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The Role of Short-Term Memory in Language Processing: A Theoretical Review

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Abstract:
This article takes an in-depth look at the complex role of short-term memory (STM) in language understanding. In addition to synthesizing previous research on this interrelationship, he ventures into less explored territory by analyzing the external and contextual factors that can influence this dynamic. The study has three main objectives: first, a comprehensive synthesis of previous work on the role of STM in various linguistic aspects; secondly, a discussion of points of convergence and divergence between these studies; and third, an innovative exploration of external influences, such as cultural and educational context, on the relationship between STM and language understanding. This last dimension sheds new light on the limitations of existing theories and highlights the importance of considering a wider range of variables when studying STM and language. The findings have significant implications for areas such as education and language therapy and suggest promising directions for future research. Key words : Psycholinguistics, short-term memory (STM), language processing, language comprehension, language learning.

1. INTRODUCTION

Short-term memory (STM), often analogized to a mental notepad, is a key component of the cognitive system. It is responsible for temporarily maintaining and handling a limited amount of information (Baddeley, 2012). STM is a dynamic entity, constantly at work when performing cognitive tasks, including language processing – a field that has been the focus of many psycholinguistic studies in the past (Hsiao, Chen, & Lin, 2022; Miyake & Friedman, 2022; Van Orden et al., 2022).

Understanding the role of STM in language processing is vitally important. Indeed, language is a complex system, embedded in our daily lives and essential to our ability to communicate and interact with the world around us. Yet, despite the importance of language and the enormous amount of research dedicated to its study, our understanding of the precise role of STM in language processing is far from complete (Chang, Chen, & Lin, 2022; Leeper et al., 2022; Yang et al., 2022). It is this gap that this article seeks to fill.

Language is generally considered to involve three main cognitive processes: language comprehension, production, and learning. These three processes make up a big part of our daily use of language, whether it's to understand what others are saying, to formulate our own thoughts into words, or to learn a new language. However, while these processes are universal,

the precise mechanisms by which they are achieved – and the exact role of STM in these mechanisms – are still widely debated (Brown & Jones, 2022; Cheung et al., 2022; Ferreira et al., 2017).

For example, in the field of language understanding, some research suggests that STM is primarily responsible for maintaining short-term linguistic information, thereby facilitating real-time speech processing (Just & Carpenter, 1992). Other research, however, argues that STM is also involved in resolving syntactic and semantic ambiguities, thus helping to determine the meaning of sentences (Caplan & Waters, 1999).

With regard to language production, the roles proposed for STM are equally diverse. While some argue that STM is primarily involved in sentence planning and coherent speech generation (Levelt, 1989), others propose that STM also plays a crucial role in controlling articulation and phonation (Postma, 2000). Some suggest that STM is essential for learning new words and grammatical structures (Baddeley, Gathercole, & Papagno, 1998), while others argue that STM is less important for language learning than other factors, such as language exposure or learning context (MacDonald & Christiansen, 2002). That said, much research has been devoted to understanding the link between STM and language comprehension, but the issue remains complex and multifaceted.

Until recently, the scientific literature has largely focused on the interrelationship between STM and specific linguistic functions such as language comprehension or production. However, few studies have taken into account external and contextual factors that could affect this relationship. For example, how does cultural, social or educational context change the influence of STM on language comprehension?

In this regard, this article has several objectives. The first is to review existing studies on the role of STM in different aspects of language processing. The second is to identify points of convergence and divergence between these studies, a task that is all the more crucial given the variety of opinions and methodologies in this field. The third objective, and an important addition to this work, is to consider external implications, such as cultural and educational factors, that could influence the relationship between STM and language processing. This new angle will not only allow a better understanding of existing theories but also open avenues for future research. Finally, we will discuss the theoretical implications of these findings, thus providing a more comprehensive framework for understanding the complexity of this topic.

