."

B.2 HERNIA TEXT

B.2.1 Hernia Text – High Cohesion

Information on Hernias

A hernia happens because of tissue from inside the belly cavity pushing through the muscles of the belly wall.

Hernias typically happen in areas of the body where there is weakness. Common areas are the groin and umbilical areas.

Hernias of the groin are most common in men. Men have weakness where the testicles pass from the inside of the belly through muscles in the groin and down into the scrotum. Groin hernias are up to 12 times more common in men. A groin hernia can also be called an inguinal hernia.

The second groin hernia that can occur is the femoral hernia. Weakness can be caused by the blood vessels of the leg passing out of the abdomen and into the thigh.

Umbilical hernias occur in or near the belly button. Weakness can be caused because the muscles of the belly wall have opened. The opening lets the umbilical cord pass through and connects the baby to the mother.

Hernia Repairs

Because small umbilical hernias are less than 2-3 cm, they can be fixed using stitches to repair the hole.

The larger umbilical and groin hernias are fixed by using surgical mesh and not stiches. Pulling the muscles tightly together with stiches to close the hole can make the muscles tear open with time which can create another hernia.

The mesh can be placed over the hernia from the outside and is called an open repair. An open repair can be done under general or local anesthesia.

Today doctors can use laparoscopes to put the mesh on the hernia from the inside out. Laparoscopic repair is performed under general anesthesia. These repairs need a little less time to recover when compared to open mesh repairs.

Studies show that open mesh repairs are as good, if not even better, than laparoscopic repairs. Open mesh repairs have less risk of hernias coming back. Open mesh repairs also have less risk of major complications.

A method of open mesh repair of groin hernias is the Lichtenstein technique. Patients will be put under sedation and have local anesthetic put around the hernia to make it numb. The skin and the first layer of the belly muscle are divided to get to the hernia. The hernia is then uncovered and pushed back into the belly cavity. Then, the mesh is stitched in place.

The wound is then stitched closed. Next, a special tape is placed over the skin. The wound is then covered with a padded pressure dressing.

Some swelling, bruising, and pain may happen. An area of numbness in the groin skin can occur.

Go back to the doctors 7 days after the procedure for a checkup.

B.2.2 Hernia Text – Low Cohesion

A hernia happens when tissue inside the belly cavity pushes through the muscles of the belly wall.

They typically happen where the body is weak. Common areas are the groin and umbilical region.

They have weakness when the testicles pass from the belly through muscles in the groin continuing to the scrotum. Groin hernias are most common in men. These types of hernias are up to 12 times more common in that population. It can also be called an inguinal hernia.

The second groin hernia that can occur is the femoral hernia. It is an area of weakness.

They can be caused by blood vessels of the leg passing out of the abdomen or the thigh.

The muscles of the belly wall have opened. Umbilical hernias occur in or near the belly button. There is a possibility of softness. The opening lets the umbilical cord pass through. It causes the abdominal area to be not as strong as before. It connects the baby to the mother.

Small umbilical hernias are less than 2-3 cm. They can be fixed using stitches to repair the hole.

The larger hernias are fixed by using surgical mesh and not stiches. Pulling the muscles tightly together with stiches to close the hole can make the muscles tear open with time. That can create another hernia.

An open repair can be done under general or local anesthesia. The mesh can be placed over the hernia from the outside. It is called an open repair.

These repairs need a little less time to recover compared to open mesh repairs. Today doctors can use laparoscopes to put the mesh on the hernia from the inside out.

This type of repair is performed under general anesthesia.

Those repairs have less risk of major complications. Open mesh repairs are as good as laparoscopic repairs. The first type of mesh repairs have less risk of hernias coming back.

A method of open mesh repair of groin hernias is the Lichtenstein technique. Patients will be put under sedation. Local anesthetic is put around the hernia to make it numb. The skin and the

first layer of the abdominal muscle are divided to get to the hernia. It is uncovered and pushed back into the belly cavity. The mesh is stitched in place.

