
| RESEARCH ARTICLE

Interactive Effects of Speech Rate, Linguistic Complexity, and Working Memory Capacity on Real-Time L2 Listening Processing

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| ABSTRACT

This study investigates the interactive effects of speech rate, linguistic complexity, and working memory capacity on real-time second language (L2) listening processing. Listening comprehension in L2 is a cognitively demanding process influenced by input characteristics such as speech speed and syntactic complexity as well as individual differences in cognitive resources, particularly working memory capacity. Grounded in cognitive load theory and models of real-time language processing, the research examines how variations in speech rate and linguistic complexity interact with learners' working memory to influence comprehension and processing efficiency during listening tasks. In addition, the study seeks to identify the extent to which cognitive limitations affect learners' ability to process spoken input under varying levels of difficulty. Understanding these relationships is crucial for explaining differences in listening performance among L2 learners and for developing more effective instructional practices. A quantitative or experimental design is employed, involving L2 learners completing listening tasks under controlled conditions of speech rate and linguistic difficulty while working memory capacity is assessed using standardized cognitive measures. Data are analyzed to explore main effects and interaction effects among the variables and to determine the moderating role of working memory in real-time listening comprehension. The expected findings aim to enhance theoretical understanding of L2 listening processes and provide pedagogical insights for optimizing listening instruction by adjusting input characteristics and task demands according to learners' cognitive capacities. The study also aims to contribute to the growing body of research on the cognitive factors underlying second language acquisition and listening development.

| KEYWORDS

second language listening, speech rate, linguistic complexity, working memory capacity, cognitive load, real-time processing, listening comprehension, L2 learning.

| ARTICLE INFORMATION

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1. introduction

Listening comprehension in a second language is one of the most demanding skills in language learning because it requires the simultaneous processing of auditory input, linguistic decoding, and meaning construction in real time. Learners must perceive sounds, recognize words, interpret grammatical structures, and integrate information to form coherent understanding, all within the limited time available during listening. Unlike reading, where individuals can pause and revisit text, listening occurs continuously and offers few opportunities for reprocessing information. This temporal pressure makes listening particularly sensitive to variations in input characteristics such as speech rate and linguistic complexity. When speech is delivered too quickly, learners may struggle to keep up with the stream of information, leading to gaps in understanding. Similarly, when linguistic structures are complex or vocabulary is unfamiliar, cognitive demands increase and comprehension may decline. These challenges are especially pronounced in second language contexts where learners are still developing automaticity in decoding and interpreting the target language.

Cognitive theories of language processing suggest that listening comprehension is not solely determined by external input but also by internal cognitive resources. Working memory capacity, which refers to the ability to temporarily store and manipulate information, plays a crucial role in managing the demands of listening. During listening, working memory allows learners to hold incoming information while simultaneously integrating it with prior knowledge and contextual cues. However, working memory is limited in capacity, and when input demands exceed these limits, comprehension difficulties arise. For example, rapid speech may overload working memory because information arrives faster than it can be processed. Likewise, complex linguistic structures may require additional cognitive effort to decode, leaving fewer resources available for meaning construction. Individual differences in working memory capacity therefore help explain why some learners perform better in listening tasks than others even when exposed to the same input conditions.

Recent research in second language acquisition has emphasized the interactive nature of listening processing. Rather than viewing speech rate, linguistic complexity, and working memory as independent factors, contemporary models propose that these variables interact to influence comprehension outcomes. A fast speech rate may not pose significant problems for learners with high working memory capacity because they can efficiently process and retain information. In contrast, learners with limited working memory may experience greater difficulty under the same conditions. Similarly, linguistic complexity may interact with working memory such that complex structures place additional demands on cognitive resources, reducing comprehension for learners with lower capacity. Understanding these interactions is essential for developing a comprehensive theory of listening processing that accounts for both input characteristics and learner differences.

From a pedagogical perspective, insights into the interactive effects of speech rate, linguistic complexity, and working memory capacity have important implications for language teaching. Listening materials and tasks can be designed to match learners cognitive abilities and developmental stages, thereby reducing unnecessary cognitive load and enhancing comprehension. For example, gradually increasing speech rate as learners gain proficiency may help them adapt to real world listening conditions without overwhelming their processing capabilities. Similarly, simplifying linguistic structures in instructional materials can support comprehension while learners build their knowledge of the target language. Recognizing the role of working memory also highlights the need for differentiated instruction that accommodates individual differences in cognitive capacity.

Despite growing interest in the factors influencing listening comprehension, fewer studies have examined the combined and interactive effects of speech rate, linguistic complexity, and working memory in real time listening processing. Much of the existing research has focused on isolated variables, leaving gaps in understanding how these factors work together during comprehension. Investigating their interactions can provide deeper insights into the cognitive mechanisms underlying listening and inform evidence based instructional practices. Such research is particularly relevant in multilingual and educational contexts where learners face diverse listening demands and varying levels of linguistic complexity.

This study aims to explore the interactive effects of speech rate, linguistic complexity, and working memory capacity on real time second language listening processing. By examining how these variables influence comprehension and processing efficiency, the research seeks to contribute to theoretical models of listening and provide practical recommendations for language instruction. Understanding these relationships can help educators design listening activities that align with learners cognitive capacities and optimize learning outcomes. Ultimately, the study endeavors to enhance knowledge of second language listening processes and support the development of effective pedagogical strategies that address the challenges of listening comprehension in real time contexts.

