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The Role of Linguistic Structure in Sentence and Text Comprehension: A Comparative Analysis of Depth-First Versus Breadth-First Models

Nahed Ghazzoul
MoDyCo (Models, Dynamiques, Corpus), Département de Sciences du langage, Paris Nanterre University, France

***Abstract*—This study assumes that linguistic structure plays a significant role in comprehending sentences and texts. It also assumes that the process of learning requires inferences to make connections across and within the local and global discourse contexts. To establish these connections, there is a need of integrating information from prior content of discourse and knowledge or from the reader's schemata to build a coherent memory that represents the events and concepts which describe the texts. To that end, the paper reviews studies on depth-first versus breadth-first models, adopted by the parsers, which address the linguistic structure in sentence and text comprehension. It further examines how the readers' or listeners' long-term memory and mental models affect the sentence and text comprehension. The findings of the study show that vocabulary depth and breadth are two important constructs to consider while assessing higher-level processing of reading comprehension. It also shows that having a comprehensive understanding of the gradations of the meaning of a word in a variety of contexts will permit the readers to develop a better understanding of the text, and in turn, to better express themselves.**

***Index Terms*—linguistic structure, text sentences, breadth-first model, depth-first model, linguistic comprehension skills**

I. Introduction

Language is a mandatory tool to communicate with other people and is closely knitted to emotional and social functioning (Rogde et al., 2019). According to Clifton et al. (2019), information about linguistic structure helps to comprehend texts and sentences. However, there is a long debate about how structural knowledge may help comprehend texts and sentences. Scholars have answered this question by stating that linguistic structure has a significant role in understanding sentences and texts (Fodor et al., 1974).

Retrospectively, in the mid-1970s, the focus was on the way linguistic structure was formulated to comprehend texts and sentences. In turn, this led to an episode of theoretical suggestions proposed by linguists and computer scientists (Frazier, 1979; Frazier & Fodor, 1978; Kimball, 1973; Marcus, 1978), who elaborated on the algorithm of using phrasal structural rules and other grammatical tools in comprehending sentences. The intrigued interest was in how such a limited amount of information guides the process of comprehension that grows in the process of discourse, driven by the development of grammar stories, and how the listeners and readers use references anaphorically to connect sentences in speech (Mandler & Johnson, 1977; Van den Broek & Helder, 2017).

In the mid of '80s, interactive connectionist theories based on sentence comprehension became more popular. They described how the limitations of the frequent use of linguistic structure, plausibility, and context could be resolved (MacDonald et al., 1994; Tanenhaus et al., 1989).

In general, research on sentence comprehension declares that the listener or reader, while going through the content, initially, constructs its meaning based on grammatical grounds, instead of going towards semantic interpretation, which sometimes requires word-to-word revision (Frazier, 1979; Frazier & Rayner, 1982). According to Frazier (1987), the analysis of a sentence is made by the reader or listener to attach every new word syntactically after knowing the phrase structure as per the grammar rules, or what he calls the depth-first, or garden-path theory. Frazier and Clifton (1996) add that garden-path theory, predicts the difficulties in comprehending sentences.

This study assumes that linguistic structure can play a pivotal and significant role in comprehending sentences and texts. Therefore, it reviews studies on depth-first versus breadth-first models, which address the linguistic structure in sentence and text comprehension. It also examines the aspects of the text that go beyond the linguistic structure and consolidate the text comprehension. Finally, the readers' or listeners' long-term memory and mental models affect the sentence and text comprehension.

II. Literature Review

A. The Task of Sentence Comprehension

The gap that exists between the word and the message is bridged by sentence comprehension. The sentence meaning is extracted from the purpose of its words, channelled by grammatical relations between the words of a sentence (Clifton, 2015). The psychology of sentence comprehension is related to a cognitive process that allows the reader to understand the way the meaning of the words is combined to satisfy the writer's or the speaker's intention. Related to sentence structure, listeners and readers must be sensitive to the elusive pieces of information. Their task is confusing as they must be liable to the structural relations that randomly extend to long distances (Clifton, 1992). The problem faced by readers and listeners relates to the universal ambiguity of the language. This ambiguity can be in the speech stream, which is segmented at various points into different words. During the process of comprehension, listeners may make interpretations based on what they hear. The memory of a sentence may be linked to the prior knowledge of the event described, resulting in a more comprehensive mental image than the original statement. The inferred information may serve as a cue for the reconstruction of original encoding at retrieval. This encoding provides the rationale for some studies based on sentence memory (Barclay et al., 1974).

