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Automatic priming and spread of activation in L2 lexical access among selected Ghanaian High School students: Do differences in vocabulary size and depth of priming remain invariant?

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Abstract— This study investigated automatic priming, schema induction, the spread of activation, and L2 lexical access through vocabulary size and depth. Employing the theoretical framework of the distributed memory representation, the underlying assumption was that conceptual knowledge was identified through connection weights linking universal processing units rather than local ones. Using an experimental pre-test-post-test design with purposive sampling of estimated one hundred and fifty (150) students from three (3) Senior High Schools in Ghana, the critical findings in this study were that cognitive differences in automatic priming, schema induction and spread of activation predicted enhanced reading comprehension in L2, especially how fast one could infer from text since these cognitive processes helped to reduce cognitive load involved in reading. The second finding was that ability to use automatic priming, schema induction and spread of activation reduced mental load to facilitate comprehension by the size and level of vocabulary readers possessed in long-term memory. The third finding was that priming, the spread of activation, and schema induction increased with increasing attentional control. Readers with high attentional control were more likely to be involved in a proactive expectancy strategic use of priming, the spread of activation, and schema induction to generate possible targets. These cognitive differences remain invariant in readers unless classroom practices are designed to help less enhanced readers strategies to promote schema induction, priming, and spread of activation.

Keywords: Automatic Priming, Schema Induction, Spread of Activation, Vocabulary Size, Comprehension

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I. INTRODUCTION

ONE of the major lessons learned from studies in Artificial Intelligence (AI) relative to how human beings process information is that unlike the computer, which can process large volumes of information, the human cognitive architecture cannot (Korteling et al., 2021). Our human intelligence, even though relatively higher than other animals, in absolute terms, may be very limited in its physical computing capacity, albeit only by the limited size of our brain and its maximal possible number of neurons and glial cells (Kahle, 1979). Therefore, human cognition is heavily constrained by load, which influences how the information is represented in the Working Memory (Parasuraman, 2003). This cognitive load limitation in humans, relative to AI has to do with the size of their workspace (Atkinson & Shiffrin, 1968). In the case of the human Working Memory, one critical aspect is economy (Miller, 1956). Human cognition, therefore, structures knowledge in a way that compensates for its limited working memory in a variety of knowledge formats such as propositions (declarative knowledge), productions (procedural knowledge), schemas, images, etc. (Gagne, 1985). Each of these forms of knowledge structure processes information to minimize mental load and enhance recall either in problem-solving, analogical reading, or engaged reading through such processes as automatic priming (Meyer & Schvaneveldt, 1971) schema induction (Halford et al., 1998; Halford et al., 2007) spread of activation (Collins & Loftus, 1975).

Ghana, for example, has made and continues to make significant progress in education for access to education, gender parity, and funding. Nevertheless, learning achievement in literacy skills in Ghanaian public basic schools shows that Ghana and African countries could do much better compared to the resources invested from both domestic and donor-funded, especially in literacy skills such as reading (Mullis et al., 2012).

For enhanced reading, for example, there is a consensus in the literature that successful reading of a word depends on its abstract representation in the mental lexicon selected based on the visual information provided (McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982). In addition, correct lexical representations need to be selected from other lexical representations during reading. This lexical selection mechanism is affected by both the nature of the word's orthography and its relevant contextual and semantic information. It is hypostasized that words having more semantic information that is associated tend to be recognized faster, generally speaking (Pexman, Hargreaves, Siakaluk, Bodner, & Pope, 2008; Pexman, Lupker, & Hino, 2002; Yap, Pexman, Wellsby, Hargreaves, & Huff, 2012). The exact psychological processes/relationship between the former and the latter have not reached a consensus in the literature on semantic information and word identification. However, what seems to have been agreed on, is that in terms of lexical access, as one is engaged in reading a text, information about the possible meaning of words could be activated contextually, even before the actual word is fully identified by the reader (Lupker, 2008). In this context, in lexical access, when words are preceded by semantically related words such as bread-butter, they are recognized faster than when preceded by semantically unrelated words such as dog-hat (Meyer & Schvaneveldt, 1971). This phenomenon in cognitive literature, termed the semantic priming effect, continues to be one of the critical observations in cognitive psychology. Important as the semantic priming effect, it continues to shape how we understand word recognition processes, the character of the semantic system, and the differences between automatic and controlled processes (McNamara, 2005; Neely, 1991). Even though the literature is replete with varied theoretical paradigms ranging from automatic (without conscious awareness) to controlled ones modulated by task contexts, it is still unclear whether single cognitive processes could so easily explain otherwise complex phenomena (Neely, 1991). Indeed, priming could be activated both before a target is presented or after a target is presented prospectively or retrospectively. A typical example of the former is automatic spreading activation priming, a prime (CAT) will instantaneously activate the target (DOG) through the associative semantic nodes that make it easier to identify these words when presented (Posner & Snyder, 1975).

Similarly, priming effects appear to result from controlled processes such as expectancy and semantic matching. In the case of expectancy, Becker (1980) submits that it operates in anticipation (prospectively) and therefore refers to generating possible candidates for the target. On the other hand, semantic matching refers to antecedent searching processes for a relationship from the target to the prime (Neely, Keefe, & Ross, 1989). Thus, the target's lexical status makes it amenable for the relationship to be diagnostic since non-words can hardly be related to their primes. In addition, the spread of activation, expectancy, and semantic matching investigators in the literature, also recognize a hybrid mechanism that blends automatic and strategic aspects. For example, Whittlesea and Jacob's (1997) retrieval account of priming is anchored on the thesis that the processing of prime appears to establish an episodic memory trace. Bodner and Masson's (1997) came up with their work on the memory-recruitment account of priming. What is implied in these studies is this: the extent to which the system could rely on the episodic trace of the priming is contingent upon the relevance of the prime's task (Anderson & Milson, 1989). Interestingly, they still operate, even when primes are presented for a short time to allow conscious processing (Bodner & Masson, 1997). Such findings contradict other empirical findings (Kinoshita, Forster, & Mozer, 2008; Kinoshita, Mozer, & Forster, 2011).

Another model that has also been used to examine empirical evidence of automatic priming, schema induction, and spread of activation since the late 1960's and the 1970's has been the Interactive Activation and Competition Model (IAC). This model was initially proposed to explain the word superiority effect (Reicher, 1969; Wheeler, 1970). In this approach, letters are often identified more quickly and accurately within a word than in a non-word or by themselves. This model, focusing on the word superiority effect, represents an example of higher-order information influencing lower-level information processing. The assumption here is that word representation must be activated partially before it can facilitate the identification of letters contained in it. McClelland and Rumelhart (1981) perceive the IAC model as having three levels of representation: a) visual input level: where input activates feature-level representation; b) which in turn activates the letter-level representation and c) then the letter representation activates the word level (that is the lexical representations. The IAC is theoretically assumed to be a localist model in that the individual features, letters, or words are represented at respective levels of representation by individual nodes. One distinctive feature of IAC is this: it works on the assumption that activation is interactive, that is, it can flow either from a lower to a higher level or from higher- to lower-level representations. A second key feature of this model is that activation is cascaded (vs. thresholded). This means that the next highest level begins receiving activation as soon as processing at the next lower level is initiated rather than after the processing at that level is complete. In the view of McClelland and Rumelhart (1981), these precipitates enhanced recognition of letters embedded in a word due to the activation letter-level representations received from the activated word-level representations.

