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Language and the Brain: Exploring the Relationship between Language Production and Comprehension as a set of separate or integrated processes

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Abstract

Abstract

Understanding how the brain processes language is a complex area of study. While it may seem simple to consider language production and comprehension as separate processes, they are interconnected. Psycholinguistics identifies these processes as crucial themes in the study of language and the mind. Investigating the link between language and the human brain is a challenging and intricate task. Throughout scientific history, many attempts have been made to understand the nature of this relationship from various perspectives (Nilipour, 2010). The field of Psycholinguisticsaims to understand how our brains process language. Language is crucial in our everyday lives, whether we are following instructions or engaging in internal dialogue. Previously, psychologists used linguistic rules hypothesized by linguists to explain our comprehension and production of language. However, recent studies focus more on the relationship between language and the brain, exploring brain regions, language processes, and their connections. These studies also analyze recent research on language production and comprehension to gain insight into the nature and dynamics of language. The primary finding is that language production and comprehension are not entirely separate processes, as they are tightly interconnected.

Keywords: Psycholinguistics, language and brain relationship, brain structure, language comprehension process, language production process

1- Introduction

Understanding language in its deepest sense is not possible without direct experience of its real-world correlates. Prior to language acquisition, perceptual data are conceptualized based on largely innate strategies, which select and highlight the most important parts of internal concepts and discourse from birth through adulthood. Schemas produced in the sensory-motor world become schemas for describing abstract words. Language may be defined as a system of symbols with known meanings that facilitate our thought processes and help us communicate with each other. Due to the growing interest in the field of communication, an increasing number of psychologists have recently devoted themselves to the study of language. Producing and understanding language is one of the most automatic tasks that humans do, but they are also the most complex. Language production is primarily focused on the formulation of separate and distinct sentences. Speech is usually composed of one or more words uttered together under a single linguistic line or embodying a single idea (e.g., Boomer, 1978; Ferreira, 1993). Comprehension involves the simultaneous integration of many types of information, such as knowledge about the alphabet or letters and their sounds, spelling, grammar, word meanings, and general knowledge of the world. In addition, general cognitive abilities such as attentional monitoring, inference, and memory retrieval are used to organize this information into a single meaningful representation.

The field of Psycholinguistics is an interdisciplinary area that explores the relationship between the mind and language. It examines the psychological and neurological factors involved in language acquisition, comprehension, production, and loss. Early psychologists initially based their descriptions of language comprehension and production on rules proposed by linguists. As psychology advanced, it became evident that language theories could not be based solely on linguistic rules. Psycholinguistics evolved as a field of inquiry in its own right, focusing on the psychological processes of language use, including production, comprehension, and language acquisition.

For skilled language users, understanding and producing language may seem simple, but psychologists recognize it as a complex interaction involving various processing components. Psychologists study different components, such as vocabulary access, syntactic structure building, sound pattern decoding, and message interpretation and expression, to understand the underlying processes of language use and learning. (Lollette, 1989).

Language production is divided into three major stages: conceptualization, formulation, and synthesis, while comprehension involves interpreting and retaining the speaker's message. The relationship between language and the brain is complex and includes various interrelated elements that need further examination. Neurolinguistics has become a dedicated discipline to study how language is processed by the brain, using non-invasive techniques to understand its neural functions (Miller & Emmas, 1983). The purpose of this paper is to explore the relationship between different brain regions/structures and language processes. It aims to provide insight into how psychologists interpret the brain in relation to language processes. The article also includes a review of recent research in the field of language production and comprehension. From the perspective of the language producer (speaker, writer), the production of a message involves forming an intention, designing sentence structure, selecting words, and finally expressing the intention as a sequence of sounds or letters. On the other hand, from the perspective of the perceiver (listener, reader), the goal is to understand or recognize elements such as letters and sounds, and to connect these words in the sentence structure to arrive at a message-level interpretation.

2- Literature review

In this section, we will explore existing literature on psycholinguistics, language production, and language comprehension. Additionally, we will delve into how psychologists interpret the interrelationship between the mind and language.