In fact, a word can have more than one lexical concept such as bank of a river, which versus the bank to deposit or withdraw money, or the word tender, which means loving or kind in one context, and easy to cut in another, or young in a third; or to give or offer in a fourth, and buy things in formal stated price in a fifth among other meanings. Readers and listeners are now aware of such uncertainties, but their cognitive process effectively resolves them in the course of sentence construction (Cutler et al., 1997). Previous studies on vocabulary in both first, and second languages indicate that knowledge of vocabulary is the best predictor to improve reading ability or increase the capability to gain new elements from the texts (Nation, 2001; Qian, 2002; Read, 2000; Tanenhaus et al., 2006). Likewise, Hu and Nation (2020) states that the amount of unfamiliar and familiar vocabulary is very important and is considered as one of the critical indicators in distinguishing the difficulties of reading a passage. Confirming the mutual relationship between vocabulary and reading comprehension, Stahl (2003) states that the knowledge of the vocabulary system of a language is the best indicator of text difficulty. This means that readers build on their previous knowledge or schema to facilitate the process of reading and writing texts.

According to Schema theory, comprehending a text is an interactive process that takes place “between the reader’s background knowledge and the text” (An, 2013, p. 130). It is necessary to have the ability to relate to textual material with one’s knowledge. Comprehending sentences, words or the whole text involves not just being dependent on one’s linguistic knowledge, rather on one's knowledge about the world. Echoing this, Shen (2008) confirms that the more knowledge one has about the world, the better the comprehension of the text he develops.

B. Schema Theory in Reading and Writing

The term schema has been first used in psychology to refer to the dynamic organisation of past experiences or reactions. It concludes that written texts do not provide meaning by themselves, but they show directions to the readers about how they can extract or construct meaning based on previous knowledge. The theory can help guide the readers to comprehend texts from a global perspective. That is why the role of schema theory in understanding texts cannot be neglected (An, 2013). The schema theory states that comprehending texts is a collaborative process between the reader's prior knowledge and the text. Understanding texts efficiently requires the ability to make associations of textual material with one's knowledge.

According to An (2013) there are three models of reading that account for the comprehension process, “such as the bottom-up model, top-down model, and interactive model. It is the interactive model that fundamentally promotes the development of theories in reading, especially schema theory. In the schema-theoretical view, reading is an interactive process” (p. 134). She adds that “interaction happens at three levels: interaction between bottom-up and top-down processing; that between lower-level and high-level skills, and between the reader's background knowledge and the knowledge presupposed in the text” (p.134). Bottom-up processing is triggered by certain data inferred from the text, whereas top-down processing starts with general assumptions depending on schemata and then looks at the more specific information to validate these assumptions. However, both processes always occur interactively and simultaneously in reading, and readers use them two interchangeably for comprehension. Therefore, it can be said that “schema theory guides readers as they make sense of new experiences and also enables them to make predictions about what they might expect to experience in a given context” (p.134). It offers a cognitive ground for integrating reading and writing instructions. It argues that writers should develop a background and structural schemata to compose and comprehend texts. It also states that some instructional strategies may enhance the development of schemata. According to Smith (1982), both reading and writing convey language, and they deal with meaning, because readers extract meaning and writers produce it. Both of these activities involve a complementary transaction between a writer, a reader and a text. At this stage, readers mostly rely on alternating effects of breadth-first and depth-first strategies to achieve the purpose of understanding. This process of reading should be the process of thinking. To develop background knowledge, it is essential to get into extensive reading programs as background knowledge which determines the depth and breadth of reading comprehension. The readers can establish a connection between old knowledge and the new knowledge (Yan, 2020), which are linked with the readers’ short-term and long-term memories as well as their reading ability. Different types of schemata have been suggested by An (2013), and this depends on the nature of content such as “formal schemata which relate to the rhetorical structure of the text; content schemata, relating

to the content of the text; and cultural schemata, which comprise general aspects of cultural knowledge shared by large sections of a cultural population" (p.130). Moreover, Carell and Wise (1998) added that linguistic schemata, which relate to the knowledge of vocabulary and grammar, play a rudimentary role in a comprehensive understanding of the text.