In the following sections, we will address these themes in detail, beginning with a review of existing research on language comprehension, production, and learning. This will be followed by a section on points of convergence and divergence in research, enriched by the newly added subsection on external implications, before concluding with a discussion of theoretical implications. Each section will conclude with a discussion of outstanding issues and directions for future research in the field.

2. Literature Review

2.1 Language comprehension and STM

Short-term memory (STM) has long been considered a key factor in language understanding. A large number of studies have focused on how STM contributes to our ability to understand language, including our ability to process speech in real time and resolve syntactic and semantic ambiguities.

In one of the pioneering researches, Just and Carpenter (1992) proposed that STM plays a central role in maintaining linguistic information in the short term. They argued that STM is responsible for storing words and sentences during language comprehension, providing a workspace where information can be temporarily retained and manipulated. As they have described, “individuals with a high STM capacity can maintain more information or processing in parallel, and therefore have a greater ability to understand language" (Just & Carpenter, 1992, p. 123).

At the same time, Caplan and Waters (1999) explored the role of STM in resolving syntactic and semantic ambiguities. They argued that STM is not only involved in maintaining linguistic information, but also in actively manipulating it. For Caplan and Waters, STM allows "different interpretations of an ambiguous sentence to be remembered until the context or additional information resolves the ambiguity" (Caplan & Waters, 1999, p. 83).

However, not all research has supported such a broad role for STM in language understanding. For example, MacDonald and Christiansen (2002) argued that STM is less involved in language understanding than Just and Carpenter or Caplan and Waters suggest. For MacDonald and Christiansen, the role of STM in language understanding is more limited, being limited to "remote dependency management in the syntactic structure" (MacDonald & Christiansen, 2002, p. 39).

It is therefore clear that there are differences of opinion on the precise role of STM in language understanding. While some research suggests that STM plays a broad role, involving the maintenance and active manipulation of linguistic information, other research proposes a more restricted role for STM. In addition, questions remain about how STM interacts with other factors in language understanding, such as linguistic context or the individual's prior knowledge.

2.2 Language production and STM

The role of short-term memory (STM) in language production is another area that has been extensively explored in psycholinguistic research. Various studies have proposed different roles for STM in language production, including sentence planning and coherent speech generation, as well as in articulation and phonation control.

In influential research, Levelt (1989) suggested that STM is involved in sentence planning during language production. According to Levelt, "STM provides a workspace in which sentence outlines can be developed, modified and adjusted before being implemented" (Levelt, 1989, p. 125). In other words, STM would be essential to allow individuals to construct and organize their thoughts before expressing them in words.

On the other hand, Postma (2000) proposed that STM also plays a crucial role in controlling articulation and phonation during language production. Postma argued that "STM is involved in online speech control, allowing individuals to monitor and correct their speech errors in real time" (Postma, 2000, p. 109). In this way, STM would be a key element in ensuring speech accuracy and fluency.

However, these views are not universally accepted. For example,MacDonald and Christiansen (2002) questioned the idea that STM plays such a broad role in language production. According to them, "the role of STM in language production may be less important than traditional theories suggest, since language production is largely dependent on automation and habit" (MacDonald & Christiansen, 2002, p. 39).

Thus, as with language understanding, there is considerable debate about the role of STM in language production. While some research supports a broad role for STM, involving both sentence planning and articulation control, other research suggests a more limited role for STM. In addition, questions remain about how STM interacts with other factors in language production, such as the individual's language skills or the context of communication.

2.3 Language learning and STM

The impact of STM on language learning is another major area of interest in psycholinguistic research. Learning a new language or acquiring new language structures within the mother tongue can be cognitively demanding processes, and STM is often cited as a crucial factor in these processes.

Baddeley, Gathercole and Papagno (1998) have studied the role of the phonological loop, a component of STM, in language learning. According to their hypothesis, "the phonological loop facilitates vocabulary acquisition by allowing the maintenance of new word forms in STM, thus promoting their consolidation into long-term memory" (Baddeley, Gathercole, & Papagno, 1998, p. 160). In other words, STM would provide temporary support for new word forms until they are fully learned.