2.1 Psychology of language

The Psycholinguistics is a branch of cognitive psychology that investigates the psychological underpinnings of language ability and performance. It focuses on the neurological and psychological factors that enable humans to use and understand language. Specifically, it employs psychological, scientific, and experimental methods to study language acquisition, production, and processing. In essence, the Psycholinguistics entails the scientific examination of mental processes and elements used in language usage.

Psycholinguistics can also be described as the theoretical and experimental study of the mental faculty. Since the linguistic revolution in the mid-1960s, the field of psycholinguistics has expanded to encompass a wide range of topics and disciplines. Similar to other branches of psychology, linguistic psychology originated in the early to mid-1960s. The Chomsky Revolution, also known as the linguistic revolution, emphasized languages and their structures, positing that they follow rules and principles, akin to chemical structures (Chomsky, 1957, 1965, and 1968).

This field has been developed and redefined in response to Chomsky. Chomsky's argument for the creation of syntactic sentences was that language exists because humans have an innate ability, and was highly critical of Skinner's 1959 book. According to Anderson, Chomsky's review still holds that the human ability to use syntax is qualitatively different from any kind of animal communication. This ability may result from the adaptation of evolved skills for other purposes (Anderson, 1998). It is very easy for language users to think that language production and language comprehension are two simple phenomena. For psycholinguistics, these two processes are part of three main themes in the study of language and the mind.

They usually study language comprehension and production as separate sets of processes. The language production system has the task of converting thoughts and desires into a movement plan for action, moving along the way through the stages of word selection, syntactic planning and phonological planning. The perception system is different from a task. Its job is to receive an auditory or visual signal as input, identify the words in that signal, and assign a structure and meaning to the input. However, researchers have good reasons for viewing production and comprehension as part of a linguistic system. One reason for this is that both comprehension and production present distinct challenges to language users. For example, language comprehension involves extracting meaning from a speech signal or printed text, while language production involves converting a preverbal message into speech or text using appropriate vocabulary, grammar, and phonetics or spelling. Another reason is that it seems to be much more difficult to produce experientially compared to reading comprehension. This is because researchers often find it difficult to control the input and extract the corresponding output when studying language production.

2.2 Language Production

According to Lollett's (1989) theory, language production comprises three major stages:

1) Deciding what to express (conceptualization),

2) Determining how to express it (formulation), and

3) Expressing it (synthesis).

While achieving conversational goals, structuring narratives, and adjusting the tide of conversation are important to understanding how people speak (Clark, 1996), the study of the Psycholinguistics has mainly focused on the formulation of single, discrete sentences. An utterance consists of one or more words spoken together under a single linguistic line or expressing an idea (e.g., Boomer, 1978; Ferreira, 1993).

Griffin and Ferreira (2006) outline three types of mental processes:

Conceptualization begins with an abstract concept or idea of what we want to say about the world or the current state. Formulating language elements to express ideas relies on our language knowledge, including grammar and vocabulary. It should be noted that slip of the tongue errors appears at all levels of formulation, from phoneme, morpheme to word level. Speaking and performing speech includes our speech content. The conceptualization stage can be seen as the main and final builder of communication. The formulation stage can be considered the conductor and orchestrator of speech sounds. Finally, the stage of expression can be seen as the musical instrument of our voice.

While Ferreira and Engelhart's view of syntax describes the processes that allow speakers to produce grammatical sentences, this paper focuses instead on the processing of the words themselves. Theories of multi-word expression or sentence production essentially describe how the word order and structure of sentences is acquired, how dependencies between words (e.g. subject-verb agreement) are adapted, and an independent account of performance (Chang, Dell, Bock, & Griffin, 2000; Ferreira, 2000; Kempen & Honkamp, 1987).

The study of language production primarily focuses on the formulation of individual sentences. An utterance consists of one or more words spoken together under a single linguistic line or expressing an idea (e.g., Boomer, 1978; Ferreira, 1993).

The field of psycholinguistics has developed to encompass a wide range of topics and disciplines. The linguistic revolution in the mid-1960s, called the Chomsky Revolution (see also Chomsky, 1957, 1965, and 1968), promoted the study of the mental faculty, specifically the structure of language and its rules and principles.