2. Review of literature

2.1 Second Language Listening Comprehension as a Real Time Processing Activity

Second language listening comprehension is widely recognized as a complex cognitive activity that requires learners to process spoken input rapidly while simultaneously constructing meaning. Unlike reading, where individuals have the opportunity to pause and revisit information, listening occurs in real time and therefore demands immediate interpretation of the incoming speech stream. Learners must identify sounds, segment the speech into meaningful units, recognize words, interpret grammatical relationships, and integrate information with prior knowledge, all within a very limited time frame. This process places considerable cognitive demands on listeners because spoken language is transient and cannot easily be revisited once it has passed. As a result, listeners must rely on efficient processing mechanisms to maintain comprehension as the speech unfolds. In second language contexts, this task becomes even more challenging because learners often have less automatic access to vocabulary, grammatical structures, and phonological patterns than native speakers. The need to decode unfamiliar linguistic forms may slow down processing and reduce the amount of cognitive resources available for higher level interpretation. Research in second language acquisition has emphasized that listening comprehension involves the coordination of multiple cognitive processes that operate simultaneously. These processes include perceptual decoding, lexical access, syntactic parsing, and the integration of meaning within a broader discourse context. At the perceptual level, learners must recognize phonological cues and distinguish between sounds that may not exist in their first language. At the lexical level, they must quickly retrieve

word meanings from memory in order to keep pace with the ongoing speech. At the syntactic level, listeners must interpret grammatical relationships that determine how words combine to form meaningful structures. Finally, at the discourse level, learners must connect pieces of information across sentences and link them with background knowledge in order to build a coherent mental representation of the message. Because these processes take place almost simultaneously, successful listening requires efficient coordination between lower level decoding mechanisms and higher level interpretive strategies.

Another important characteristic of real time listening is the limited capacity of cognitive resources available during processing. Human information processing systems operate under constraints that restrict how much information can be held and manipulated at a given moment. When the demands of the listening task exceed these cognitive limits, comprehension may be disrupted. For example, if a listener is still attempting to decode earlier segments of speech while new information continues to arrive, the processing system may become overloaded. This can lead to missed information or incomplete interpretation of the message. In second language listening, such difficulties are common because learners may allocate substantial attention to recognizing individual words or structures, leaving fewer resources available for constructing overall meaning. The dynamic and time sensitive nature of listening also means that comprehension is strongly influenced by the characteristics of the spoken input. Factors such as the speed of delivery, the clarity of pronunciation, and the complexity of linguistic structures can significantly affect the ease with which listeners process speech. When speech is delivered rapidly or contains complex constructions, the cognitive load placed on the listener increases considerably. Under these conditions, learners must rely on efficient processing strategies and sufficient cognitive capacity in order to maintain comprehension. Consequently, real time listening can be understood as an interaction between the linguistic properties of the input and the cognitive resources available to the listener. Understanding second language listening as a real time processing activity therefore provides an important foundation for investigating the factors that influence listening performance. By examining how learners manage the demands of rapid speech and complex linguistic information while relying on limited cognitive resources, researchers can gain deeper insight into the mechanisms that support successful comprehension. Such an understanding is essential for identifying the conditions under which listening becomes particularly challenging and for developing instructional approaches that help learners cope with the cognitive demands of real time spoken language processing.

2.2 Working Memory in Second Language Listening

Working memory plays a central role in second language listening because it supports the temporary storage and manipulation of information that is necessary for understanding spoken language. Listening requires learners to retain segments of speech while simultaneously processing incoming information and integrating it into a coherent message. In real time communication, spoken input unfolds rapidly and cannot easily be revisited, which means that listeners must rely on their working memory to maintain previously heard words and phrases while interpreting new ones. Working memory therefore functions as a mental workspace that allows learners to hold linguistic information long enough to analyze its structure and meaning. This cognitive system is particularly important in second language contexts where learners often face additional processing challenges due to limited vocabulary knowledge, unfamiliar grammatical structures, and less automatic recognition of phonological patterns. In the field of cognitive psychology, working memory is commonly described as a system responsible for temporarily storing and manipulating information during complex cognitive tasks such as comprehension, reasoning, and learning. One influential model proposes that working memory consists of several interacting components that coordinate the processing and storage of information. These components enable individuals to retain verbal information while engaging in higher level cognitive operations. During listening comprehension, working memory allows the listener to keep track of previously heard words, interpret syntactic relationships between elements in a sentence, and integrate information across clauses and sentences. Without sufficient working memory capacity, it becomes difficult to maintain the sequence of ideas presented in speech, which may lead to partial understanding or misinterpretation of the message.

In second language listening, the demands placed on working memory are often greater than those experienced in first language processing. Learners must allocate attention not only to understanding meaning but also to decoding unfamiliar sounds, recognizing words that may not yet be fully automatized, and interpreting grammatical structures that require conscious processing. These additional demands can quickly consume the limited cognitive resources available within working memory. As a result, learners with lower working memory capacity may struggle to keep pace with spoken input, especially when speech is delivered rapidly or when sentences contain complex structures. In contrast, individuals with greater working memory capacity are generally better able to maintain and process information simultaneously, which allows them to sustain comprehension even under more demanding listening conditions. Research in second language acquisition has shown that individual differences in working memory capacity are strongly associated with variation in listening performance. Learners with higher working memory capacity tend to demonstrate better comprehension because they can retain larger amounts of information while simultaneously analyzing linguistic structures and constructing meaning. They are also more capable of integrating contextual cues and background knowledge with incoming speech. Conversely, learners with limited working memory resources may experience difficulty maintaining earlier parts of an utterance while processing new information, which can result in fragmented

understanding. This relationship highlights the importance of considering cognitive factors when examining listening comprehension, as linguistic proficiency alone may not fully explain differences in performance among learners.

The role of working memory becomes particularly evident when listeners are exposed to challenging input conditions such as rapid speech or complex linguistic structures. Under these circumstances, the amount of information that must be processed within a short period of time increases significantly, placing additional pressure on cognitive resources. Working memory capacity therefore acts as a critical factor that determines how effectively learners can manage the demands of real time listening. By maintaining relevant information while new input is processed, working memory enables listeners to construct coherent interpretations of spoken discourse despite the transient nature of auditory language. For this reason, understanding the role of working memory in second language listening provides important insight into the cognitive mechanisms that support successful comprehension and helps explain why learners respond differently to the same listening conditions.

2.3 Effects of Speech Rate on L2 Listening Comprehension

Speech rate is widely recognized as a crucial factor influencing second language listening comprehension because it directly affects the pace at which linguistic information is delivered to the listener. In spoken communication, speech unfolds continuously and listeners must process incoming information as it occurs. When the rate of speech is slow or moderately paced, learners have more time to identify sounds, recognize words, and interpret grammatical structures. This additional processing time can support comprehension, particularly for second language learners who may still be developing automatic recognition of vocabulary and syntactic patterns. In contrast, when speech is delivered at a rapid pace, the amount of information that must be processed within a limited time frame increases considerably. As a result, learners may struggle to keep up with the flow of input, which can lead to incomplete understanding or missed information. The influence of speech rate on listening comprehension is closely related to the cognitive demands involved in real time language processing. Listening requires learners to decode phonological signals, access lexical meanings, and integrate information across clauses and sentences while new speech continues to arrive. When speech is presented too quickly, listeners may not have sufficient time to complete these processes before additional information is introduced. This situation can create a bottleneck in processing because the listener is still attempting to interpret earlier segments of speech while new segments must also be processed. In second language contexts, this challenge is particularly significant because learners often require more time than native speakers to recognize words and interpret grammatical relationships. Consequently, faster speech rates can increase cognitive load and reduce the efficiency of comprehension processes.