The wound is stitched closed. A special tape is placed over the skin. It is covered with a padded pressure dressing.

Some swelling, bruising, and pain may happen. An area of numbness in the groin skin can occur.

Go back to the doctors 7 days after the procedure for a checkup.

B.3 ATHEROSCLEROSIS TEXT

B.3.1 Atherosclerosis Text – High Cohesion

Atherosclerosis

Arteries are blood vessels that carry blood to your heart and other parts of your body. Atherosclerosis is when things like fat and plaque buildup inside your arteries.

The plaque hardens your arteries, and makes them narrow. Then there is less blood going to important parts of your body like your heart. This can cause serious problems. It can cause heart attack, stroke, or even death.

Plaques can build up in any artery in the body. If it is in different arteries it can cause different diseases.

Coronary heart disease (CHD) happens when plaque builds up in the coronary arteries. These arteries send blood to your heart. It can cause chest pain and heart attack. CHD is the number one cause of death in the United States. This is for men and women.

Carotid artery disease can cause stroke. Carotid artery disease happens when plaque builds up in the carotid arteries. These arteries send blood to your brain.

It can make you feel numb. It can cause pain. It can cause infections. Peripheral arterial disease (PAD) happens when plaque builds up in arteries that send blood to your arms, legs, and pelvis.

Atherosclerosis starts when something hurts the inner layers of the arteries. The buildup of plaque in the arteries may start in childhood. Many things can hurt the arteries: smoking, high fat and cholesterol in the blood, high blood pressure, and too much sugar in the blood. People get too much sugar in the blood because they have insulin resistance or diabetes.

When arteries get hurt, your body starts a healing process. This healing process makes plaque buildup. It builds up in the place where the arteries were damaged.

Some things make it more likely that you will get atherosclerosis. These are called risk factors. Here are some risk for atherosclerosis: high cholesterol, high blood pressure, smoking, diabetes, being overweight, and not getting enough physical activity. Being older is a risk factor. People who have someone in their family who had heart disease when they were young, have more chance of getting atherosclerosis.

You can control most of these risk factors. This means that you can slow down atherosclerosis. Maybe you can keep it from happening.

Changing your lifestyle can help treat atherosclerosis. Lifestyle changes include a healthy diet, exercise, not smoking, a healthy weight, not smoking, and lowering your stress.

If changing your lifestyle does not work, your doctor might want to use medicines. Medicines can help control atherosclerosis. They make the plaque buildup more slowly, or even make some plaque go away.

If your atherosclerosis is severe, your doctor might suggest surgery.

Treatments have also improved the quality of life for people with atherosclerosis. Many people are diagnosed with atherosclerosis. Treatments for atherosclerosis are improving. The risk of dying from atherosclerosis is lower now.

If you’ve been diagnosed with atherosclerosis, see your doctor for care. Follow your treatment plan. Take all of the medicines, the way your doctor prescribed them. Call your doctor if you have new symptoms, or they get worse.

B.3.2 Atherosclerosis Text – Low Cohesion

Arteries are blood vessels that carry blood to your heart and other body parts. Atherosclerosis is when things like fat and plaque build-up in them.

The plaque hardens them. They get narrow. Serious problems can happen. Less blood can enter important parts of your body. One could have a heart attack, stroke, or die

Plaque can build up in any artery. Problems with different arteries can create different diseases.

Coronary heart disease (CHD) is plaque build-up in the coronary arteries. These send blood to the heart. One can suffer chest pain and heart attack. CHD is the number one cause of death in the United States.

Carotid artery disease is the build-up of plaque in the carotid arteries. These arteries send blood to your brain. It can cause stroke.

You can feel numb. It can cause pain. It can cause infections. Peripheral arterial disease (PAD) is the build-up of plaque in arteries that send blood to your limbs.