The first issue is how to produce words. The simplest meaningful sentence consists of one word. The production of a word begins by specifying its semantic and practical features. That is, a speaker decides on an intention or content to express (e.g., a desired outcome or observation) and encodes situational constraints on how to express the content (e.g., polite or informal speech, monolingual or mixed languages). This process, called conceptualization or message planning, has traditionally been considered paralanguage and language neutral (Garrett, 1975; Lulette, 1989). However, speakers may include different information in their messages when preparing to speak in different languages.

Formulation comes after word production and is divided into word selection and sound processing (Fromkin, 1971; Garrett, 1975). The decision to use a word in a person's vocabulary is based on the semantic and pragmatic features called subject language (Kappman and Hojibers, 1983), lexical entry, lexical representation, the word's presence in a speaker's vocabulary, and targets the individual. able to express specific meaning and action. Sound processing involves constructing the phonetic form of a selected word by retrieving its individual sounds and organizing them into stressed and unstressed syllables (phonological encoding) and then specifying the motor programs to realize those syllables (phonological encoding). The last process, which is the discharge of motor programs to pronounce the sounds of a word, is called articulation.

It is interesting to note that recent models of word production largely agree on the basic facts about how the system works, with minimal changes in explanatory mechanisms. When the models differ, the bias relates to different stages of production, such as word selection or phonological encoding, and different aspects of these stages, such as speed of processing or how processing may lead to speech errors. This means that most of the production features described below are accounted for (at least in some detail) by most production models.

2.3 Language Comprehension

Language production and comprehension have traditionally been viewed as separate processes in language processing. However, we suggest that production and understanding are interconnected, allowing people to predict themselves and others. Both production and perception involve action, and perception is a form of action. Language production and comprehension rely on specific levels of linguistic representation, such as semantics, syntax, and phonology. Speakers and listeners use covert imitation and forward modeling to make predictions at these levels, bridging production and comprehension processes and using these predictions to monitor future utterances. These explanations account for various behavioral and neuroscience findings in language processing.

In the latter half of the 20th century, language psychologists focused primarily on speech perception, neglecting research on listening and other high-level perceptual modalities like vision. Current research is starting to address this gap, drawing on principles governing all perception that have been known for over a century.

Speech perception researchers traditionally aimed to study how listeners perceive spoken audio signals as sequences of consonants and vowels, known as segments or phonetic units. Speech sounds are described using brackets to enclose phonetic symbols, such as [j] for the 'y' sound in "yeah" and [o] for "oh". In contrast, phonemes are abstract linguistic units that roughly correspond to letters in written language, and phonemes represent the smallest units that can change the meaning of a morpheme (Trubetskoy, 1969). The experimental study of speech perception generally aligns with the consensus among linguists and psychologists.

Speech perception researchers aim to define the smallest units of language study. The existence of phonemes or speech sounds as distinct units is not entirely clear outside of linguistic theory (e.g., Luto, 2000). The concept of phonemes is likely influenced by experience with written language. It is unlikely that listeners extract preliminary phonemes for word recognition, and there is no evidence of a specific brain region for producing phonemes independently of words.

Traditionally, speech perception is conceptualized as the recovery of phonemes from audio signals, focusing on segmentation and invariance problems. The segmentation problem arises from the lack of alignment between phonetic units and written letters, as they overlap in time. Invariance pertains to the variability of sound patterns and their partitioning. Difficulties in speech perception stem from assuming discrete phonetic units that may not accurately represent connected speech. Acoustic perception of word boundaries overlaps with neighboring sounds, compounding the issues of invariance and segmentation. In second language acquisition literature, it is commonly assumed that understanding and producing foreign sounds are directly related. The ability to produce a sound correctly depends on perceiving it accurately. The relationship between perception and production has been explained through various theoretical frameworks. Some propose a shared representation for perception and production, while others advocate for separate representations with complex connections between the two methods (e.g., Pisoni, 1995; Goldstein & Fowler, 2003; Falaj, 1995, 2003).