Research in second language acquisition has consistently shown that variations in speech rate can have a substantial impact on listening performance. Many studies have found that moderately slowed speech tends to facilitate comprehension for language learners, especially those at lower proficiency levels. A slower rate allows learners to segment the speech stream more effectively and to allocate attention to the recognition of key lexical and grammatical elements. It also provides greater opportunity to integrate information and construct meaning across larger units of discourse. However, excessively slow speech may also present certain limitations because it can alter the natural rhythm and prosody of spoken language, potentially making the input sound unnatural or fragmented. For this reason, the relationship between speech rate and comprehension is not always linear and may depend on the balance between providing sufficient processing time and maintaining the natural characteristics of speech. Another important aspect of speech rate is its interaction with other linguistic and cognitive factors involved in listening comprehension. The difficulty associated with rapid speech often becomes more pronounced when the spoken input also contains unfamiliar vocabulary or complex grammatical structures. Under such conditions, learners must devote additional cognitive resources to decoding and interpretation, which may further reduce their ability to keep pace with the incoming speech. Conversely, when linguistic content is relatively simple or familiar, listeners may be better able to manage faster speech rates because fewer cognitive resources are required for decoding. These observations suggest that speech rate should not be viewed in isolation but rather as a factor that interacts with other elements of the listening process.

Understanding the effects of speech rate on second language listening comprehension is therefore essential for both theoretical and pedagogical purposes. From a theoretical perspective, examining how learners respond to different rates of speech can provide insight into the cognitive mechanisms that support real time language processing. From a pedagogical perspective, knowledge of speech rate effects can inform the design of listening materials and instructional practices that support learner comprehension. For example, instructors may choose to adjust the speed of listening input according to learners proficiency levels or gradually expose students to faster speech as their processing abilities improve. By recognizing the role that speech rate plays in shaping listening difficulty, educators and researchers can better understand the conditions that facilitate or hinder successful comprehension in second language listening contexts.

2.4 Linguistic Complexity in Spoken Input

Linguistic complexity in spoken input is another important factor that influences second language listening comprehension because it determines the level of difficulty learners face when interpreting spoken language. In listening contexts, linguistic complexity generally refers to the structural and lexical features of speech that affect how easily a listener can decode and understand the message. These features may include the complexity of grammatical structures, the density of information within sentences, and the level of vocabulary difficulty present in the spoken discourse. When spoken input contains simple and familiar structures, learners are more likely to process the information efficiently and construct meaning with relative ease. However, when speech includes complex syntactic patterns or unfamiliar lexical items, the cognitive demands placed on the listener increase significantly, which may hinder comprehension. From a processing perspective, linguistic complexity requires listeners to engage in more elaborate syntactic and semantic analysis during comprehension. Complex sentences often contain multiple clauses, embedded structures, or less frequent grammatical patterns that demand careful interpretation. In real time listening situations, learners must analyze these structures quickly while simultaneously processing new incoming information. This task can become particularly challenging for second language learners who may not yet have fully developed automatic recognition of grammatical relationships in the target language. As a result, they may allocate considerable attention to interpreting the form of the sentence, leaving fewer cognitive resources available for constructing the overall meaning of the message.

Lexical complexity also plays a crucial role in shaping the difficulty of spoken input. Vocabulary that is rare, specialized, or unfamiliar to the learner may slow down comprehension because listeners must attempt to infer meaning from context or rely on partial recognition of the word. When several unfamiliar words appear within a short segment of speech, the listener may struggle to maintain a coherent understanding of the message. In contrast, when vocabulary is frequent and familiar, learners can process the input more automatically and devote greater attention to higher level interpretation. The degree of lexical difficulty within spoken discourse therefore contributes significantly to the overall linguistic complexity of the listening material.

Another aspect of linguistic complexity involves the density of information contained in spoken language. Sentences that convey several ideas within a short span of time require listeners to retain and integrate multiple pieces of information simultaneously. In real time listening situations, this increased informational load may place substantial pressure on the listener cognitive system. Second language learners may find it difficult to track relationships between ideas or maintain earlier parts of the message while processing new information. Consequently, high levels of informational density can reduce comprehension accuracy and make it more difficult for learners to build a coherent representation of the discourse. The impact of linguistic complexity becomes particularly evident when it interacts with other factors that influence listening comprehension. For instance, complex grammatical structures may be easier to process when speech is delivered at a moderate pace, but they may become considerably more challenging when combined with rapid speech. Similarly, learners with greater cognitive resources may be better equipped to manage complex linguistic input than those with more limited processing capacity. These observations highlight the importance of examining linguistic complexity not only as an independent variable but also as part of a broader system of factors that shape listening performance.

Understanding the role of linguistic complexity in spoken input is therefore essential for both research and pedagogy in second language listening. From a research perspective, examining how learners respond to varying levels of linguistic difficulty can provide insight into the cognitive processes involved in real time language comprehension. From a pedagogical perspective, awareness of linguistic complexity can guide the selection and design of listening materials that are appropriate for learners proficiency levels. By gradually increasing the complexity of spoken input as learners develop greater linguistic knowledge and processing ability, educators can support the development of more effective listening skills while avoiding unnecessary cognitive overload.

2.5 Interaction of Cognitive and Input Factors in L2 Listening Processing

Listening comprehension in a second language is not determined by a single factor but rather emerges from the interaction between characteristics of the spoken input and the cognitive resources available to the listener. In real time listening situations, learners must process incoming speech rapidly while managing a range of linguistic and cognitive demands. Input related factors such as speech rate and linguistic complexity influence the amount of information that must be processed within a given period of time, while cognitive factors such as working memory capacity determine the extent to which learners can successfully handle these demands. As a result, listening performance reflects a dynamic relationship between external features of the spoken message and internal cognitive mechanisms that support comprehension.