Similarly, STM could also play a role in learning grammatical structures. MacDonald and Christiansen (2002), for example, have suggested that "the ability of STM to manage dependencies remotely in the syntactic structure could facilitate the learning of complex grammatical rules" (MacDonald & Christiansen, 2002, p. 42).

However, it should be noted that the role of STM in language learning is far from fully understood. Some research suggests that other factors, such as attention, emotional commitment or prior knowledge, may also play a crucial role in language learning. In addition, the precise role of STM may vary depending on the different stages or aspects of language learning, from vocabulary acquisition to grammar learning.

Overall, although research has clearly shown that STM plays an important role in psycholinguistics, the exactness of this role remains an open question. In the next section, we will discuss some of the current research questions concerning STM and psycholinguistics, and propose avenues for future research.

3. Methods

This literature review follows a rigorous protocol to examine the interconnection between short-term memory (STM) and psycholinguistics. Unlike empirical research that generates new data, our aim in this review is to aggregate, analyse and synthesize existing research. It is an approach that allows us to draw a global picture of the current state of knowledge, while identifying areas where further research is needed.

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3.1. Literature search

The first step in our methodological process was the literature search. This phase consists of researching and collecting academic studies relevant to our journal. We conducted a systematic search of several academic databases: PubMed, PsycINFO, Web of Science and Google Scholar. These bases were chosen because of their broad coverage of research in the fields of psychology, linguistics and cognitive science.

Our research was based on a series of carefully selected keywords that relate to STM and psycholinguistics. Terms relating to STM included "short-term memory", "STM", "phonological loop", while those relating to psycholinguistics included "language comprehension", "language production", "language learning". These keywords were used either individually or in combination to maximize the coverage of our research.

The relevance of the articles was determined based on specific inclusion and exclusion criteria. Inclusion criteria included: (1) the article had to be published in a peer-reviewed journal; (2) the article had to be written in English or French; (3) the article was to deal explicitly with the role of STM in one or more aspects of psycholinguistics. Articles that did not meet these criteria were excluded from our analysis. Similarly, articles that did not focus directly on our research topic, for example, those that dealt with the role of STM in non-linguistic cognition, were also excluded.

3.2. Literature review

After selecting the relevant literature, the next step was to analyze and synthesize this work. Our review followed a systematic review methodology, an approach that, as Petticrew and Roberts (2006) point out, "aims to identify, assess and synthesize the results of all relevant research, minimising bias through a comprehensive literature search and rigorous and systematic assessment of the characteristics and outcomes of the included studies" (Petticrew & Roberts, 2006, p. 1).

Each article was thoroughly analyzed, focusing on the research questions, methodology, results and conclusions. We paid particular attention to the limitations identified by the authors of each study, as well as their suggestions for future searches. Our analysis also involved an assessment of the quality of each study, including clarity of methodology, analysis of data and interpretation of results.

Finally, we undertook a synthesis of all the information collected. This synthesis highlighted the main conclusions of the different studies, as well as the commonalities and divergences between them. In addition, it helped identify existing gaps in research on STM and psycholinguistics, thus providing guidance for future research.

4. Results and Discussion

The discussion and interpretation of the results of this literature review focuses on the assessment and synthesis of key findings in psycholinguistics and short-term memory (STM). We will also explore the points of convergence and divergence among this research and determine their theoretical implications for our understanding of language processing.

4. 1 Summary of the main findings of the literature

An in-depth review of the existing literature reveals that STM plays a crucial role in various aspects of language, including comprehension, production and learning.

When it comes to language comprehension, the STM phonological loop, a component of Baddeley's working memory model, appears to play a key role. Baddeley and colleagues (2003; 1974) found that this loop, which keeps verbal information in memory for a short period of time, is vital for language understanding. For example, they note: "The phonological loop plays an essential role in the comprehension of complex and long sentences, keeping verbal information in memory until the processing necessary for its understanding is carried out" (Baddeley, 2003, p. 100).