C. Psychological Models of Sentence Comprehension

Earlier theories of grammar state that the rules which form a linguistic theory are identified by language users and applied when learning them. This was not the situation with the directions given by the early transformational grammar. Their rules were functional on domains such as clauses, and soon it became clear that people did not wait to the end of the clause to understand a sentence. The comprehensive review of readability research by Chall (1958) in the first half of the 20th century divided the earlier work into "experimental and survey studies" and "quantitative associational studies".

Likewise, Buswell (1937) was at the University of Chicago, when he surveyed 1,000 adults with different educational backgrounds. To assess their reading levels, he used traditional tests of vocabulary and paragraphs and asked participants to read ads, and telephone directories. At the end, he found out that there was a correlation between reading skills, and the number of years of education and reading practices.

In the 1970s, grammar used more restrictive rules which led to the development of a new set of grammar-based theories. These theories stated that people use grammar rules among a wide range of alternative practices to analyze a sentence (Frazier, 1987; Frazier & Clifton, 1996; Mitchell, 1994). For example, readers join every new word to a sentence structure in the easiest and quickest possible way by using different grammatical links such as relative pronouns to increase the clarity of the sentences. Generally speaking, the study of sentence comprehension emphasizes on how the listeners and readers map words which construct the meaning of what they read. This task of mapping is guided by their familiarity with the grammar of their language (Safi et al., 2020). Despite the fact that what Safi et al., (2020) are saying is true, but one cannot forget the role of the level of proficiency of the students, and the amount of the vocabulary they know in the process of facilitation of mapping and their language.

Understanding the meaning of the sentence based on lexis has been extended by the lexicalist theories of sentence comprehension (MacDonald et al., 1994). They claim that lexical structure, context and frequency are natural effects which help the readers to comprehend sentences. They vary from depth-first to breadth-first processing (Clifton, 2000), and focus on the unique contributions of individual words rather than on the broad applicability of word combinations.

In the 1970s and '80s, linguistic theory moved away from suggesting the applicability of rules to making claims about the information contained in the individual lexical items, whereas, the contemporary theories of sentence comprehension differ in the range of information they claim that guide the analysis of the sentence. For example, Garden-path theories are based on modular learning. They state that a single analysis is, first, constructed, and later evaluated. This means that different modules or areas in the brain are responsible for specific processes which are thought to be competed with an interactive model (Fodor, 1978). Furthermore, they claim that only certain necessarily relevant types of information affect initial decisions about sentence structure. They explain more adequately how sentence structures are created and this is called a garden path sentence. According to Forrest and van Schijndel (2020), a garden-path sentence is the sentence which is confusing and ambiguous because it includes a group of words that could carry more than one meaning. It creates a momentarily vague interpretation as it includes a phrase or a word that can be understood in multiple ways, so readers would go for a seemingly familiar meaning, whereas the real meaning refers to something else. Inferring the actual meaning requires rereading the sentence, and a careful consideration of the allegorical interpretation.

Rahman and Iqbal (2019) have investigated the relationship between breadth and depth of vocabulary knowledge and reading comprehension. Their study sample consisted of 124 students enrolled in public sector secondary school 10th grade. The results of the data analysis showed a high correlation between depth of vocabulary knowledge and reading comprehension, but a moderate relationship was seen between breadth of vocabulary knowledge and reading comprehension. The regression test showed that vocabulary depth has high predictive power compared to vocabulary breadth.

More discussion of sentence comprehension models will be presented the following sections.

D. First-Pass Effects in Sentence Processing

The two dimensions that are depth-first versus breadth-first processing have focused on effects in sentence processing. Depth-first theories such as garden-path, which is the means of making early predictions about the initial stages of parsing that refers to the syntactic analysis of the language, indicate that a single analysis is initially created, evaluated, and then kept. Some garden-path theories used eye-tracking data to show some commotions of reading that appear quickly, on the first fixation in a region of text (Frazier & Rayner, 1982; Rayner et al., 1983).