From a cognitive perspective, listening requires the coordination of several processes that operate simultaneously. Learners must perceive phonological signals, identify words, analyze grammatical structures, and integrate information across segments of discourse. These operations take place while the speech stream continues to unfold, which means that listeners must constantly balance the processing of new information with the retention of previously heard material. The ability to manage these demands

depends largely on the efficiency and capacity of the listener cognitive system. When cognitive resources are sufficient, learners are more likely to maintain accurate representations of the spoken message and construct meaningful interpretations. However, when the cognitive demands of the task exceed the available processing capacity, comprehension may break down.

The characteristics of spoken input can significantly influence the level of cognitive effort required during listening. Rapid speech may reduce the time available for decoding and interpretation, while linguistically complex structures may require additional analytical processing. When such challenging input conditions occur, listeners must allocate greater cognitive resources in order to maintain comprehension. Learners with greater working memory capacity may be able to store and manipulate larger amounts of information simultaneously, allowing them to cope more effectively with demanding listening conditions. In contrast, learners with more limited cognitive resources may struggle to retain earlier parts of the message while processing new segments of speech, leading to gaps in understanding.

The interaction between cognitive and input related factors is particularly evident when listening tasks involve multiple sources of difficulty. For example, speech that is delivered rapidly and contains complex grammatical structures can place a heavy burden on the listener processing system. Under these circumstances, comprehension may depend strongly on the listener ability to allocate attention efficiently and maintain relevant information in working memory. If cognitive resources are insufficient to manage both the speed and complexity of the input, the listener may experience processing overload and fail to construct a coherent representation of the message. Conversely, when input conditions are less demanding, even learners with lower cognitive capacity may be able to process the speech successfully. Recognizing the interaction between cognitive resources and input characteristics provides a more comprehensive understanding of second language listening comprehension. Rather than attributing listening difficulty solely to the properties of the spoken message or to learner ability, this perspective emphasizes the dynamic relationship between the two. Listening performance can therefore vary depending on how well the characteristics of the input align with the cognitive capacities of the learner. This view highlights the importance of considering both linguistic and cognitive variables when examining listening processes in second language contexts.

From a pedagogical standpoint, acknowledging the interaction between cognitive and input factors has important implications for the design of listening instruction. Educators may enhance learner comprehension by selecting materials that balance linguistic complexity and speech rate with the cognitive abilities of their students. Gradual exposure to more challenging listening conditions can help learners develop strategies for managing increasing processing demands while strengthening their capacity to interpret spoken language in real time. Understanding how cognitive and input related factors work together therefore contributes to the development of more effective approaches to second language listening instruction and provides valuable insight into the mechanisms that support successful comprehension.

3. Methodology

3.1 Research objectives

The study aimed to investigate the cognitive and linguistic factors that influenced second language listening comprehension during real time processing. Listening comprehension in a second language requires learners to process spoken input, decode linguistic information, and construct meaning within a limited time frame. Because listening performance is shaped by both characteristics of the input and the cognitive resources of the listener, the study sought to examine how these variables interacted to affect comprehension outcomes. The primary objective was to explore the effects of speech rate, linguistic complexity, and working memory capacity on real time listening processing and to determine how these factors contributed to variation in listening performance among second language learners. More specifically, the study aimed to determine the extent to which variations in speech rate influenced learners ability to process and understand spoken language. Speech that is delivered at different speeds places varying levels of temporal demand on the listener. Rapid speech may reduce the time available for decoding and interpretation, whereas slower speech may provide additional processing opportunities. By examining the impact of speech rate on listening outcomes, the study sought to clarify how temporal characteristics of spoken input affected comprehension in real time listening situations.

Another objective of the study was to examine the effect of linguistic complexity on second language listening comprehension. Linguistic complexity, reflected in syntactic structures and vocabulary difficulty, can increase the cognitive demands associated with listening. Complex sentences and unfamiliar lexical items may require additional processing effort, which can influence learners ability to construct meaning from spoken messages. The study therefore aimed to investigate how variations in linguistic difficulty affected comprehension and whether learners responded differently to input that varied in structural and lexical complexity.

The study also sought to examine the role of working memory capacity in second language listening processing. Working memory functions as a cognitive resource that allows learners to temporarily store and manipulate information during comprehension. Individual differences in working memory capacity may therefore explain variation in listening performance among learners exposed to the same input conditions. By measuring working memory and analyzing its relationship with

listening outcomes, the study aimed to provide insight into the cognitive mechanisms that support successful comprehension in real time listening tasks.

Finally, the study aimed to explore the interaction between speech rate, linguistic complexity, and working memory capacity in shaping listening performance. Rather than treating these variables as independent factors, the research sought to determine how they influenced one another and how their combined effects impacted comprehension outcomes. Understanding these interactions was important for developing a more comprehensive model of second language listening that accounted for both input characteristics and individual cognitive differences. The findings were expected to contribute to theoretical knowledge in second language acquisition and to provide implications for instructional practices that support listening development in language learning contexts.

3.2 Data collection

3.2.1 Research design

The study adopted a quantitative experimental research design to examine the effects of speech rate, linguistic complexity, and working memory capacity on second language listening comprehension during real time processing. An experimental design was appropriate for this study because it allowed the researcher to systematically manipulate specific characteristics of the listening input while observing how these variations influenced learners comprehension performance. By controlling the conditions under which listening tasks were presented, the study aimed to identify the individual and combined effects of the selected variables on listening outcomes. In this research, speech rate and linguistic complexity functioned as the primary independent variables, while listening comprehension performance served as the main dependent variable. Working memory capacity was treated as an individual difference variable that could influence how learners responded to variations in the listening input. The experimental design enabled the researcher to present participants with listening tasks that differed in terms of speech rate and linguistic complexity, creating multiple listening conditions. This approach made it possible to compare learners performance across different input conditions and to determine how changes in speech speed and linguistic difficulty affected comprehension.