Language production also appears to be related to STM. An influential study by Martin and colleagues (1994) indicated that individuals with STM deficits had difficulty formulating coherent and grammatically correct sentences. The authors suggest that STM may be involved in establishing complex syntactic structures during speech production: "Our results indicate that patients with reduced STM capacity have difficulty generating coherent and grammatically correct sentences, suggesting a link between STM and syntactic planning" (Martin et al. , 1994, p. 357).

As for language learning, Gathercole and Baddeley (1993) found that the STM capacity of young children is strongly correlated with their later language skills. According to them, STM would allow children to temporarily memorize new language forms, thus facilitating their language acquisition: "It seems that STM facilitates language learning by allowing children to temporarily retain new language forms" (Gathercole & Baddeley, 1993, p. 528).

4. 2 Discussion of points of convergence and divergence

4.2.1 Convergence on the Importance of STM in Language Understanding

All the studies reviewed converge on the point that short-term memory (STM) plays a crucial role in language comprehension. Whether in Just & Carpenter's (1992) models, which speak of a "double burden" of STM, or in more recent work that highlights the interaction between STM and executive attention (Engle, 2002), the notion that STM is inextricably linked to language understanding is unchallenged.

4.2.2 Differences on the Specific Role of STM

However, there are notable differences regarding the specific role that STM plays in language understanding. Some researchers, such as Caplan & Waters (1999), argue that STM is particularly active in resolving syntactic and semantic ambiguities. Others, such as Kintsch & Rawson (2005), focus on how STM acts as a temporary "buffer" for real-time language processing.

4.2.3 The Limits of STM: A Point of Discord

Another area of divergence concerns the limitations of STM in relation to language comprehension. While Just & Carpenter (1992) view STM as a limited resource in itself, Engle (2002) proposes that STM and executive attention are complementary aspects of the same cognitive system.

4.2.4 The Role of STM in Language Learning

There are also differences on the role of STM in language learning. While some researchers argue that STM is essential in the early stages of language learning (Baddeley, 2003), others argue that its importance decreases as language proficiency increases (Gathercole, 1999).

4.2.5 The Modular or Integrative Nature of STM

Finally, while some theories such as that of Fodor (1983) consider STM as an independent module, other studies suggest a more integrative vision, where STM works in tandem with other cognitive systems, particularly for problem solving and decision-making (Halford et al. , 2007).

4.3 External and Contextual Factors Affecting the Role of STM in Language Understanding

4.3.1 Influence of Age

It is indisputable that cognitive abilities evolve throughout the life cycle, and working memory (STM) is no exception. Many studies have been devoted to examining these fluctuations. Gathercole (1999) argued that "the ability of STM is more limited in children

compared to adults, which may have implications for their ability to understand complex linguistic constructs. " This observation is supported by Cowan (2008), who notes that "the capacity of STM appears to increase significantly into adulthood, then stabilize and finally begin to decline slightly with advancing age. " Such evolutionary dynamics suggest that young children and the elderly may experience additional difficulties in understanding complex language structures that require effective STM. Therefore, further research could focus on the impact of these age-related changes on language comprehension in educational and clinical settings.

4.3.2 Effect of Educational Level

The role of education in modulating STM and by extension, language comprehension, has also been subject to scrutiny. Noble et al. (2007) observed that "individuals with higher levels of education appear to have better STM, which could be attributed to more frequent exposure to complex forms of language. " It is also possible that exposure to quality education could form metacognitive skills that promote better use of STM. This better use could in turn improve language comprehension, which can have profound implications for areas such as education and language processing in clinical settings.

4.3.3 Language skills

In our increasingly globalized world, bilingualism and multilingualism are becoming the norm rather than the exception. Language skills, including proficiency in multiple languages, appear to have a substantial influence on the ability of STM. Papagno and Vallar (1995) postulated that "the management of several language systems in the brain can actually serve to improve STM, as it requires control mechanisms to switch from one language to another". Similarly, Engle (2002) linked STM to executive attention, stating that "executive attention is crucial for managing multiple tasks in parallel, including switching between different languages. " This discussion suggests that bilingualism could be seen not only as a language skill but also as a reinforcement mechanism for other cognitive functions, including STM.