Atherosclerosis starts with something hurting the arteries. The buildup of plaque in the arteries may start in childhood. People may have too much sugar in the blood from insulin resistance or diabetes. Many things can hurt the arteries: smoking, high fat and cholesterol in the blood, high blood pressure, and too much sugar in the blood.

Age can affect a person's overall health. Your body starts a healing process to heal hurt arteries. Plaque builds up where the arteries are hurt.

Some things make it more likely that you will get this disease. Some risk factors for atherosclerosis are high cholesterol, high blood pressure, smoking, diabetes, being overweight,

and not getting enough physical activity. People who have someone in their family who had heart disease at a young age may get atherosclerosis.

Maybe you can keep it from happening. You can control most of these risk factors. You can slow down the disease process.

Lifestyle changes include a healthy diet, exercise, not smoking, a healthy weight, and low stress. Changing your lifestyle can help treat it.

Your doctor might want to use medicine. Changing your lifestyle might not work. Medicine can help control it. It makes the plaque build-up more slowly. It may make plaque go away.

The worse it is, the more your doctor may encourage surgery. Atherosclerosis can range in severity.

Treatments have improved the quality of life for people with this disease. Many people are diagnosed with it. Treatments for atherosclerosis are improving. Call your doctor if symptoms persist. The risk of dying from it is now lower than ever.

See your doctor for care when you've been diagnosed with this disease affecting your arteries. Symptoms can persist or get worse. Follow your treatment plan. Take all of the medicines, the way your doctor prescribed them.

APPENDIX C

C.1 HERNIA COMPREHENSION QUESTIONS

1. What is a hernia?
    a. Tissue pushing through the abdominal wall (belly cavity)
2. What are the treatment options?
    a. surgery
3. What are common areas in which a hernia may occur?
    a. Groin or umbilical area
4. What would doctors use to put the mesh on the hernia from the inside out?
    a. Laparoscopes
5. Why do hernias occur in/around the belly button?
    a. Weak area

1. Why do open mesh repairs require more recovery time?
    a. It is typically used to repair a larger hernia
2. Would the Lichtenstein technique be used for large or small hernias?
    a. Large hernias
3. Why do hernias tend to occur at areas of weakness in the body?
    a. It is easier for the tissue to push through weak parts of the body
4. Why is the mesh repair more effective than stitches?
    a. They help prevent additional hernias compared to the use of stitches
5. Why would an umbilical hernia be repaired with stiches?
    a. They are usually smaller (2-3 cm)

1. What are risk factors that increase your likelihood of developing a hernia?
    a. Family history, overweight / obese, chronic cough, chronic constipation, smoking (aka chronic cough)
2. What are the common symptoms of a hernia?
    a. Bulge/ lump in affected area, pain or discomfort (typically in the abdomen), burning or aching sensation at the site of buldge

C.2 ATHEROSCLEROSIS COMPREHENSION QUESTIONS

1. What is atherosclerosis?
    a. When fat and plaque build-up inside your arteries
2. What are risk factors associated with atherosclerosis?
    a. High cholesterol, high blood pressure, smoking, diabetes, overweight, not enough physical activity, age, and family history
3. How can you prevent atherosclerosis?
    a. Healthy diet, exercise, not smoking, healthy weight, and lowering stress
4. What are treatment options for atherosclerosis?
    a. Medication or surgery
5. What can decreased blood flow lead to?
    a. Heart attack or stroke

1. Why would your doctor only recommend surgery for severe atherosclerosis?
    a. Other treatments may work (i.e. medicine) and be less risky
2. Why would low blood flow to certain parts of your body be a problem?
    a. Certain parts of your body aren't getting the blood they need
3. Why are fewer people dying from atherosclerosis?
    a. Treatments are improving
4. Why do different types of conditions develop from atherosclerosis?
    a. Atherosclerosis in different parts of the body would cause different conditions
5. Why would narrow arteries be a problem?
    a. Decreased blood flow to important parts of your body