Participants were exposed to a series of listening tasks in which speech rate and linguistic complexity were systematically varied. Some listening passages were presented at a slower rate, while others were delivered at a faster rate. Similarly, the linguistic content of the passages varied in terms of syntactic structure and vocabulary difficulty. By manipulating these features, the study examined how learners processed spoken input under different levels of cognitive demand. Participants listening comprehension was assessed through comprehension questions designed to measure their understanding of the spoken material. In addition to the listening tasks, participants working memory capacity was measured using a standardized cognitive task designed to assess their ability to temporarily store and process information. The inclusion of this measure allowed the researcher to explore how individual differences in working memory related to listening performance under varying input conditions. By comparing the listening outcomes of learners with different levels of working memory capacity, the study aimed to determine whether cognitive resources moderated the effects of speech rate and linguistic complexity.

Overall, the experimental design enabled a systematic investigation of the relationships between cognitive factors and characteristics of spoken input in second language listening. By examining how learners performed across controlled listening conditions, the study generated empirical evidence that clarified the role of speech rate, linguistic complexity, and working memory capacity in real time listening processing. This design provided a structured and reliable framework for collecting data that contributed to a deeper understanding of the cognitive mechanisms underlying second language listening comprehension.

3.3 Participants

The participants in the study consisted of second language learners enrolled in higher education or language learning programs where English was studied as a foreign or second language. Selecting learners from this population was appropriate because they possessed sufficient exposure to the target language while still demonstrating variation in listening proficiency and cognitive processing abilities. A sample of intermediate and advanced level learners was recruited in order to ensure that participants were capable of engaging with the listening tasks while still displaying meaningful differences in comprehension performance. Including learners from these proficiency levels allowed the study to examine how variations in speech rate, linguistic complexity, and working memory capacity influenced listening outcomes among individuals who had developed foundational language skills but continued to face challenges in real time processing. The sample size was determined based on the requirements of quantitative experimental research and statistical analysis. A sufficiently large number of participants was selected to ensure that the findings were statistically reliable and generalizable to a broader population of second language learners. Participants were recruited through educational institutions and language programs where English instruction was provided. Recruitment followed ethical research procedures, and participation was voluntary. Each participant was informed about the purpose of the study, the nature of the listening tasks, and their right to withdraw from the research at any time without penalty. Informed consent was obtained prior to participation in accordance with ethical guidelines for research

involving human subjects. To capture individual differences in cognitive processing, participants' working memory capacity was assessed using a standardized cognitive task. This measure allowed the researcher to classify participants according to their working memory resources and to examine how these differences related to listening performance under varying input conditions. Additionally, demographic information such as age, language background, and previous exposure to English listening materials was collected to describe the characteristics of the sample and to control for potential confounding variables. However, the primary focus of participant selection remained on learners' second language listening abilities and cognitive capacity rather than demographic variation. By selecting participants who represented a typical population of second language learners, the study generated findings that were relevant to language learning contexts and educational practice. The inclusion of learners with diverse cognitive and linguistic profiles enabled the investigation of how individual differences interacted with input characteristics to influence listening comprehension. This approach contributed to a comprehensive understanding of second language listening processes and provided empirical evidence that may inform instructional strategies and pedagogical decision making in language education.

3.4 research instruments

The study employed multiple research instruments in order to collect data on listening comprehension performance, working memory capacity, and the effects of speech rate and linguistic complexity on real time processing. Using more than one instrument allowed for a comprehensive examination of both cognitive and linguistic variables and strengthened the validity of the research findings. Listening comprehension was measured through structured listening tasks accompanied by comprehension questions. Participants listened to spoken passages that varied in speech rate and linguistic complexity and then answered questions designed to assess their understanding of the material. The questions targeted different levels of comprehension, including factual understanding, inference, and the ability to integrate information from the passage. The listening tasks were carefully designed to reflect real time listening conditions in which learners had to process information as it was presented.

Working memory capacity was assessed using a standardized cognitive task that measured the ability to temporarily store and manipulate information. Such tasks required participants to remember sequences of items or to process information while simultaneously retaining other data in memory. This measure was important because working memory plays a central role in language processing and may influence how effectively learners managed the cognitive demands of listening. By obtaining working memory scores for each participant, the study examined the relationship between cognitive capacity and listening performance under different input conditions. The manipulation of speech rate and linguistic complexity constituted another important component of the research instruments. Listening passages were recorded or selected in versions that differed in delivery speed and structural complexity. Some passages were presented at a slower rate to allow greater processing time, whereas others were delivered at a faster rate to simulate more demanding listening conditions. Similarly, passages varied in linguistic complexity by including differences in sentence structure and vocabulary difficulty. These variations enabled the study to investigate how input characteristics influenced comprehension and how learners responded to different levels of linguistic and temporal demand. Data collection also included demographic information and background details about participants' language learning experience. Although these data were not the primary focus of the study, they provided useful contextual information and helped control for potential confounding variables. For example, previous exposure to English listening materials or differences in educational background might influence listening performance. Collecting such information allowed the researcher to describe the sample more accurately and to interpret the results with greater precision. By combining listening tasks, working memory measures, and controlled variations in speech rate and linguistic complexity, the research instruments provided a structured approach to data collection. These instruments were designed to capture both cognitive and linguistic dimensions of second language listening processing, enabling a detailed analysis of the factors that influenced comprehension. The use of validated and systematic instruments contributed to the reliability and credibility of the research findings.

4. Results

The results of the study revealed clear patterns regarding the effects of speech rate, linguistic complexity, and working memory capacity on second language listening comprehension. Data analysis indicated that variations in input characteristics influenced learners' comprehension performance, with faster speech rates and higher levels of linguistic complexity generally associated with reduced understanding. Participants with greater working memory capacity tended to perform better in listening tasks, particularly under conditions of increased cognitive demand. Moreover, interaction effects suggested that the impact of speech rate and linguistic complexity was moderated by individual differences in working memory, highlighting the role of cognitive resources in real time listening processing. The following sections present the results in detail under specific headings, providing a systematic analysis of each variable and its contribution to listening comprehension outcomes.