II. STATEMENT OF PROBLEM

The emphasis in the literature for characterizing a 'prototypical' reader continues to be questioned, with increasing evidence that readers typically vary on dimensions regarding the moderation of word recognition performance (Andrews, 2012). Generally, the literature on semantic priming, for example, has focused principally on data at the level of the group, which are then collapsed across participants without teasing out respective individual differences. This means that systematic differences among skilled readers, for example, vis-a-vis less skilled readers, rarely factored into readers' performances (Plaut & Booth, 2000). Individual differences which affect semantic priming effect, such as ability in reading, comprehension skills, size of vocabulary, and attentional control, all of which implicate automatic semantic priming, schema induction, and spread of activation in lexical access (which do not remain invariant during lexical access) are rarely factored into the debate, hence this study. This raises the question of whether semantic priming effects are reliable without considering these inherent differences and the extent to which one's semantic priming effect could be expected to align with other measures (Lowe & Rabbit, 1998). Directly connected to this is that an unreliable dependent measure makes it harder for investigators to detect between-group differences on this measure (Waechter, Stolz, & Besner, 2010). Therefore, to bridge this gap, this study used an adapted version of the Semantic Priming Project (SPP) (Hutchison et al., 2013) to investigate whether individual differences, such as ability in reading comprehension, size of vocabulary, and attentional control remain invariant in lexical access and its implication for classroom practice.

Additionally, reading appears to be effortless and independent of, for example, central attention. Consequently, the notion of autonomous word processing seems to have been an implicit assumption, especially in the early models dealing with words processing (Forster, 1976; McClelland & Rumelhart, 1981; Morton, 1969) as well as in modern ones (Coltheart et al., 2001; Plaut et al., 1996; Seidenberg & McClelland, 1989). For example, one of the leading experimental procedures to investigate the dependency of mental processes on attention has been the overlapping task paradigms (Keele, 1973; Pashler, 1984; Pashler & Johnston, 1989; Schweickert, 1978; Telford, 1931; Welford, 1952). Even in this instance, evidence obtained for the autonomy of visual word recognition has resulted in conflicting evidence (Allen et al., 2002; Cleland, Gaskell, Quinlan, Tamminen, 2006; Lien et al., 2006; McCann, Remington, Van Selst, 2000). In this context, this study was undertaken to investigate how individual differences in reading comprehension, lexical access, size of vocabulary, and attentional control implicated priming and spread of activation.

III. SIGNICANCE OF THE STUDY

The findings of this study would significantly benefit stakeholders in basic education, especially reading teachers and teacher trainees in Faculties and Colleges of Education, to understand the psychological underpinnings of automatic priming, the spread of activation in lexical access, and how individual differences implicate all these in reading. Often in trying to identify the differences between skilled and less skilled readers, little attention is paid to underlying fundamental individual differences, especially readers' vocabulary size, executive functions, etc., based on which teachers could design effective classroom interactions. Secondly, global data show that for the last fifty years, primary school enrollment has been nearly universal in the case of high-income countries, while low- and middle-income countries lagged in 1970. Still, they have since made significant progress (UNESCO Institute for Statistics (UIS), 2020) since the Millennium Development Goals, and later as part of the SDG's. However, notwithstanding the high enrollments, especially in Sub-Sahara Africa, many students are not learning. It is estimated that nine in ten African children cannot read with comprehension by age 10 (UIS, 2020). Reading with comprehension continues to be a bane in many African nations. The outcome of this study will help teachers come to terms with some of the underlying individual differences that implicate lexical access in reading comprehension.

IV. THEORETICAL FRAMEWORK

The study employed a distributed memory model of semantic priming, such as the Spread of the Activation Principle, Compound cue theory' and distributed memory representation.

Spread of Activation Principle

Several fundamental and varied principles in the literature have explored the issues regarding how knowledge is represented. One critical principle is the concept of knowledge as an interconnected network of nodes representing individual concepts (Masson, 1995). Another fundamental principle is a process termed 'automatic spreading activation' This is assumed to enhance access to knowledge in a network. Thus, when a node in the link is activated, this activation spreads to related nodes. In so doing, information about the concept spreads and becomes available. This process cues the mental/cognitive system to identify related concepts if they appear in the environment. Together, the network representation and the spreading activation have formed critical theories of knowledge representation and processing (Anderson, 1983; Collins & Loftus, 1975). Posner and Snyder (1975) and Neeley (1977) distinguished between consciously controlled and automatic processes to develop the semantic priming effects theory. In this theory, automatic spreading activation among related concepts constitutes a central role. As used in this study' semantic priming is the facilitation effect of the presentation of a word for identifying a pertaining word such as CAT-DOG. The theory has also been expanded to investigate both automatic spreading activation and the processes of expectancy and semantic matching, which has been used as a plausible explanation for varied priming effects (Neely, 1991; Neely & Keefe, 1989; Neely, Keefe & Ross, 1989). Automatic spreading activation, notwithstanding, has become an essential component regarding varied explanations of semantic phenomena (Balota, Black & Cheney, 1992; Dagenbach, Horst & Carr, 1990; McNamara, 1992 a; 1992b)

Compound-cue theory

Besides the spreading activation principle mentioned above, an alternative view of semantic priming was developed in the late 1980's and early 1990's which does not refer to the spread of the activation principle. It is called 'compound cue' theory. According to this theory, a prime and a target could be combined or integrated at the level of encoding, and it is the familiarity of this compound cue which is determined by accessing the Long-Term Memory (LTM) (Dosher & Rosedale, 1989; Mckoon & Ratcliff, 1992; Whittlesea & Jacoby, 1990). The underlying theoretical submission in the compound-cue theory is that decisions regarding a target are determined by the degree of familiarity of the compound cues in lexical decisions. The compound cue is relatively familiar for prime-target pairs, and a stronger match to existing LTM representations is obtained. The underlying assumption is that there is an inverse relationship between the strength of memory match and response latency.

Distributed memory representation

In addition to the spread of activation and compound cue models, there is a third view of semantic priming effects from the perspective of connectionist modeling. Three models have emerged, making assumptions on knowledge representation and stimulus identification relevant to semantic priming (Hinton & Shallice, 1991; Sharkey & Sharkey, 1992). The key underlying feature of this model is the use of distributed representations. Conceptual knowledge is identified through connection weights linking processing units. This scheme is different from the spread of activation theories.