1. Atherosclerosis is a specific type of what condition?
    a. Arteriosclerosis
2. What possible surgeries are used to treat atherosclerosis?
    a. Angioplasty, stenting, bypass

APPENDIX D

D.1 HERNIA QUESTIONS AND ANSWERS

Hernia questions and answers

Type	Question	Correct answer	Other acceptable answers	Unacceptable answers
Explicit	What is a hernia?	Tissue pushing through the abdominal wall (belly cavity)		
	What are the treatment options?	Surgery	▪ Have to use the word repair	▪ Stiches / mesh
	What are common areas in which a hernia may occur?	Groin or umbilical area	▪ Need to have at least one ▪ Belly button / abdomen / abdominal area	
	What would doctors use to put the mesh on a hernia from the inside out?	Laparascopes		
	Why do hernias occur in/around the belly button?	It's a weak area	▪ Soft area / softness	
Implicit	Why do open mesh repairs require more recovery time?	It's typically used for a larger hernia	▪ Incision size	
	Would the Lichtenstein technique be used for large or small hernias?	Large hernias		
	Why do hernias tend to occur at areas of weakness in the body?	it is easier for tissue to push through	▪ Muscles can separate more easily ▪ Easier to break through ▪ Path of least resistance	
	Why is the mesh repair more effective?	They help prevent additional hernias compared to the use of stitches	▪ Stiches leave individuals more vulnerable to new hernias	
	Why would an umbilical hernia be repaired with stitches?	They are usually smaller (2-3cm)	▪ The area is small enough to not cause another hernia	
Test	What are risk factors that increase your likelihood of developing a hernia?	Family history, overweight, chronic couch, chronic constipation, smoking, pregnancy, weight lifting, injury		
	What are common symptoms of a hernia?	Bulge/lump in affected area, pain or discomfort (typically in abdomen), burning or aching at site of bulge		
Familiarity	How familiar were you with the topic "Hernias" prior to this study?	N/A		

D.2 ATHEROSCLEROSIS QUESTIONS AND ANSWERS

Atherosclerosis questions and answers

Type	Question	Correct answer	Other acceptable answers	Unacceptable answers
Explicit	What is atherosclerosis?	Build-up of fat and plaque in the arteries		
	What are risk factors associated with atherosclerosis?	High cholesterol, high blood pressure, smoking, diabetes, overweight, not enough activitiy, age, family history	▪ Minimum of 2	
	How can you prevent atherosclerosis?	Healthy diet, exercise, not smoking, healthy weight, low stress	▪ More specific than "change lifestyle"	▪ Lifestyle changes
	What are treatment options for atherosclerosis?	Medication or surgery	▪ Need both	
	What can decreased blood flow lead to?	Heart attack or stroke	▪ Need both	
	Why would your doctor only recommend surgery for severe atherosclerosis?	Other treatments may work and be less risky	▪ Other tx options are effective ▪ Surgery is risky ▪ It's dangerous	
Implicit	Why would low blood flow to certain parts of your body be a problem?	Certain parts of your body aren't getting the blood they need		
	Why are fewer people dying from atherosclerosis?	Treatments are improving	▪ Better medicines ▪ More treatments	
	Why do different types of conditions develop from atherosclerosis?	Atherosclerosis in different parts of the body would cause different conditions	▪ Affects different parts of the body ▪ Depends where the blood is heading that's blocked	
	Why would narrow arteries be a problem?	Decreased blood flow to important parts of your body	▪ Restricted blood flow ▪ Less blood can flow ▪ Disrupt blood flow	
Test	Atherosclerosis is a specific type of what condition?	Arteriosclerosis		
	What possible surgeries are used to treat atherosclerosis?	Angioplasty, stenting, bypass	▪ Just need 1	
Familiarity	How familiar were you with the topic "Atherosclerosis" prior to this study?	N/A		

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