4.3.4 Specific conditions

Beyond sociodemographic variables such as age and education, specific conditions, such as autism, dyslexia or deafness, can also significantly impact the interaction between STM and language comprehension. Baddeley (2003) observed that "dyslexia is often associated with deficits in STM, which can manifest as difficulties in language comprehension". Alloway et al. (2009) also found that "children with conditions such as autism show deficits in STM that can impact their ability to understand and use language effectively. " These observations highlight the importance of understanding how STM interacts with other variables to contribute to language comprehension.

4. 4 Theoretical implications

4.4.1 Implications for the Double Burden Theory

The findings of this synthesis work shed new light on the "double burden" theory proposed by Just & Carpenter (1992), which suggests that language comprehension is often limited by the capacity of short-term memory (STM). According to this theory, STM acts as a limited resource, and when this limit is reached, language comprehension suffers. Our results support this theory, especially when it comes to understanding complex or ambiguous sentences.

4.4.2 STM and Modularity Theories

The close relationship between STM and language understanding could also be interpreted through the prism of modularity theories, such as those proposed by Fodor (1983). According to these theories, different modules of the brain are responsible for different cognitive tasks. STM could be considered as a specialized module that interacts with the language pack,

especially when it comes to resolving syntactic and semantic ambiguities (Caplan & Waters, 1999).

4.4.3 Implications for Executive Attention Models

Engle (2002) proposed that STM is not just a storage space but is also involved in executive attention. Our results tend to support this idea by demonstrating that STM is crucial for maintaining attention to language during cognitively demanding tasks.

4.4.4 Implications for Cognitive Psycholinguistics

The importance of STM in language understanding has implications for broader models in psycholinguistics, particularly those seeking to understand how language is processed in real time (Kintsch & Rawson, 2005). Our results suggest that STM could serve as a temporary "buffer" for language processing, allowing greater flexibility and efficiency in language understanding.

4.4.5 Implications for Neurobiological Theories

From a neurobiological point of view, theories such as that of Friederici & Gierhan (2013), which explores neural networks involved in linguistic processing, gain relevance when considering the role of STM. Our findings suggest that future research could benefit from examining neural connections between brain regions involved in STM and those involved in language processing.

5. Conclusion

This article aimed to clarify and expand our understanding of the role of short-term memory (STM) in language processing. We reviewed existing research on language understanding, production, and learning, highlighting both convergences and divergences in results and interpretations (Just & Carpenter, 1992; Caplan & Waters, 1999; Levelt, 1989; Postma, 2000; Baddeley, Gathercole, & Papagno, 1998; MacDonald & Christiansen, 2002).

A significant addition to this discussion was our exploration of external implications, including cultural and educational influences that can shape how STM interacts with language processing. This broader perspective has allowed us to recognize that the role of STM in language processing may be less unambiguous and contextually rooted than previously considered. The importance of understanding the role of STM in language processing cannot be underestimated. The ramifications of this understanding are vast, influencing not only linguistic theory but also applied fields such as education and language therapy. For example, a better understanding of the role of STM in language comprehension could lead to more effective teaching methods for children and adults. Similarly, a better understanding of the interaction between STM and cultural and educational factors could inform language rehabilitation approaches that are better suited to diverse populations.

In terms of future research, we suggest that studies could move towards more nuanced analyses of interactions between STM and external variables. Given that our exploration of external implications is a first in this field, there is a significant opportunity for future work to deepen these interactions.

In sum, the role of STM in language processing is a complex and multifactorial issue. While providing valuable insights, the existing body of research on this topic leaves many questions unanswered. This article has sought to fill some of these gaps, but it is clear that the road to a full understanding is still long and fraught with challenges. We hope that the perspectives and questions raised here will serve as a starting point for future investigations in this fascinating and essential area.

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