In contrast, the spread of activation is a local representation (that is, single mode) the distributed model more universal. In addition, the nature of this model being distributive, also differentiates it from other word identification in the connectionist models where local representation is used (McClelland & Rumelhart, 1981). Besides this model, it is also different from Seidenburg and McClelland (1989) distributed memory model of word identification because of the inclusion of a model representing word meaning. This distributed memory model modifies the connectionist network called Hopefield net (Hopefield, 1982; Hopefield & Tank, 1986). This network brand does not differentiate between processing units such as input, hidden, and output as in other computational models or other connectionist architecture (Rumelhart & McClelland, 1986). Rather, for each given unit in the network, all weighted connections are linked up with other units within the network (Masson, 1995). These connection weights in the Hopefield net are explained by a learning rule derived from Hebb (1949). This rule involves changing connection weights between processing units based on activation values at units when the pattern is instantiated. The rule is this: there is an increase in connection weights, two units take on the same value and decrease when units have a different value (Masson, 1995)

Distributed memory representation and lexical access in reading

The implication that could be derived from the above discussion on distributed memory representation is not unrelated to semantic priming in lexical access. This is because semantic priming is theoretically grounded on the fundamental assumption that in text discourse, especially in reading, semantically related words have similar activation patterns across meaning units (Masson, 1995). This similarity occurs because of two theoretical assumptions: a) the reader constructs the meaning of a concept from the context in which the concepts occur, and b) frequent concepts concurring most of the times, share much contextually-based meaning as has been established in the literature (Ntim, 2017; Ntim 2015; Mckoon & Ratcliff, 1992), notwithstanding the controversy regarding whether or not the consequences of co-occurrence are semantic.

Individual differences in vocabulary and lexical access

Individual differences such as a) vocabulary size; b) depth of vocabulary knowledge; c) lexical organization, and d) automaticity of receptive-productive knowledge can hardly be ignored in examining the relationship between automatic priming and spread of activation on the one hand, and on lexical access on the other. Qian (2002) proposed the four dimensions of vocabulary acquisition, which differentially impact lexical access via automatic priming, activation spread, and overall text comprehension. The first dimension of vocabulary size refers to the quantity or number of words an individual has, at least superficially, in terms of primary meaning. The second dimension of the depth of vocabulary knowledge has to do with all lexical characteristics such as the following: a) phonemic; b) graphemic; c) morphemic; d) syntactic; e) semantic; f) collocational; g) phraseological properties; h) frequency and i) register. The next dimension, lexical organization, refers to word storage, connection, and representation in a learner's mental lexicon. At the same time, the last automaticity of receptive-productive knowledge involves fundamental processes through which access to word knowledge for receptive and productive purposes is achieved. For lexical access to become automatic to enhance reading, the following processes must be in place: phonological encoding and decoding, access to structural and semantic features from the lexicon, lexical-semantic integration and representation, and morphological parsing and composing. Qian (2002) submits that these dimensions are intrinsically connected and interact closely with one another in all fundamental processes underlying vocabulary development and use. Individual differences in any of these dimensions are closely related to whether a reader can cognitively see connections and use the spread of activation/automatic priming to make meaning.

This is because in reading alone, the following cognitive/mental processes occur in the mind: Decoding: means using the printed word to generate word meanings in the WM. Two mental sub-processes are involved: a) matching and b) recoding. Matching is when a reader uses sight to recognize words or vocabulary (letter and word identification). In recoding, the printed word is sorted into sound patterns (phenomes), and then the sound patterns activate theword's meaning in Long-term Memory (LTM). (Gough & Tunmer, 1986; Hoover & Gough, 1990). Literal comprehension combines activated word meanings to form propositions (networks of interrelated ideas). It functions to derive literal meaning from print. It is composed of two mental processes: lexical access and parsing. During lexical access, the meanings of words are identified Inferential comprehension involves going beyond the idea explicitly stated to summarize and/ or elaborate on these ideas. It involves three sub-processes: integration, summarisation and elaboration. Comprehension Monitoring is the cognitive process in which readers determine whether they understand what they are reading. If they realize that they cannot articulate the main idea of the passage, they can take steps to repair their comprehension before continuing to read. Thus, readers utilize both bottom-up and top-down strategies simultaneously or alternately to comprehend the text (Reader uses top-down strategies until they encounter an unfamiliar word, then employ decoding skills to achieve comprehension (De Debat, 2006). These processes are supposed to be fast. The more they delay, the more it adds to the mental load and obstructs comprehension (Ntim, 2015). However, these mental processes are also essentially modulated by these dimensions of vocabulary. As indicated in the introduction, priming is a cognitive phenomenon that is both ubiquitous and automatic. Exposure to a stimulus or an idea unconsciously influences the subsequent experience with a related stimulus, so the idea of a table knife would activate a related stimulus, such as a fork or a tablespoon.

The underlying theoretical assumption common to all the theories reviewed is that priming reflects automatic spreading activation among related structures encoded in the LTM. It is this relationship/connection that can cause priming in lexical access both at the speech and at the semantic level. For example, in the speech production domain, words could be related to each other at the semantic level (that could activate the following ideas: a) that both dog and cat are both animals, b) they are both pets, and c) they both have furs. Similarly, at the phonological level, stimuli such as cat, hat, and cap all share common phonemes. It is the knowledge of these relationships that investigators have made it possible to use priming to assess the different stages of the mental/cognitive system to infer spreading activation in reading comprehension among related words at the level of semantics, syntactic and phonology (Anderson, 1983; Balota & Lorch, 1986; Collins & Loftus, 1975; Neely, 1977; Posner & Snyder, 1975). For example, the observation that a response to a target (e.g., dog) is faster when a semantically related prime precedes it (e.g., cat), compared to an unrelated prime (e.g., car). Thus, priming may occur because the prime partially activates related words or concepts, facilitating their later processing recognition. The underlying theoretical assumption is that priming reflects automatic spreading activation among related structures encoded in the LTM. This relationship/connection can cause priming in lexical access both at the speech and at the semantic level. Thus, priming may occur because the prime partially activates related words or concepts, facilitating their later processing recognition. Other variables, such as size and vocabulary level, lexical frequencies, models of lexical access, dominant and subordinate meanings, etc., all tend to influence priming and spread of activation. Using the 'distributed memory representation of knowledge structures' as the theoretical/conceptual framework, the underlying thesis of this study is that, since priming and spread of activation help to reduce the mental load on the reader to enhance reading, nevertheless, individual differences of readers mentioned above could not be discounted. These individual differences modulate automatic priming, schema induction, and spread of activation in L2 lexical access.

V. RESEARCH QUESTIONS

1) How does automatic priming in reading comprehension influence students' lexical access in L2?

2) What is the relationship between vocabulary size in semantic memory and lexical access in L2 through schema induction?

3) How does attentional control through the spread of activation affect lexical access in L2?

VI. OBJECTIVE OF THE STUDY

The following three objectives guided this study:

1) To investigate how automatic priming in reading influences readers lexical access in L2.