Moreover, the researchers who use eye-tracking data to back-up depth-first parsing models, acknowledged that different measures could specify disruptions. Altmann et al. (1992) proposed that any effect which makes itself noticeable in the form of second-pass reading times cannot say to be having a first-pass parsing effect. The differences

that occur in the first-pass reading times could be related to the parsing effects. They were cautious while conceptually differentiating between first-pass parsing effects and first-pass reading times. If possible, to disseminate a methodological principle like the first-pass time effect is equal to initial-analysis effects. It is better to look at the eye-tracking record to settle the questions if the initial analysis is constructed after following the same principle as the final analyses.

The purpose of such research is to find if early information affects the initial investigation. Comprehending the text efficiently requires the ability to make associations of textual material to one's knowledge. It called for re-examining the eye-movement record for evidence if early information eradicates the initial disturbance that comes with disambiguation, or if it just speeds up the revision and reanalysis. For example, Clifton (1992,1993) confirmed Stowe's (1989) observation in the self-paced incremental grammaticality-judgment task that appeared in his eye-tracking data, but only in sentence regions that followed the ambiguity and in measures of total reading time.

First-pass time in the ambiguity region showed different effects, reflecting plausibility of structurally determined analysis and not thematic preferences observed by Stowe. Let's discuss both approaches separately.

E. Depth-First Approach

This approach is applied during top-down parsing, where parsing refers to the process of segmenting sentences into units so the meaning of the sentence can be understood. Top-down parsing is a kind of search technique that means that if there is more than one grammatical rule applicable at one point, the parser will explore only one possibility, and look at others when that one fails to serve the purpose. A top-down search is an example of a depth-first approach. Consider Figure 1

		State	Comments
1.	s	*mia loved vincent*	`s ---> [np, vp]`
2.	np vp	*mia loved vincent*	`np ---> [pn]`
3.	pn vp	*mia loved vincent*	`lex(mia,pn)`
			We've got a match
4.	vp	*loved vincent*	`vp ---> [iv]`
			We're doing depth first search. So we ignore
			the other vp rule for the moment.
5.	iv	*loved vincent*	No applicable rule. Backtrack to the state in
			which we last applied a rule. That's state 4.
4'.	vp	*loved vincent*	`vp ---> [tv]`
5'.	tv np	*loved vincent*	`lex(loved,tv)`
			Great, we've got match!
6'.	np	*vincent*	`np ---> [pn]`
7'.	pn	*vincent*	`lex(vincent,pn)`
			Another match. We're done.

Figure 1: Depth-First Approach (Raffaella, 2014).

By looking at the sentence, "Mia loved Vincent," we find that it starts from the abstract and then moves to the concrete part, and makes use of context-free grammar (CFG). Top-down search is an example of depth-first approach because when a parser (interpreter/compiler) is faced with a choice, he/she selects one and works out of its consequences. If the parsers' option turns out to be incorrect by any chance, he or she backtracks. For example, in figure 1, a choice was given through which the verb phrase (vp) was built- either by using the intransitive verb or the transitive one. In step 4, the parser used the intransitive verb, but as it did not work out (state 5), he/she backtracked and then tried transitive verb (state 4'), which eventually worked out (Raffaella, 2014).

F. Breadth-First Approach

This approach is applied during bottom-up parsing. The difference between the two approaches is that all possible choices are used at once, rather than selecting one at a time. It is like working with a big bag that contains all the possibilities to look at. Therefore, a set-theoretic brace indicates that this bag is used. When parsing starts, the bag has only one item. Consider Figure 2 (Raffaella, 2014).

	State	Comments
1.	{⟨ s, *mia loved vincent*⟩}	s ---> [np, vp]
2.	{⟨ np vp, *mia loved vincent*⟩}	np ---> [pn]
3.	{⟨ pn vp, *mia loved vincent*⟩}	Match!
4.	{⟨ vp, *loved vincent*⟩}	vp ---> [iv], vp ---> [tv, np]
5.	{⟨ iv, *loved vincent*⟩,	No applicable rule for iv analysis.
	⟨ tv np, *loved vincent*⟩}	lex(loved,tv)
6.	{⟨ np, *vincent*⟩}	np ---> [pn]
7.	{⟨ pn, *vincent*⟩}	We're done!

Figure 2: Breadth-First Approach (Raffaella, 2014).