4.1 Effects of Speech Rate on Second Language Listening Comprehension

The results indicated that speech rate had a significant and consistent influence on second language listening comprehension, as variations in the speed of delivery directly affected the amount of time participants had available to process, decode, and interpret spoken input in real time. Listening comprehension in a second language is a cognitively demanding activity that requires the simultaneous coordination of bottom-up processing, such as phonological decoding and lexical recognition, and top-down processing, such as prediction, inference, and integration of meaning. When the speech rate was reduced and the listening passages were presented at a slower tempo, comprehension scores improved noticeably, and participants demonstrated a greater ability to accurately decode linguistic information, recognize familiar and unfamiliar vocabulary, and construct coherent meaning from the input. The additional processing time afforded by slower speech appears to have reduced cognitive pressure on working memory, allowing learners to allocate more attentional resources to understanding the message rather than struggling to keep up with its delivery. As a result, learners were better able to segment speech into meaningful units, identify key ideas, and retain information long enough to respond accurately to comprehension questions. In addition, slower speech rates seemed to facilitate more effective integration of linguistic elements, enabling participants to connect words and phrases into a coherent mental representation of the text. This improved integration suggests that learners were not only decoding individual words more successfully but were also better able to construct global meaning across sentences and discourse segments. The reduced temporal pressure likely allowed for more strategic use of contextual clues, enabling learners to compensate for unknown vocabulary and ambiguous structures through inference. Consequently, slower delivery created a more supportive listening environment in which learners could engage in both analytical and interpretive processing, leading to higher overall comprehension performance. In contrast, when the speech rate increased and the input was delivered at a faster pace, comprehension performance declined significantly. Participants reported increased difficulty in keeping up with the flow of information, often describing the experience as overwhelming or too rapid to process effectively. At higher speeds, learners frequently missed important lexical items, failed to notice grammatical markers, or were unable to fully integrate earlier information before new input was introduced. This resulted in fragmented understanding, where only partial segments of the message were retained, leading to lower accuracy in comprehension tasks. The accelerated pace of delivery placed substantial demands on cognitive processing systems, particularly working memory, which was required to temporarily store and manipulate incoming information while simultaneously decoding subsequent input. Faster speech rates also appeared to disrupt the balance between bottom-up and top-down processing. Because learners were preoccupied with decoding rapidly occurring linguistic signals, they had fewer cognitive resources available for higher-level interpretive processes such as inference, prediction, and global comprehension. This imbalance often resulted in surface-level understanding without full grasp of the overall message. In some cases, participants relied heavily on isolated keywords rather than constructing a coherent discourse representation, which further contributed to misunderstandings and errors in answering comprehension questions. These difficulties highlight the vulnerability of second language listeners to temporal constraints, particularly when input exceeds their processing capacity.

Overall, these findings demonstrate that speech rate functions as a critical determinant of listening performance in second language contexts because it fundamentally shapes the temporal and cognitive conditions under which comprehension occurs. When speech is too fast, the cognitive system may become overloaded, leading to breakdowns in processing, reduced accuracy, and incomplete mental representations of the input. Conversely, slower speech provides additional processing time that supports decoding, integration, and interpretation, thereby enhancing comprehension outcomes. The results therefore underscore the importance of considering input speed as a key pedagogical variable in listening instruction, as optimal comprehension is more likely to occur when the temporal demands of the task are aligned with learners' processing capacities and proficiency levels.

4.2 Effects of Linguistic Complexity on Listening Comprehension

The results revealed that linguistic complexity exerted a clear and noticeable effect on second language listening comprehension, as passages containing more complex syntactic structures and less frequent vocabulary were consistently associated with lower comprehension scores compared to simpler listening materials. Participants demonstrated better understanding when the spoken input included straightforward sentence structures and familiar lexical items, since these conditions reduced the cognitive effort required for decoding and interpretation. In these simpler conditions, learners were able to process information more efficiently, follow the progression of ideas more easily, and integrate meaning across sentences with greater accuracy, which ultimately led to improved performance on comprehension tasks. In contrast, listening passages with higher linguistic complexity created additional processing demands for learners. Complex grammatical structures, embedded clauses, and unfamiliar vocabulary required participants to spend more time decoding individual elements of speech while simultaneously trying to follow the overall message. This often led to difficulties in maintaining a coherent understanding of the input, as learners struggled to retain earlier information while processing new segments in real time. As a result, many responses showed partial comprehension or misunderstandings of key ideas, particularly when questions required a global

understanding of the passage. These findings suggest that linguistic complexity influences listening performance primarily by increasing cognitive load during real-time processing. When input is linguistically demanding, learners must allocate greater mental resources to decoding language forms, which can limit their ability to integrate meaning effectively. Conversely, simpler linguistic input reduces processing burden and allows learners to focus more on constructing overall meaning, leading to better comprehension outcomes. Overall, the results highlight that the level of linguistic complexity in spoken input is an important factor shaping second language listening performance and should be carefully considered in both instructional design and assessment contexts.

4.3 Interaction Between Working Memory Capacity and Input Characteristics in Listening Performance

The results demonstrated a clear interaction between working memory capacity and input characteristics in shaping listening performance. Participants with higher working memory capacity consistently achieved better comprehension scores, particularly under conditions of rapid speech and high linguistic complexity. These learners were able to retain and manipulate larger amounts of information while processing incoming speech, which allowed them to maintain a coherent representation of the message even when the input placed substantial cognitive demands on the processing system. In contrast, participants with lower working memory capacity experienced greater difficulty under the same conditions because their limited cognitive resources reduced their ability to store and integrate information while decoding new input. When speech was delivered quickly or contained complex linguistic structures, these learners often struggled to keep pace with the flow of information, leading to partial understanding and lower performance on comprehension tasks. The interaction effects indicate that working memory capacity moderated the impact of input characteristics on listening outcomes, meaning that the influence of speech rate and linguistic complexity varied depending on the cognitive resources available to the listener. Learners with greater capacity were more resilient to demanding listening conditions, whereas those with lower capacity were more sensitive to increases in processing difficulty. These findings support the view that listening comprehension results from a dynamic relationship between input features and individual cognitive differences rather than from either factor alone. Understanding this interaction provides important insight into real time listening processes and highlights the role of cognitive resources in managing the demands of second language comprehension.