2) To examine the relationship between readers vocabulary size and lexical access in L2 through schema induction while reading.

3) To examine how attentional control through spread of activation affect lexical access in L2.

VII. METHODS

Research approach and design

This study used the experimental research approach with the pre-test and post-test design to examine the relationship between a predictor (independent) variable and a dependent variable in which the predictor variable was manipulated to see its effect on the dependent variable. The predictor variables manipulated were automatic priming and the spread of activation, and the dependent variable was lexical access in L2. The underlying thesis tested was that lexical access ability in L2 depended on the predictor variables of how fast a reader could automatically do priming and spread of activation while involved in second language comprehension. The submission made was that the ability to do automatic priming and spread of activatioin to faciliate L2 comprehension was also predicated on inherent indivudal differences, such as the vocabulary size of a reader, depth of one's vocabulary, one's lexical organization, one's automaticity of receptive-productive knowledge. These individual differences, hypothesized to predict L2 lexical access, were tested experimentally through pre-test and post-test experimental design.

Participants

This study investigated the relationship between individual differences in text discourse and how these differences affect L2 lexical access. Using experimental research of pre-test-post-test design with purposive sampling of an estimated one hundred and fifty (150) respondents drawn from students in three (3) Senior High Schools in three (3) administrative regions of Ghana: Ahafo, Ashanti, and Bono. All these were Form Three Students. Students tested in this study were from the same middle-class background in Berekum, Kumasi, and Sunyani urban and semi-urban areas. In our efforts to exclude extraneous variables influencing the validity of our results, significant differences in the parental socioeconomic background were avoided: respondents were chosen from the same parental socioeconomic status. The parents of these respondents were professionals and university graduates. Fifty percent of respondents were females, and the other half were males. Twenty-five (25%) percent were from single-parent homes, while the other seventy-five (75%) came from two-parent family backgrounds. All respondents were identified as normal Ghanaians, ranging from 15-18 years of age, who were native speakers of Akan (specifically Asante Twi) with English as a second language. For forty percent (40%) of these children, English was not the primary language spoken at home, even though they were from the same middle-class Ghanaian parentage in which both or one of the parents were university graduates.

Measures

We specifically tested how differences in comprehension ability, size and depth of vocabulary, and executive functions, such as attention control through the psychological processes of automatic priming, schema induction, and spread of activation, differentiated between students in text discourse in L2 lexical access. The conceptual framework of this study was grounded on the theoretical assumption of the distributed memory representation of knowledge structures which makes the fundamental assumption that in text discourse, semantically related words have similar activation patterns across meaning units (Rumelhart & McClelland, 1986; Masson, 1995). Based on this assumption, this study empirically tested whether, readers could construct meaning from texts in which frequent concepts concur. The thesis of this study was that differences in pre-existing attributes in reading ability, size, depth of vocabulary, and attentional control significantly differentiate between readers. These differences resulted in differences in the cognitive/psychological processes of knowledge structuring during the reading process, in which readers construct meaning through automatic priming, schema induction, and spread of activation.

Procedure

This study used the Gates- MacGinite Mature Reading Test (MR) adapted. The test was administered to three (3) groups. Two (2) of them were experimental, and one (1) was a control group. The pre-test was applied to all three groups before the experimental treatment. The average scores in the pre-test were collated into mean scores and standard deviations. To ensure the random assignment of groups, the students with the highest and lowest averages were eliminated to ensure the validity of the results. Those with the closest scores outside of the extremely good and extremely poor outliers were selected. Out of the estimated one hundred and fifty (150), one hundred and twenty (120), including 80 males and 40 females, participated in the study. Experimental and control groups were randomly assigned as shown in Table 1 below:

Data Analysis

Table 1: Pre-test Study Group

Groups	Branch	Over-all Gates-MacGinite Reading Test score	The mean pre-test score (Size of vocabulary t)	The mean pre-test score (Depth of - vocabulary)	The mean pre-test score (Reading Comprehension
Control	A	86.16	18.26	10.21	52.42
Experimental 1	D	85.65	18.66	9.80	51.33
Experimental 2	E	85.68	19.84	9.74	50.24

After the pre-test, participants were randomly assigned into Experimental 1, Experimental 2, and Control. Experimental groups 1 and 2 were exposed to vocabulary proficiency and receptive lexical knowledge treatment for three days. In addition to increasing the size and depth of vocabulary for the three-day treatment, they were also exposed to the LexTale test (Lemhöfer & Broersma, 2012). This test was originally designed to assess testees' receptive lexical knowledge proficiency and to help researchers study participants with an advanced level of English as a second language in experimental settings. Using this instrument as one of the measuring instruments, the two experimental groups were given different passages in English (L2), including English words and pseudowords, to enhance the size and depth of vocabulary in L2 for the three days. The passages were used to test and teach specifically the two experimental groups how to identify text discourse situations that assessed the level of intersection/overlap between questions asked and the target answer in the passages, along four lexical tasks: verbatim, transform verbatim, paraphrase, and transform paraphrase. Verbatim questions, as the name implies, have to do with questions explicitly stated in a text; the difference was that different words with the same semantic meaning were used; paraphrase questions were those that did not use correct answers, but were paraphrased in different words, but with the same fundamental meaning; transformed paraphrase: these were questions in the passages requiring multiple sentence meanings to be able to answer.

In addition, experimental groups were given passages to read to test their lexical access in L2. These passages were deliberately constructed focusing on the associative network consisting of paragraphs (nodes), so each paragraph (node) represents an information item. Each paragraph (node) was part of an intentionally constructed logical layer defined as follows: Abstraction layer: to integrate information items with abstract semantic meaning. More precisely, in contrast to the knowledge base used, this was to support the modeling of entity attributes; conceptual layer: this second layer in the passages was used to associate entity attributes according to their semantic relationship. Thus, each entity attribute had a representation at the conceptual layer; Entity layer: finally, the entity layer associated entities with information items (entity attributes) of the conceptual layer (e.g., a word possessing the attribute of a 'bank' that is a bank where we keep money, and a bank of a river, to test students' ability to use automatic priming, schema induction and spread of activation to instantiate word meanings, based on inference such as the 'robbers robbed the bank'. Bank, as used here in this statement, is certainly associated with the bank where money is deposited, as opposed to the bank of a river at the conceptual layer (ref. priming methods). The purpose was to tease out how automatic priming, schema induction, and spread of activation as mental/cognitive processes continue to be critical in lexical access and reading comprehension. The more readers can instantiate associative patterns and automatically induce schemas, the more they see connections in reading, therefore, the less they spend time generating meaning in a text, and the more they have attention allocated to other cognitive resources. The control group was not exposed to any of these treatments. All the scores were computed into mean and standard deviation. The higher the mean scores individuals could attain, the better they were in reading comprehension and lexical access, size of vocabulary, and lexical access and attention control. The experiment on research question three on attentional control (AC) was measured principally through an adapted version of Hutchinson's (2007) AC battery to investigate individual differences in primming in reading for both forward associates, as well as backward associates and symmetric associates (IFA; e.g., atom– bomb) and backward associates (BA, e.g., fire– blaze), as well as symmetric associates (SYM; e.g., brother–sister, respectively). Associative strengths were equal bidirectionally. Therefore, we predicted that AC would relate positively to proactive expectancy generation. The reason for this prediction was that cognitively, a text reader needs to generate and maintain likely targets in working memory between prime and target.