In Figure 2, the breadth-first approach is considered, looking at stage (five); this is when a crucial difference occurs. This is because both the ways of building verb phrases (VP) are applied at once. In the next step, the intransitive analysis is discarded, whereas the transitive analysis is kept in the bag, and finally, the outcome is achieved in the seventh step (Raffaella, 2014). For a better understanding, a comparison of both approaches was necessary.

G. Empirical Evidence of Depth and Breadth-First Approaches

There are numerous studies about the relationship between vocabulary size, and reading comprehension, and the connection between the two. The number of studies related to reading comprehension, and vocabulary depth and breadth is limited, conversely. Rashidi and Khosravi (2010) found in their study of Iranian EFL learners that there is a high positive correlation between vocabulary breadth, depth and reading comprehension. Another study conducted by Li and Kirby (2015) found out that there is a moderate correlation between breadth and depth of vocabulary, "but the relationship of these two constructs to reading comprehension showed intriguing results, as vocabulary breadth correlated more strongly with a multiple-choice task, whereas depth of vocabulary correlated more strongly with a more demanding summary task" (p. 1081).

Qian (1999) is considered one of the first researchers who has recognised the significance of the depth and the size of vocabulary knowledge in reading comprehension. In his study, he measured vocabulary breadth, vocabulary depth and reading comprehension in four tests. As a result he established a high positive correlation between the scores obtained in the four tests.

Furthermore, the prediction of reading proficiency benefited significantly from both the breadth and depth of vocabulary. What is remarkable in this case is that, in addition to the prediction offered by vocabulary breadth alone, vocabulary depth also added 11 percentage points of explained variation to reading test scores. The research unequivocally demonstrates the value of extensive vocabulary in reading comprehension (Qian, 1999). The usefulness of vocabulary depth as a predictor of reading comprehension is further supported by Qian's 2002 study, which found out that vocabulary depth scores alone explained about 59% of the variation of the findings whereas vocabulary breadth scores alone explained about 54% of the same variance (Harkio & Pietila, 2016, p.1081).

Harkio and Pietil ä(2016) echoed the results of Qian's (2002) study. They found out that both vocabulary breadth and depth appear to be the best indicators of reading comprehension in competence levels lower than the advanced level. However, advanced students are likely to possess a wide variety of other language skills, such as the application of linguistic knowledge or reading methods, which may be applied when facing reading difficulties. On the other hand, at the developing and beginning stages of competence, both vocabulary size and depth are good predictive and explanative factors of reading comprehension (p.1085).

Similarly, Binder et al. (2017) investigated the association between vocabulary breadth; vocabulary depth; reading comprehension and reading rate among college students. Their study focused on the role of vocabulary depth on the literacy measures in the selected sample of skilled readers. It was found that vocabulary depth and breadth both were significantly associated with reading comprehension as well as reading rate. Moreover, when both types of vocabulary knowledge clarified the unique variance in reading comprehension, only the vocabulary breadth was able to explain the unique variance in reading rate. Lastly, their study found out that although vocabulary breadth was significantly associated with vocabulary depth measures, the two depth measures were not significantly associated with each other.

Likewise, Ouellette's (2006) study on the vocabulary topic of grade 4 students also showed that there are different effects of the breadth and depth of several literacy skills like recognition of words, reading rate, and reading comprehension. He further stated that the breadth-first approach described the differences in decoding skills. This finding's interpretation suggests that having more words in one's vocabulary could expose a reader to phonemic units more frequently, which might improve decoding speed. Additionally, he discovered that reading comprehension skills could only be uniquely predicted by depth-first and that both depth and breadth reflected variation in word recognition.

In addition, other researchers (Roth et al., 2002; Snow et al., 1995; Nation & Snowling, 2004) discovered a strong correlation between vocabulary depth and reading comprehension for developing readers.

H. Comparing Depth-First and Breadth-First Approaches

The breadth-first approach has an advantage over the depth-first method as it does not consider one choice only that might turn out to be incorrect. Considering depth first and breadth-first vocabulary knowledge, they both explained the unique variance in reading comprehension, but only breadth explained the unique variance in reading rate (Binder et al., 2017). The results suggest that breadth and depth approaches make substantial independent contributions to comprehension, whereas only the breadth-first approach makes an essential contribution to the reading rate.