In 1987, Ann Cutler wrote a chapter entitled "Speaking for Listening" in which she described how speakers adapt

their output to the needs of listeners at all levels of the speech production process. The phonological retrieval effect refers to a tool used by psychologists to examine reading comprehension. People seek coherence and rationality, even if they add a voice or invent a word that has not been spoken. First, people don't necessarily hear every word spoken to them. Understanding is not passive recording of anything heard or seen. Second, even the smallest changes in discourse that the listener attends to are strongly influenced by comprehension. Finally, comprehension is not a simple item-by-item analysis of words in a linear sequence.

Voicing onset time (VOT) refers to the brief burst of air that occurs before all stop consonants are uttered, providing listeners with phonetic information to distinguish between sounds such as k/ and g/. The acquisition of this phonetic ability cannot be fully explained by exposure or language training alone. Because the ability to focus on VOT differences is inherent, we categorize these minor vocal differences as non-continuous binaries. Categorical perception refers to listening to a stream of speech and automatically segmenting this continuous stream of sound into the phonemes of the listener's native language, which is apparently unique to humans and appears to be an aspect of UG, and a genetic predisposition to understand and produce language. Categorical perception is the most well-known pattern of perceptual performance with speech sounds. Three common properties define categorical perception: accurate labeling performance (recognition), discontinuous discrimination performance (almost perfect across the recognition boundary and near chance on both sides), and the ability to predict discrimination performance based solely on labeled data (Wood, 1976).

2.5 Language and the Human Brain

Language is a fundamental aspect of human intelligence, as it enables the exchange of thoughts, feelings, and perceptions. Research has demonstrated that specific areas of the human brain are responsible for language production and understanding. Damage to these areas can lead to language loss. Scientists have long sought to understand how the human brain learns language. Many studies have focused on applying brain-centered educational principles to learning. These studies aim to integrate these principles into content and teaching environments. It is believed that the application of these principles, based on the structure and function of the human brain, can yield tangible results. Language, like music, contains powerful rhythmic patterns, and syllable timing helps listeners distinguish sounds and understand speech. The ability to recognize differences in sounds is crucial for language acquisition, even in infants.

The study of the relationship between language and the brain serves scientific purposes and aims to find therapeutic solutions for language abnormalities. The Psycholinguistics is an interdisciplinary field that investigates the interrelationship between the mind and language. It explores how language and speech are acquired, produced, understood, and lost. Modern research integrates natural sciences, biology, neuroscience, and more to explore how the human brain works and how language, reasoning, and emotions are represented and transformed in humans and other organisms.

Language processing is an intrinsic human trait, and knowledge of its neurobiological basis has improved significantly over the past decades. The study of brains has led researchers to identify and understand that different areas in the left and right hemispheres of the brain support specific language functions. Networks and connections involving temporal cortex and inferior and lateral frontal cortex support syntactic processes. These networks have been validated by both functional and structural connectivity data. Electrophysiological measurements show that in these networks, the syntactic processes that form the local structure precede the grammatical and semantic relations in a sentence.

Language as a system is controlled by the brain and is different from, but closely related to, general cognition. There are two hemispheres in the human brain. The left hemisphere is the "logical brain" and is involved in language and analysis, and the right hemisphere is the "creative brain" involved in dreaming and imagination. The left hemisphere controls the right side of the body, while the right hemisphere controls the left side. The first research on the speech and language centers of the brain dates back to the early 19th century. Doctors emphasized that patients who had brain injuries with damage to the left hemisphere lost their speech and language abilities, while those with damage to the right hemisphere did not.

The relationship between language and the brain is complex, and to better understand the psychology of language, we need to explore this relationship. There are several subfields that study how the brain processes language using non-invasive techniques to examine neural function. For example, the neuroscience of language has become its own discipline. The Psycholinguistics focuses on the cognitive processes that help form grammatical and meaningful sentences beyond just vocabulary and grammar, and the processes that enable us to understand speech, words, texts, and so on (Emas & Miller, 1983).