VIII. RESULTS

Descriptive statistics of pre-test and post-test scores

Table 2: Descriptive statistics of pre-test and post-test scores

	Groups	N	Mean Scores		Standard Deviation	
			Pre-test	**Post-test**	**Pre-test**	**Post-test**
Automatic priming in Reading and lexical access in L2	Experimental group 1	40	34.14	44.10	0.81	0.79
	Experimental group 2	40	33.05	37.12	0.76	0.76
	Control group	40	33.01	25.16	0.67	0.65
Size of vocabulary and lexical access in L2 through schema induction	Experimental group 1	40	36.16	43.98	0.79	0.66
	Experimental group 2	40	35.89	42.99	0.74	0.64
	Control group	40	30.19	28.98	0.66	0.60
Attention control and lexical access in L2 through spread of activation	Experimental group 1	40	36.18	45.65	0.78	0.70
	Experimental group 2	40	36.19	45.81	0.77	0.72
	Control group	40	22.20	19.89	0.67	0.61

Test of Homogeneity of Variances

Table 3: Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
7.058	2	290	.001

That is, the test for homogeneity of variances was significant with F(2, 290)=7.059, p<0.05 (two-tailed). Therefore, the Welch's F was used for the ANOVA test, and Games- Howell was used for the Post Hoc test.

Robust Tests of Equality of Means

Table 4: Robust Tests of Equality of Means

	Statistic	df1	df2	Sig.
Welch	6.168	2	191.925	.000

The robust test of equality of means, as seen in Table 4, shows that there were some s significant differences among the three study variables groups in respect of the control group F(2, 191.925)= 6.168 p<0.05 (two-tailed). Again, since the test result on equality of means was significant, we needed to compare the three study variables vis-à-vis the control group (since the differences between the two experimental groups were insignificant) to know where the difference was. Games-Howell test was run, and the result is as shown in Table 5 below:

Table 5. Comparison of mean post-test scores on automatic priming in reading and lexical access in L2, size of vocabulary and lexical access in L2 through schema induction, attention control, and lexical access in L2 through the spread of activation

		Mean Difference	p-Value
automatic priming in reading and lexical access in L2	Control Group	12. 83	0.000
size of vocabulary and lexical access in L2 through schema induction	Control Group	13.89	0.000
attention control and lexical access in L2 through spread of activation	Control Group	17 8.3	0.000

IX. DISCUSSION

The underlying reason for this paper was to examine the psychological idea that automatic priming, schema induction, and spread of activation in lexical access varies as a function of readers ability to automatically generate these cognitive processes through the size and depth of vocabulary and attentional control through spread of activation. In all three post-tests conducted to find some answers to the research questions, as indicated in Table 2, the differences between the two experimental groups, on the one hand, and the control, on the other, were statistically significant. The two experimental groups exposed to systematic interventions in the three psychological processes of automatic priming, schema induction, and spread of activation understandably outperformed the control group in all the post-tests results. As indicated in this study, the results appear to, overall, support the assumption that association effect either through automatic priming, schema induction, or spread of activation is not underscored by a single mechanism (Koriat & Melkman, 1981). Rather these cognitive processes (especially spread of activation) seem to result from either or both of the subsequent processes: a) a spreading activation process in which the processing of a semantic element automatically activates all associated elements in the semantic network, or b) an active-attentional process which involved the anticipation of, and the preparation for, a prime-related target word or an active-attentional process involving the anticipation of, and c) the preparation for, a prime-related target word.

After participants had undergone some treatment, the post-test results' data suggest how existing knowledge guides cognitive processes of what functions as relevant units, especially in lexical access and text discourse. This indicates how subsequent cognitive learning processes such as automatic priming, schema induction and spread of activation seemed to get better differentiated, and thus leading to the progressive differentiation of larger chunks in text into smaller units and using these to control any possible uncertainty in communication. It is in this respect that the findings in this study seem to corroborate Ramscar and Baayen (2013), Ramscar and Port (2015). Given that all the participants in this experimental pre-test-posttest research were relatively of the same higher mental/cognitive ability and were randomly assigned into two experimental groups and control. After treatment, the two experimental groups performed relatively better, indicating the possible effect of the treatment. This supports the submission that in cognitive processes, be it automatic priming, schema induction or spread of activation, depending on what is already known, new relations could be easy or difficult (especially in text discourse) depending on how easy it is off for a reader to be able to differentiate them as distinct (Ellis, 2006; Milin, Feldman, Ramscar, Hendrix, & Baayen, 2017).

Even though some research findings raise doubts about a single mechanism underlying context, such as in Stroop tasks, categorization tasks, as lexical decision tasks, such as Collins and Loftus (1975), the data as indicated in this study strongly suggest that the association effect in the post-test results in all the three study variables may be seen to have resulted from either or both of the following cognitive processes: a) spreading activation in which processing of semantic element automatically activated all the related/associative elements in the semantic network, or b) an active-attentional process induced anticipation of, and the preparation for some prime-related target. The comparison of mean post-test scores under the attention control variable and lexical access suggests this. This critical finding of the correlation between priming, induction, and attentional control, as shown in Table 4, seems to corroborate Hutchison, Heap, Neely, and Thomas's (2014) in which priming, for example, increased with attentional control as well as Hutchison's (2007) finding in which effects in pronunciation, for example, was linearly related to attention control. The most plausible explanation for this seemed to be that when readers were high in attention control either through effective automatic priming or schema induction, attentional constraints were limited. Therefore, readers with limited attentional constraints engaged in a more proactive strategy to generate likely associated targets (Becker, 1980) than those with more constraints. This also resonates with Balota, Yap, Cortese, and Watson's (2008) discussion on the relationship between prelexical processes, such as expectancy, and a general shift in priming. Thus, individual differences in mental processing, such as the three variables examined in this study, do not remain invariant. The number and complexity of information units being processed at any time in text discourse, if not circumvented through automatic priming, the spread of activation and schema induction resulted in higher mental load, which obstructed skilled reading (Sweller, van Merriënboer, & Paas, 2019). The probability that what was read, understood, and learned (i.e., encoded into long-term memory) was largely contingent on readers ability to integrate new information into existing schemata. This was influenced by the degree of the cognitive load imposed by the complexity of the written material during reading (Kintsch, 2009). Thus, whether a reader was obstructed was directly related to mental economy, which in turn was highly correlated with the ability to structure knowledge/information in any of the three study variables of this study, that is, automatic priming, spread of activation, and schema induction.