Supporting the breadth-first approach, Roberts (2008) indicates that the structure matters as any paper should be developed progressively and logically in technical writing, just like placing brick by brick. Writers also need to identify their readers' level of interest and technical knowledge. In short, the information should be presented in a sequence of increasing difficulty. People tend to continue reading only when the helpful information is presented initially. The study suggests that to communicate effectively with the audience, the authors should write to read breadth-first and not read depth-first as seen in Figure 3:

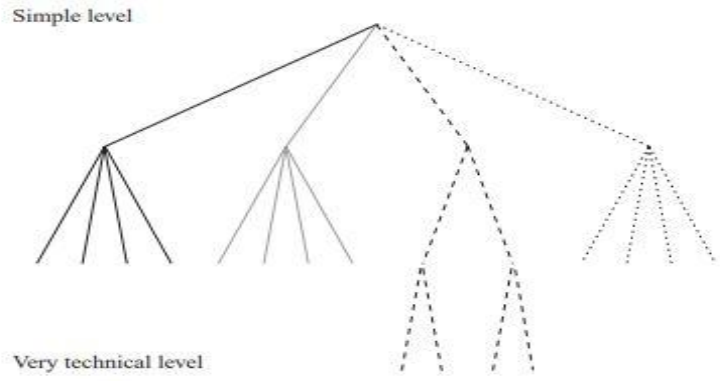

Figure 3: Simplistic Schematic Diagram of the Tree of Knowledge, (Tony,2008).

The problem is that readers can get muddled up if the author writes using the depth-first approach, and because of technical language, they can get confused as they have little or no idea where the discourse is leading. As a result, they face difficulty in understanding the document and, therefore, quit reading (Roberts, 2008). Therefore, writers should use the breadth-first approach because the information is provided in technicality (Figure 4). Roberts (2008) urges researchers to take up a breadth-first approach to writing because, at any stage of the document, the reader will have an overview, and will be allowed to place the technical material upon the framework which has already been built for them by the writer. Furthermore, the breadth-first approach enables the reader to keep their interest intact in the writer's efforts in the form of a document. Consider Figure 4:

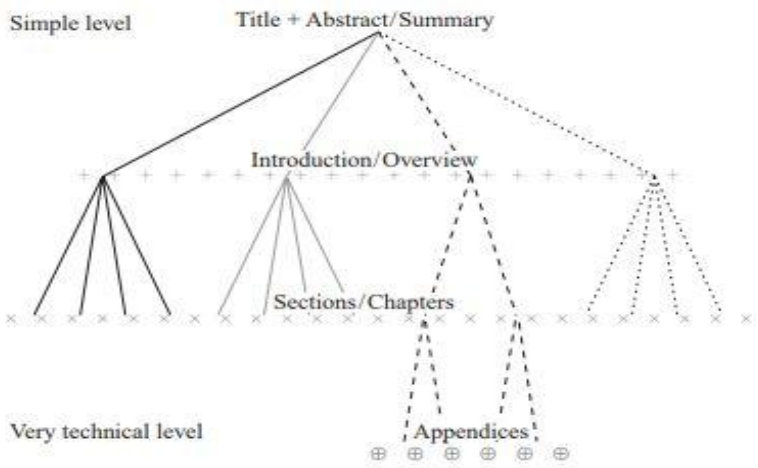

Figure 4: Allocation of Various Parts of a Document to the 'Tree of Knowledge (Tony, 2008).

In context of the above, another study conducted by Bear (1983) suggested a breadth-first parsing model over depth-first for processing natural language. The study came up with a breadth-first parser model for context-free languages. The model works with alternatives that are consistent with the information that appears first. On the other hand, certain

studies suggest that a blend of depth-first and breadth-first would give a more desirable outcome. For example, Uszkoreit (1991) declares that strategies combine both different types of constraints in declarative grammar and a layer of controlled information of detachable layer. The controlled information becomes the basis for the parameterised managed linguistic deduction, a form of linguistic processing that permits the creation of acceptable models of language performance without offering a clear definition of linguistic competence. Thus, the language processor can employ this information to organize the sequence of conjuncts and disjuncts being developed in order to combine breadth-first and depth-first techniques, reducing unwanted derivations and constraint-relaxation.