This understanding is crucial for modern linguistics. The human language faculty is considered a unique natural ability to acquire implicit knowledge of immense complexity in flexible, appropriate, and inexhaustible ways. Our brains consist of neurons and nerve cells, which are the primary information processing units of the nervous system. Language is a function of the human brain's structure, and specific areas have been identified with language capabilities. Due to the lack of comprehensive data on how the human brain functions, current research draws on biology, neuroscience, language, reasoning, and emotion to understand the representation and transformation in the nervous system. Linguistic psychologists are particularly interested in the theories of language acquisition and how the mind contributes to a person's ability to learn language.

In the 1950s, a renowned linguist, Noam Chomsky, proposed a theory called nativism. This theory asserts that children do not acquire the tools they need to understand language solely by listening to what they hear, but rather through the function of the language acquisition mechanism (Umbridge and Lyons, 2011). This theory suggests that all individuals are born with a universal grammar that enables them to learn language. The Psycholinguistics seeks to develop a model that illustrates how the brain processes language. It is nearly impossible to do or think anything without using language. Whether it involves internal

dialogue in one's mind or following written instructions, language is an integral part of our brains and lives, just like any other skill. For over a century, it has been understood that our language abilities are typically located in the left hemisphere of the brain, specifically in two areas: Broca's area (involved in speech production and expression) and Wernicke's area (involved in reading comprehension). Therefore, damage from stroke or trauma to either of these areas can result in language and speech difficulties, or aphasia. Often, a stroke or injury can cause brain damage and impaired language function.

The discussion about the relationship between language and the brain often revolves around the division of tasks in the two brain hemispheres. Diagnosis of the dominant hemisphere is usually based on the presence of speech centers. Hemispheric superiority in language and specific language functions can be determined through various methods, including studying people with language impairments (Hudson, 2000).

The traditional view considers the left hemisphere as the dominant one, responsible for processing various information and containing language centers. Recent studies, however, suggest that the right hemisphere plays a more important role than previously thought (Mansouri and Raqibdoost, 2017). Recent research on the specialized functions of the brain hemispheres has indicated different roles for both.

Most evidence suggests that the left hemisphere processes the main aspects of grammar, while the right hemisphere is important for analyzing and understanding meta-linguistic and pragmatic aspects. Studies on brain-damaged patients have shown that those with damage to the left hemisphere often experience language-related issues, such as aphasia and disturbances at phonetic, syntactic, and semantic levels. On the other hand, patients with right-hemisphere damage seem to have problems at higher levels of language, particularly in speech (Hideko and Aiko, ۲۰۰۳). The right hemisphere appears to be involved in metaphor processing, but it's uncertain whether this role is specific to metaphor processing or extends to other semantic aspects. Additionally, this hemisphere is used in processing unfamiliar sentences with themes featuring distant semantic relations.

3- Methodology

In the following chapter, we will discuss the research design and its fundamental principles. The chapter will conclude with a descriptive analysis of the main findings derived from the secondary data examined in the paper. It's important to note that the linguistic approaches utilized in this study do not involve any calculations or counting. Rather, a descriptive qualitative approach is employed, relying primarily on existing literature in the research area.

3.1 Research Design

The research plan employed for this study is the library research plan. All data collected is currently available in print or published on the Internet. The materials utilized in this study are predominantly secondary data.

3.2 Main Findings

Based on various studies in the field of language production and comprehension, this research has established the following main finding:

1. It has been confirmed that language is located in the left hemisphere of the brain. While language acquisition and dissolution may occur over time or simultaneously, language production and comprehension happen at specific points in time.

2. Both language learners and researchers often consider production and comprehension as part of a linguistic system because they both present unique challenges to language users. Language comprehension involves extracting meaning from speech or text, while language production involves converting a preverbal message into speech or text using appropriate vocabulary, grammar, and phonology or orthography. Additionally, it is generally more difficult to produce language than to comprehend it experientially. Researchers find it challenging to control input and extract corresponding output when studying language production.

3. Understanding goes beyond simply recording whatever is heard or seen. It involves the listener internalizing the speaker's interpretation, processing it, and drawing conclusions from it, whether positive or negative.

4. Cognitive psychology aims to understand the nature of mental representations of information and the processes that operate on those representations.