X. CONCLUSION

The critical findings from this present study were that cognitive differences in automatic priming, schema induction, and spread of activation predicted enhanced reading comprehension in L2, especially how fast one could infer from text since they helped to reduce cognitive load involved in reading as has been established in the literature. Second, the ability to use automatic priming, schema induction, and spread of activation to reduce mental load to facilitate comprehension was also determined by the size and level of vocabulary that the reader possessed in his/her long-term memory. Third, a major finding was that priming, the spread of activation, and schema induction increased with increasing attentional control. The most plausible explanation was that those high in attentional control were more likely to be involved in a proactive expectancy strategic use of priming, the spread of activation, and schema induction to generate possible targets. These differences remain invariant unless classroom practices are deliberately designed to help less enhanced readers strategies to promote induction, priming, and activation besides increasing the size and depth of vocabulary.

10. Limitations of this Study

This study was conducted in only three (3) regions out of the sixteen (16) administrative regions of the study area. Findings may not represent the entire study area, even though they offer some reliable psychological indicators of how the variables studied implicate lexical access of second language readers. There is a need for further research on how automatic priming, schema induction, and spread of activation also implicate lexical access for readers in the native/maternal language (L1) of similar respondents in senior high schools to ascertain whether they perform better in L1 or L2 for lexical access.

References

Acero, A. R., Cano-Prous, A., Castellanos, G., Martín-Lanas, R., & Canga-Armayor, A. (2017). Family identity and severe mental illness: A thematic synthesis of qualitative studies. *European Journal of Social Psychology, 47*(5), 611-627. https://doi.org/10.1002/ejsp.2240.

Allen, P. A., Lien, M. C., Murphy, M. D., Sanders, R. E., Judge, K. S., & McCann, S. R., (2002). Age differences in overlapping-task performance: evidence for efficient parallel processing in older adults. *Psychol. Aging, 17(*3), 505–519. https://doi.org/10.1037/0882-7974.17.3.505.

Anderson, J. R. & Milson, R. (1989). Human memory: An adaptive perspective. *Psychological Review, 96*(4), 703–719. https://doi.org/10.1037/0033-295X.96.4.703.

Anderson, J. R. (1983). A spreading activation theory of memory. *Journal of verbal learning and verbal behavior, 22*(3), 261-295. https://doi.org/10.1016/S0022-5371(83)90201-3.

Andrews, S. (2012). Individual differences in skilled visual word recognition and reading: The role of lexical quality. In J. S. Adelman (Ed.), *Visual word recognition volume 2: Meaning and context, individuals, and development* (pp. 151–172). Hove: Psychology Press.

Atkinson, R. C., Shiffrin, R. M. (1968). Human memory: a proposed system and its control processes. In K. W. Spence & J. T. Spence (Eds.). *The Psychology of Learning and Motivation: Advances in Research and Theory* (pp. 89–195). New York: Academic.

Balota, D. A., & Lorch, R. F. (1986). Depth of automatic spreading activation: Mediated priming effects in pronunciation but not in lexical decision. *Journal of Experimental Psychology: Learning, memory, and cognition, 12*(3), 336-345. https://doi.org/10.1037/0278-7393.12.3.336.

Balota, D. A., Black, S. R., & Cheney, M. (1992). Automatic and attentional priming in young and older adults: reevaluation of the two-process model. *Journal of Experimental Psychology: Human Perception and Performance, 18*(2), 485–502. https://doi.org/10.1037/0096-1523.18.2.485.

Balota, D. A., Yap, M. J., Cortese, M. J., & Watson, J. M. (2008). Beyond mean response latency: Response time distributional analyses of semantic priming. *Journal of Memory and Language, 59*(4), 495–523. https://doi.org/10.1016/j.jml.2007.10.004.

Becker, C. A. (1980). Semantic context effects in visual word recognition: An analysis of semantic strategies. *Memory & Cognition, 8,* 493–512. https://doi.org/10.3758/BF0321376.

Bodner, G. E., & Masson, M. E. J. (2003). Beyond spreading activation: An influence of relatedness proportion on masked semantic priming. *Psychonomic Bulletin and Review, 10*(3), 645-652. https://doi.org/10.3758/BF03196527.

Cleland, A. A., Gaskell, M. G., Quinlan, P. T., & Tamminen, J., (2006). Frequency effects in spoken and visual word recognition: Evidence from dual-task methodologies. *Journal of Experimental Psychology: Human Perception and Performance, 32*(1), 104–119. https://doi.org/10.1037/0096-1523.32.1.104.

Collins, A. M., & Loftus, E. F. (1975). A spreading-activation theory of semantic processing. *Psychological Review, 82*(6), 407–428. https://doi.org/10.1037/0033-295X.82.6.407.

Coltheart, M., Rastle, K., Perry, C., Langdon, R., & Ziegler, J. (2001). DRC: a dual route cascaded model of visual word recognition and reading aloud. *Psychol. Rev, 108*(1), 204–256. https://doi.org/10.1037/0033-295X.108.1.204.

Dagenbach, D., Horst, S., & Carr, T. H. (1990). Adding new information to semantic memory: How much learning is enough to produce automatic priming?. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16*(4), 581–591. https://doi.org/10.1037/0278-7393.16.4.581.

De Debat, E. V. (2006). Applying current approaches to the teaching of reading. *English teaching forum, 44*(1), 8-15. Retrieved from https://files.eric.ed.gov/fulltext/EJ1107882.pdf.

Dosher, B. A., & Rosedale, G. (1989). Integrated retrieval cues as a mechanism for priming in retrieval from memory. *Journal of Experimental Psychology: General, 118*(2), 191–211. https://doi.org/10.1037/0096-3445.118.2.191.

Ellis, R. (2006). Current Issues in the Teaching of Grammar: An SLA Perspective. *TESOL Quarterly, 40*(1), 83-107. https://doi.org/10.2307/40264512.

Forster, K. I. (1976). Accessing the mental lexicon. In: Wales, R.J., Walker, E.W. (Eds.), *New Approaches to Language Mechanisms* (pp. 257–287). Amsterdam, North-Holland.

Gagné, E. D. (1985). *The cognitive psychology of school learning*. Boston, MA: Little, Brown and Company.

Gagne, R. (1985). *The conditions of learning and theory of instruction Robert Gagné*. New York, NY: Holt, Rinehart ja Winston.

Gough, P. B., & Tunmer, W. E. (1986). Decoding, reading, and reading disability. *Remedial and special education, 7*(1), 6-10. https://doi.org/10.1177/074193258600700104.

Halford G. S., & Busby, J. (2007) Acquisition of structured knowledge without instruction: the relational schema induction paradigm. *Journal of Experimental Psychology: Learning, Memory and Cognition. 33*(3), 586–603. https://doi.org/10.1037/0278-7393.33.3.586.