5. Discussion

5.1 Effects of Speech Rate on Second Language Listening Comprehension

The results concerning the effects of speech rate on second language listening comprehension indicate that temporal characteristics of the input play a crucial role in shaping learners ability to process spoken language in real time. Faster speech was associated with lower comprehension performance because the increased speed reduced the time available for decoding and interpreting linguistic information. When speech is delivered rapidly, listeners must process incoming data at a pace that may exceed their cognitive processing capacity, leaving limited opportunities to analyze vocabulary, grammatical structures, and meaning before new information arrives. This condition can create a processing bottleneck in which learners struggle to retain earlier segments of speech while attempting to understand subsequent information, leading to partial or fragmented comprehension. The findings support theoretical perspectives in cognitive processing that emphasize the importance of temporal constraints in listening tasks. Real time listening requires simultaneous decoding and interpretation, and when speech is too fast, the cognitive system may become overloaded. Under such circumstances learners are more likely to miss important details or fail to integrate information into a coherent mental representation of the message. Conversely, slower speech rates facilitated comprehension by providing additional processing time and reducing the cognitive demands associated with rapid decoding. When learners had more time to process the input, they were better able to recognize words, analyze grammatical relationships, and construct meaning, which resulted in higher comprehension scores. These results align with previous research suggesting that moderated speech rates support listening performance by allowing sufficient time for information processing. From a pedagogical perspective the findings highlight the importance of considering speech rate when designing listening materials and instructional activities. Materials that are too fast may hinder comprehension, particularly for learners who are still developing proficiency in the target language, whereas appropriately paced input can enhance understanding and support skill development. The results therefore underscore the need to balance natural speech characteristics with the processing capacities of learners in educational contexts, ensuring that listening tasks provide opportunities for meaningful comprehension without imposing excessive cognitive demands.

5.2 Effects of Linguistic Complexity on Listening Comprehension

The results regarding the effects of linguistic complexity on second language listening comprehension indicate that the structural and lexical characteristics of spoken input had a significant and consistent influence on learners' ability to process and understand messages in real time. Passages containing complex syntactic structures, such as multiple embedded clauses, long sentence constructions, passive forms, and dense grammatical relationships, as well as less frequent or specialized vocabulary, were systematically associated with lower comprehension scores when compared to passages characterized by simpler

grammatical structures and more familiar lexical items. This pattern suggests that increased linguistic complexity places substantial cognitive demands on listeners, requiring them to allocate additional attentional and mental resources to decoding sentence structures, interpreting unfamiliar words, and integrating multiple linguistic elements into a coherent mental representation of the message. When learners were exposed to simpler linguistic input, they were able to process information more efficiently and with less cognitive effort, which allowed them to focus more on meaning construction rather than linguistic decoding. In these conditions, participants demonstrated improved ability to follow the progression of ideas, identify key information, and respond to comprehension questions with greater accuracy. This improvement reflects a smoother interaction between bottom-up processing (word recognition and syntactic parsing) and top-down processing (inferencing and prediction), which together support more effective comprehension. As a result, simpler input conditions created a more accessible listening environment that reduced processing strain and facilitated more stable understanding of the spoken message. In contrast, higher levels of linguistic complexity disrupted this balance by increasing the difficulty of real-time processing. Learners often struggled to simultaneously decode complex sentence structures while retaining earlier segments of information in working memory, leading to fragmentation in comprehension. The presence of unfamiliar vocabulary further compounded these difficulties, as learners were required to infer meaning from context or pause cognitive processing to interpret individual lexical items. This dual burden frequently resulted in incomplete or inaccurate mental representations of the message, particularly in cases where comprehension questions required synthesis of information across multiple parts of the passage. These findings strongly suggest that linguistic complexity influences listening performance primarily by increasing cognitive load during processing. When input is linguistically demanding, learners must devote a greater proportion of their limited cognitive resources to form-level processing, which reduces the capacity available for higher-level interpretive tasks such as integrating ideas, drawing inferences, and maintaining global coherence. This imbalance can ultimately hinder the construction of a unified understanding of the spoken discourse. Conversely, when linguistic input is less complex, cognitive resources can be more effectively distributed toward meaning-making processes, resulting in improved comprehension outcomes and greater overall accuracy.

Furthermore, the results support cognitive models of second language listening that emphasize the interaction between input complexity and working memory limitations. Real-time listening requires learners to continuously store, update, and process incoming information, and when linguistic complexity exceeds processing capacity, breakdowns in comprehension are more likely to occur. These findings are also consistent with prior research suggesting that unfamiliar vocabulary and syntactically dense structures significantly hinder comprehension, particularly when they are combined with other challenging variables such as increased speech rate or reduced contextual support. From a pedagogical perspective, these results highlight the importance of carefully selecting, adapting, and sequencing listening materials in accordance with learners' proficiency levels. Rather than exposing learners immediately to highly complex input, instructional design should incorporate a gradual increase in linguistic difficulty, allowing students to progressively develop the necessary cognitive strategies and processing skills required for more demanding listening tasks. Scaffolded exposure to complex language can help learners build confidence, reduce anxiety, and strengthen their ability to manage higher levels of linguistic and cognitive load over time.

Overall, the findings demonstrate that linguistic complexity is a central factor in second language listening comprehension, as it significantly shapes both the ease of real-time processing and the accuracy of comprehension outcomes. Its influence extends beyond individual word or sentence understanding to affect overall discourse processing, highlighting the need for careful attention to input design in both teaching and assessment practices in second language listening instruction.

5.3 Interaction Between Working Memory and Input Characteristics

The results concerning the interaction between working memory and input characteristics in second language listening performance demonstrate that cognitive resources significantly moderated the effects of speech rate and linguistic complexity on comprehension outcomes. Learners with higher working memory capacity consistently achieved better comprehension scores, particularly under demanding listening conditions involving rapid speech and complex linguistic structures. This pattern suggests that working memory functions as a critical cognitive resource that supports real time language processing by enabling listeners to temporarily store and manipulate information while decoding and interpreting spoken input. Individuals with greater working memory capacity were better able to retain earlier segments of speech, integrate information across sentences, and construct coherent meaning despite the temporal and linguistic demands of the task. In contrast, learners with lower working memory capacity experienced greater difficulty under the same conditions because their limited cognitive resources reduced their ability to process multiple pieces of information simultaneously. When speech was delivered quickly or contained complex grammatical structures, these learners often struggled to keep pace with the incoming information, leading to fragmented comprehension and lower performance on listening tasks. The interaction effects observed in the study support theoretical models of listening that emphasize the dynamic relationship between input difficulty and individual cognitive differences. Listening comprehension is not determined solely by characteristics of the input or by learner ability in isolation, but rather by the interaction between these factors. Rapid speech and high linguistic complexity increase processing demands, and the extent