5. Language is a function of human brain structure, and several brain regions have been identified with language capabilities.

6. Until recently, evidence for speech production behavior has heavily relied on speech errors, whether experimental or natural, and it is noted that speech errors do not occur randomly.

4- Results and discussion

The study of language is crucial for understanding human knowledge. However, the neural basis of language is still a topic of debate due to its ambiguity. Instead of defining language as mere speech or communication, it is suggested to view language as a biologically determined computational cognitive mechanism, generating an infinite set of hierarchically structured expressions. Recent brain imaging studies have supported this perspective, highlighting language as an independent cognitive mechanism involving dynamic interactions, syntax, and semantics. It is argued that a language system must be connected to the real world through perception, similarly to

how a perceptual system must express its outputs through language, whether spoken or written.

Psycholinguistics focuses on the linguistic function of speech production and comprehension. Early language psychologists relied on linguistic rules for understanding language comprehension and production. However, as the field has developed, it became evident that psychological theories of language should account for the characteristics of the human brain and the structure of language. Thus, the Psycholinguistics has emerged as an independent and comprehensive research field, not solely reliant on linguistics. (Fodor, Burr, & Garrett, 1974).

The relationship between language and the human brain is reciprocal, with language being a function of the structure of the human brain. Various brain regions have been associated with language capabilities. Overall, modern research draws on biology, neuroscience, language, reasoning, and emotion to understand how the human or animal neural system processes language, as well as machine linguistics and information theory. Language psychologists focus on theories of language acquisition and the role of the mind in language learning.

The main concerns of cognitive psychology are to comprehend the nature of mental representations of information and the processes that operate on those representations. In the past decade, extensive research has focused on cognitive psychology within the field of language. This is partly due to the accessibility of language as a field of study and the early stage provided by linguistics and philosophy for investigating the psychological functions fundamental to the production and understanding of human language. Although progress has been made in other areas of cognition, the Psycholinguistics remains one of the most promising and profitable areas for investigating cognitive performance. Advances in understanding our ability to process, store, recall, and retrieve information are leading to a detailed empirical understanding of the nature of language processing.

The scientific study of the human mind started decades ago with the emergence of cognitive science. Cognitive sciences have been utilized by other fields in order to achieve new advancements. Cognitive neuroscience, which studies cognitive functions according to the function and structure of the brain, provides a suitable theoretical basis for language teaching with a cognitive approach. Their approaches are useful in language teaching, with brain-compatible learning principles being particularly beneficial.

Historically, language studies postulated separate processing "streams" for language production and comprehension. It is now acknowledged that the production and comprehension processes are closely related and intertwined. While production processes are used when people produce language, comprehension processes are used during the understanding of language. Therefore, it is also possible for production processes to be used during understanding and vice versa.

The study of language processing has largely overlooked the influence of language on perception. Current perspectives treat language production and comprehension as separate processes. This disconnect is evident in recent handbooks and textbooks on the Psycholinguistics (e.g. Gaskell 2007; Harley 2008). However, it is important to note that perception and production are considered as distinct areas that need to be investigated. For instance, researchers suggest that understanding a spoken or written sentence may involve different processes compared to generating descriptions.

In the neuroscience of language, the traditional Lichtheim-Broca-Wernicke model proposes separate anatomical pathways for production and comprehension, based on aphasia-related lesion-correlations (Ben Shalom & Popel, 2008). On the other hand, some researchers argue against this dichotomy. They propose that production and perception are closely connected and this connection is fundamental to our ability to predict both our own and others' behaviors.

5- Conclusions

The Psycholinguistics highlights that language production and comprehension are not as straightforward as they may seem. Early theories assumed separate brain processing for language production and comprehension. However, the current understanding, backed by extensive data, emphasizes the strong interrelation between production and comprehension in language processing. Language processing is a characteristic of the human species, and current accounts of language processing, production, and comprehension are quite distinct from each other. This gap is clearly reflected in the structure of recent handbooks and textbooks on the Psycholinguistics (e.g. Gaskell 2007; Harley 2008). This construct does not simply reflect ease of performance, but also considers comprehension and production as two different questions to investigate.

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