Halford, G. S., Bain, J. D., Maybery, M. T., & Andrews, G. (1998) Induction of relational schemas: Common processes in reasoning and complex learning. *Cognitive Psychology, 35*(3), 201–245. https://doi.org/10.1006/cogp.1998.0679.

Hebb, D. O. (1949). Temperament in chimpanzees: I. Method of analysis. *Journal of Comparative and Physiological Psychology, 42*(3), 192–206. https://doi.org/10.1037/h0056842.

Hinton, G. E., & Shallice, T. (1991). Lesioning an attractor network: Investigations of acquired dyslexia. *Psychological Review, 98*(1), 74–95. https://doi.org/10.1037/0033-295X.98.1.74.

Hoover, W. A., Gough, P. B. (1990). The simple view of reading. *Reading Writing, 2*, 127–160. https://doi.org/10.1007/BF00401799.

Hutchison, K. A. (2007). Attentional control and the relatedness proportion effect in semantic priming. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 33*(4), 645–662. http://dx.doi.org/10.1037/0278-7393.33.4.645.

Hutchison, K. A., Balota, D. A., Neely, J. H., Cortese, M. J., Cohen-Shikora, E. R., Tse, C-S., … & Buchanan, E. (2013). The Semantic Priming Project. *Behavior Research Methods, 45*, 1099–1114. https://doi.org/10.3758/s13428-012-0304-z.

Hutchison, K. A., Heap, S. J., Neely, J. H., & Thomas, M. A. (2014, February 17). Attentional Control and Asymmetric Associative Priming. *Journal of Experimental Psychology: Learning, Memory, and Cognition*. http://doi.org/10.1037/a0035781.

Kahle, W. (1979). Band 3: nervensysteme und Sinnesorgane, in Taschenatlas deanatomie. Stuttgart. In W. Kahle, H. Leonhardt & W. Platzer (Eds). New York, NY, United States: Thieme Verlag.

Keele, S. W. (1973). *Attention and Human Performance*. Goodyear, Pacific Palisades, CA.

Kinoshita, S., Forster, K. I., & Mozer, M. C. (2008). Unconscious cognition isn't that smart: Modulation of masked repetition priming effect in the word naming task. *Cognition, 107*(2), 623-649. https://doi.org/10.1016/j.cognition.2007.11.011.

Kinoshita, S., Mozer, M. C., & Forster, K. I. (2011). Dynamic adaptation to history of trial difficulty explains the effect of congruency proportion on masked priming. *Journal of Experimental Psychology: General, 140*(4), 622-636. https://doi.org/10.1037/a0024230.

Kintsch, W. (2009). Learning and constructivism. In S. Tobias & T. M. Duffy (Eds.), *Constructivist Instruction: Success or failure?* New York, NY: Routledge.

Koriat, A., & Melkman, R. (1981). Individual differences in memory organization as related to word-association, object-sorting, and word-matching styles. *British Journal of Psychology, 72*(1), 1–18. https://doi.org/10.1111/j.2044-8295.1981.tb02157.x.

Korteling, J. E., van de Boer-Visschedijk G. C., Blankendaal, R. A., Boonekamp, R. C., & Eikelboom, A. R. (2021) Human- versus Artificial Intelligence. *Frontiers in Artificial Intelligence, 4*, 622-364. https://doi.org/10.3389/frai.2021.622364.

Lemhöfer, K., & Broersma, M. (2012). Introducing LexTALE: A quick and valid lexical test for advanced learners of English. *Behavior research methods, 44*, 325-343. https://doi.org/10.3758/s13428-011-0146-0.

Lien, M. C., Allen, P. A., Ruthruff, E., Grabbe, J., McCann, R.S., Remington, R. W., (2006). Visual word recognition without central attention: evidence for greater automaticity with advancing age. *Psychology and Aging, 21*(3), 431–447. https://doi.org/10.1037/0882-7974.21.3.431.

Lowe, C., & Rabbitt, P. (1998). Test/re-test reliability of the CANTAB and ISPOCD neuropsychological batteries: Theoretical and practical issues. *Neuropsychologia, 36*(9), 915–923. https://doi.org/10.1016/S0028-3932(98)00036-0.

Lupker, S. J. (2008). Visual word recognition: Theories and findings. In M. J. Snowling, C. Hulme (Eds.), *The Science of Reading: A Handbook* (pp. 39–60). Oxford: Blackwell Publishing https://doi.org/10.1002/9780470757642.ch3.

Masson, M. E. J. (1995). A distributed memory model of semantic priming. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21*(1), 3–23. https://doi.org/10.1037/0278-7393.21.1.3.

McCann, R. S., Remington, R. W., & Van Selst, M. (2000). A dual-task investigation of automaticity in visual word processing. *Journal of Experimental Psychology: Human Perception and Performance, 26*(4), 1352–1370. https://doi.org/10.1037/0096-1523.26.4.1352.

McClelland, D. (1982). Understanding psychological man: A state of the science report. *Psychology. Today, 16*(5), 40–59.

McClelland, J. L., & Rumelhart, D. E. (1981). An interactive activation model of context effects in letter perception: I. An account of basic findings. *Psychological Review, 88*(5), 375-407. https://doi.org/10.1037/0033-295X.88.5.375.

McKoon, G., & Ratcliff, R. (1992). Spreading activation versus compound cue accounts of priming: Mediated priming revisited. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 18*(6), 1155–1172. https://doi.org/10.1037/0278-7393.18.6.1155.

McNamara, T. P. (1992a). Priming and constraints it places on theories of memory and retrieval. *Psychological Review, 99*(4), 650–662. https://doi.org/10.1037/0033-295X.99.4.650.

McNamara, T. P. (1992b). Theories of priming: I. Associative distance and lag. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 18*(6), 1173-1190. https://doi.org/10.1037/0278-7393.18.6.1173.

McNamara, T. P. (2005). *Semantic priming: Perspectives from memory and word recognition*. Hove, UK: Psychology Press.

Meyer, D. E., & Schvaneveldt, R. W. (1971). Facilitation in recognizing pairs of words: Evidence of a dependence between retrieval operations. *Journal of Experimental Psychology, 90*(2), 227–234. https://doi.org/10.1037/h0031564.

Milin, P., Feldman, L. B., Ramscar, M., Hendrix, P., & Baayen, H. (2017). Discrimination in lexical decision. *PLoS ONE, 12*(2), e0171935. https://doi.org/10.1371/journal.pone.0171935.

Miller, G. A. (1994). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review, 3*(2), 81–97. https://doi.org/10.1037/h0043158.

Morton, J., (1969). Interaction of information in word processing. *Psychological Review, 76*(2), 165–178. https://doi.org/10.1037/h0027366.

Mullis, I. V., Martin, M. O., Foy, P., & Arora, A. (2012). *Trends in international mathematics and science study (TIMSS) 2011 international results in mathematics*. TIMSS & PERLY, International study Center, Lynch School of Education: Boston College.