to which learners can manage these demands depends on their working memory capacity. Learners with greater cognitive resources are more resilient to challenging listening conditions because they can allocate sufficient resources to decoding and retaining information, whereas those with lower capacity are more susceptible to processing overload. These findings have important pedagogical implications. Listening instruction should account for individual differences in cognitive capacity and provide materials that gradually increase in difficulty. Tasks that initially use moderated speech rates and simpler linguistic structures can help learners develop processing skills and listening strategies before introducing more demanding input. Additionally, awareness of working memory limitations suggests that educators should design listening activities that minimize unnecessary cognitive load, allowing learners to focus on meaning construction and comprehension. Overall, the results highlight the importance of considering both cognitive and input related factors in second language listening. The interaction between working memory and characteristics of the spoken input shapes comprehension outcomes and explains variation in performance among learners. Understanding this relationship contributes to a more comprehensive view of listening processes and supports the development of instructional approaches that accommodate cognitive diversity and promote successful language learning.

6. Conclusion

The study investigated the effects of speech rate, linguistic complexity, and working memory capacity on second language listening comprehension in real time processing. The findings demonstrated that listening performance was influenced by both input characteristics and cognitive resources. Faster speech rates and higher levels of linguistic complexity reduced comprehension because they increased processing demands and limited the time available for decoding and interpretation. Learners with greater working memory capacity performed better under demanding conditions, highlighting the role of cognitive resources in managing the challenges of listening. The interaction between working memory and input characteristics suggested that comprehension outcomes depend on the dynamic relationship between external features of spoken language and individual differences in processing capacity. These results contribute to a deeper understanding of second language listening processes by emphasizing that listening difficulty arises from both temporal and linguistic factors as well as cognitive variability among learners. Pedagogically, the findings underscore the importance of designing listening materials that consider speech rate and linguistic complexity and that gradually increase in difficulty to support skill development. By aligning input conditions with learners processing capacities, educators can enhance listening comprehension and promote more effective language learning. Overall, the study provides empirical evidence that listening comprehension is shaped by the interaction of cognitive and input related factors and highlights the need for instructional approaches that address these dimensions in second language education.

6.1 Pedagogical Implications

The findings of this study have important pedagogical implications for second language listening instruction, as they clearly demonstrate the combined influence of input characteristics and cognitive resources on learners' comprehension outcomes. In particular, the results suggest that effective listening instruction should not only focus on exposing learners to authentic spoken language but should also carefully regulate the level of difficulty in terms of speech rate and linguistic complexity. Educators are encouraged to design listening materials that begin with slower speech and simpler syntactic structures, allowing learners sufficient time to decode input, recognize vocabulary, and construct meaning without excessive cognitive strain. This gradual approach helps reduce anxiety, supports comprehension, and builds learners' confidence in handling spoken English in real time. As learners progress, listening tasks should be systematically adjusted to include faster speech rates and more complex linguistic structures in a controlled and scaffolded manner. This progression is essential for developing more advanced listening skills, as it enables learners to gradually adapt to the processing demands of real-world communication. Rather than exposing students abruptly to highly challenging input, a staged increase in difficulty allows for the development of more efficient real-time processing strategies, improved lexical recognition, and stronger ability to integrate information under time pressure. In this sense, input modification becomes a key pedagogical tool for balancing accessibility and challenge in listening instruction. In addition, the findings regarding working memory capacity highlight the importance of addressing individual differences in cognitive resources within the classroom. Since learners vary in their ability to temporarily store and process auditory information, instruction should incorporate scaffolding techniques that support weaker listeners while still challenging more advanced ones. Teachers can achieve this by providing guided listening practice, breaking down listening tasks into smaller segments, and offering pre-listening activities that activate background knowledge and reduce cognitive load. Strategy training is also essential, as learners can benefit from explicit instruction in techniques such as predicting content, identifying key ideas, taking structured notes, and summarizing information after listening. These strategies help learners manage the demands of real-time comprehension more effectively. Furthermore, post-listening activities can play a significant role in reinforcing comprehension and reducing cognitive overload. Activities that encourage learners to reflect on what they have heard, compare answers, and discuss meanings collaboratively can deepen understanding and support long-term retention of information. Repeated exposure to listening materials, combined with varied tasks, can also strengthen processing efficiency and gradually improve learners' ability to cope with complex input. Beyond classroom instruction, these findings have implications for the

design of listening materials in textbooks, digital platforms, and multimedia resources. Developers should ensure that materials are carefully graded in terms of speech rate and linguistic complexity, with clear progression across proficiency levels. Providing opportunities for repeated listening, adjustable playback speeds, and scaffolded comprehension tasks can further enhance accessibility and learning effectiveness. Overall, by aligning instructional design with both cognitive and linguistic factors identified in this study, educators can create more effective and supportive listening environments. Such an approach not only improves comprehension performance but also fosters learners' confidence, autonomy, and long-term ability to understand spoken language in diverse academic and real-world contexts.

6.2 Limitations of the study

The study had several limitations that should be considered when interpreting the findings. First, the sample consisted of learners from a specific educational context and proficiency level, which may limit the generalizability of the results to other populations of second language learners with different linguistic backgrounds or levels of listening proficiency. Second, the experimental nature of the research, while useful for controlling input variables such as speech rate and linguistic complexity, may not fully reflect the complexities of listening in authentic real world communication where additional factors such as background noise, speaker accents, and interactive discourse can influence comprehension. Third, working memory capacity was measured using standardized cognitive tasks, but these measures may not capture all dimensions of cognitive processing that contribute to listening performance in natural settings. Furthermore, the study focused on immediate comprehension outcomes and did not examine long term development of listening skills, which means that the findings provide insight into real time processing but do not address how learners listening abilities evolve over time. Finally, although the manipulation of input characteristics allowed for systematic analysis of their effects, listening comprehension is influenced by multiple interacting variables, and the study could not account for all potential factors that shape performance. These limitations suggest that future research should explore broader populations, incorporate more ecologically valid listening conditions, and examine longitudinal outcomes to provide a more comprehensive understanding of second language listening processes.

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