On the same line, Kintsch (2005) argues that the construction-integration model (CI) gives an insight into the relationship between the depth-first and breadth-first approach in processing comprehension. In every step of the analysis, ranging from basic linguistic processing to knowledge integration stage, both approaches, depth-first and breadth-first, combine to determine the nature of the mental depictions formed in comprehension.

A study conducted by Andrews and Bond (2009) shows that readers, who have a good quality of lexical representations, signified by effective spelling depends less on top-down context than poor spellers. This comparison shows that vocabulary depth and breadth are two important constructs to take into account while assessing higher-level processing like reading comprehension. Knowing a lot of words is necessary for both reading and the speed of the reading (reading rate). Having an inclusive understanding of the gradations of the meanings of words in a variety of milieus, will permit the reader to develop a better understanding of the text, and an ability to express himself or herself in an effective way.

III. Conclusion and Recommendations

The objective of this review is to investigate the role of linguistic structure in sentence and text comprehension. It further points out to the theoretical debate areas, which include depth-first and breadth-first approaches adopted by the parsers. Moreover, one needs to go beyond the linguistic structure to understand how to comprehend sentences and texts. The findings of this study indicate that linguistic comprehension instruction can improve the readers' and listeners' linguistic comprehension skills, and vocabulary development plays a pivotal role in this process. Even though linguistic awareness plays a vital role in comprehending texts and sentences, only few intervention studies have been conducted on reading comprehension's generalized outcomes.

A successful comprehension follows a resultant discourse, a representation that can be retrieved, updated, manipulated, and applied to answer the questions and solve them. Moreover, to carry out a comparative analysis of the two models, the review has included studies conducted on these two parsing models, such as; the depth-first and breadth-first models. Even so, not many studies have been conducted revealing which approach supersedes the other, however, some studies suggest that a blend or mixture of both approaches can help the parsers build a better understanding of grammar concepts to comprehend texts and sentences. Nonetheless, other studies urge researchers to take-up the breadth-first approach as it gives more room for readers to consider more than one choice at once, and explain the unique variance in reading rate.

In general, it can be said that this area of research is still in need of further elaboration and investigation for better understanding of how these different components develop the vocabulary depth, and properly assess it.

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Nahed M.A. Ghazzoul is an assistant professor of Linguistics. She holds a PhD in Linguistic from Lancaster University, UK. 2008; a Certificate in Learning and Teaching in Higher Education, from Lancaster University, UK. 2006; an MA in Linguistics (TESOL), University of Surrey, UK. 2004, a postgraduate Diploma in Linguistic Studies, University of Aleppo, Syria. 1999, a Postgraduate Diploma in Translation and Arabicization, University of Aleppo, Syria. 1992, and a Bachelor Degree in English Language and Literature, Homs University, Syria. She worked at different educational places, including Aleppo University/Syria, Lancaster University/UK, Jerash University, and Alzaytoonah University/Jordan.

Currently, she is a full-time assistant professor and researcher at Paris Nanterre University, MoDyCo Research Centre, Faculty of Languages. She was granted a post-doctoral fellowship by CARA at East Anglia University in October 2019. In January-2020/December-2020, she was a full-time postdoctoral fellow at Columbia University, Columbia Global Centre Amman.

Dr Ghazzoul is a member of the International Parliament for Scientists of Human Development. She is also a member of the Arab Center for Human Rights and International Peace; a member of the Graduate Women International (GWI), and a member of the European Association for Teaching Academic Writing (EATAW). She received the Translation Award for Literary Genres: Arabic-English 2007. UAE. The winning work has been Published by the Higher Commission in Charge of Sheikh Hazza' bin Zayed Al Nahayan's Sons' Awards for Arab Children's Culture, Abu Dhabi, United Arab Emirates, 2007. She also received Al-Butani Award for Short Story Contest, 2001. She published a couple of articles among which:

- Ghazzoul, N. (2022). "The Unheard Voices: At-Risk Syrian Academics in Jordan, Lebanon, and Turkey", in *Academics in Exile: Networks, Knowledge Exchange and New Forms of Internationalization.* Eds. Vera Axyonova, . Florian Kohstall, & Carola Richter, Majuskel Medienproduktion GmbH, Wetzlar.
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