Neely, J. H. (1991). Semantic priming effects in visual word recognition: A selective review of current findings and theories. In D. Besner & G. Humphreys (Eds.), *Basic processes in reading: Visual word recognition* (pp. 236-264). Hillsdale, NJ: Erlbaum.

Neely, J. H., Keefe, D. E., & Ross, K. L. (1989). Semantic priming in the lexical decision task: Roles of prospective prime-generated expectancies and retrospective semantic matching. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15*(6), 1003–1019. https://doi.org/10.1037/0278-7393.15.6.1003.

Ntim, S. (2015). Comprehension skills differences between proficient and less proficient readers in word-to-text integration processes: Implications for interventions for students with reading problem. *International Journal of Learning, Teaching & Educational Research, 13*(13), 41-61. Retrieved from https://ijlter.myres.net/index.php/ijlter/article/view/1015.

Ntim, S. (2017). Does text familiarity predict schema automation to reduce working memory capacity constraints for enhanced reading comprehension? A study from Ghana. *International Journal of Research Studies in Psychology, 6*(2), 103-116. https://doi.org/10.5861/ijrsp.2017.1892.

Parasuraman, R. (2003) Neuroergonomics: Research and practice, *Theoretical Issues in Ergonomics Science, 4*(1-2), 5–20. https://doi.org/10.1080/14639220210199753.

Pashler, H., (1984). Processing stages in overlapping tasks: evidence for a central bottleneck. *Journal of Experimental Psychology: Human Perception and Performance, 10*(3), 358–377. https://doi.org/10.1037/0096-1523.10.3.358.

Pashler, H., Johnston, J.C., (1989). Chronometric evidence for central postponement in temporally overlapping tasks. *The Quarterly Journal of Experimental Psychology, 41*(1), 19–45. https://doi.org/10.1080/14640748908402351.

Pexman, P. M. (2012). Meaning-based influences on visual word recognition. In J. S. Adelman (Ed.), *Visual Word Recognition, Meaning and Context, Individuals and Development* (Vol. 2, pp. 24-43). London: Psychology Press. https://doi.org/10.4324/9780203106976.

Pexman, P. M., Hargreaves, I. S., Siakaluk, P. D., Bodner, G. E., & Pope, J. (2008). There are many ways to be rich: Effects of three measures of semantic richness on 96 visual word recognition. *Psychonomic Bulletin and Review, 15*, 161–167. https://doi.org/10.3758/PBR.15.1.161.

Pexman, P. M., Lupker, S. J., & Hino, Y. (2002). The impact of feedback semantics in visual word recognition: Number-of-features effects in lexical decision and naming tasks. *Psychonomic Bulletin and Review, 9*, 542-549. https://doi.org/10.3758/BF03196311.

Plaut, D. C., & Booth, J. R. (2000). Individual and developmental differences in semantic priming: Empirical and computational support for a single-mechanism account of lexical processing. *Psychological Review, 107*(4), 786–823. https://doi.org/10.1037/0033-295X.107.4.786.

Plaut, D. C., McClelland, J. L., Seidenberg, M. S., & Patterson, K. (1996). Understanding normal and impaired word reading: computational principles. *Psychological Review, 103*(1), 56–115. Retrieved from https://citeseerx.ist.psu.edu.

Posner, M. I., & Snyder, C. R. R. (1975). Attention and cognitive control. In R. Solso (Ed.), *Information processing and cognition: The Loyola symposium* (pp. 55-85). Hillsdale, NJ: Erlbaum.

Qian, D. D. (2002). Investigating the relationship between vocabulary knowledge and academic reading performance: An assessment perspective. *Language learning, 52*(3), 513-536. https://doi.org/10.1111/1467-9922.00193.

Ramscar, M., & Baayen, H. (2013) Production, comprehnsion and synthrsis: A communicative perspective on language, *Frontiers in Psychology, 4*(233), 1-4. https://doi.org/10.3389/fpsyg.2013.00233.

Ramscar, M., & Port, R. (2015). "Categorization (without categories)". In E. Dabrowska & D. Divjak (Eds.), *Handbook of Cognitive Linguistics* (pp. 75-99). Berlin, München, Boston: De Gruyter Mouton. https://doi.org/10.1515/9783110292022-005.

Reicher, G. M. (1969). Perceptual recognition as a function of meaningfulness of stimulus material. *Journal of Experimental Psychology, 81*(2), 275-280. https://doi.org/10.1037/h0027768.

Rumelhart, D.E. & McClelland, J. (1986). On learning the past tense of English verbs. In D. E. Rumelhart & J. L. McClelland (Eds.), *Parallel Distributed Processing* (Vol. 2). Cambridge, Mass: MIT Press.

Schweickert, R. (1978). A critical path generalization of the additive factor method: analysis of a Stroop task. *Journal of Mathematical Psychology, 18*(2), 105–139. https://doi.org/10.1016/0022-2496(78)90059-7.

Seidenberg, M. S., & McClelland, J. L. (1989). A distributed developmental model of word recognition and naming. *Psychological Review, 96*(4), 523–568. https://doi.org/10.1037/0033-295X.96.4.523.

Sharkey, A. J., & Sharkey, N. E. (1992). Weak contextual constraints in text and word priming. *Journal of Memory and Language, 31*(4), 543-572. https://doi.org/10.1016/0749-596X(92)90028-V.

Sweller, J., van Merriënboer, J. J., & Paas, F. (2019). Cognitive architecture and instructional design: 20 years later. *Educational Psychology Review, 31*, 261–292. https://doi.org/10.1007/s10648-019-09465-5.

Telford, C. W. (1931). The refractory phase of voluntary and associative responses. *Journal of Experimental Psychology, 14*(1), 1–36. https://doi.org/10.1037/h0073262.

UNESCO Institute for Statistics (UIS). (2020). *Trends in International Mathematics and Science Study*. Retrieved from https://naec.news.

Waechter, S., Stolz, J. A., & Besner, D. (2010). Visual word recognition: On the reliability of repetition priming. *Visual Cognition, 18*(4), 537-558. https://doi.org/10.1080/13506280902868603.

Welford, A.T. (1952). The "psychological refractory period" and the timing of high-speed performance: A review and a theory. *British. Journal of Psychol, 43*(1), 2. Retrieved from https://www.proquest.com.

Wheeler, D. D. (1970). Processes in word recognition. *Cognitive Psychology, 1*(1), 59–85. https://doi.org/10.1016/0010-0285(70)90005-8.

Whittlesea, B. W. A., & Jacoby, L. L. (1990). Interaction of prime repetition with visual degradation: Is priming a retrieval phenomenon? *Journal of Memory and Language, 29*(5), 546-565. https://doi.org/10.1016/0749-596X(90)90051-Z.

Yap, M. J., Pexman, P. M., Wellsby, M., Hargreaves, I. S., & Huff, M. J. (2012). An abundance of riches: Cross-task comparisons of semantic richness effects in visual word recognition. *Frontiers in Human Neuroscience, 6,* 1–10. https://doi.org/10.3389/fnhum.2012.00072.