

**Spatial Language as an Embodied Memory Tool: A Comparison of Speech and Sign  
Language Linguistic Processing**

Marley Bridger

University College (Cognitive Science), University of Toronto

## **Abstract**

Embodied cognition is a rapidly developing and topical subject in the field of cognitive science. Sign language possesses the unique visuospatial nature of utilizing gestures to communicate. Recent advancements in technology have enabled comparisons between information processing in spoken verbal languages and in visual sign languages. Deaf sign language users deprived of auditory stimulation exhibit neural plasticity, as visual information is treated as auditory information due to its universal linguistic structure. The modal differences between the languages and the brain's ability to make adjustments in neural connections has implications for short-term memory. The visual nature of sign language also impacts long-term memory. Sign language's use of bodily movement relative to the environment as a means of communication makes it a form of embodied cognition. The various impacts of sign language on memory explore significant topics in the enhancing capabilities of embodied cognition. While a critique of embodied cognition as a theory utilizes lexical representations as support for its argument, sign language can be used as evidence to the contrary, supporting that visuospatial lexical representations are in fact embodied. Sign language's embodied nature and its positive impacts on cognition are an important subject area for advancing research in cognitive science.

*Keywords:* embodied cognition, extended cognition, sign language, visuospatial processing, neural plasticity, memory

## Introduction

Communication is a crucial facet of human cognition. Just as many spoken languages exist as means of communication, so do various sign languages. These sign languages have a distinct visuospatial modal feature, using gestures to converse. They incorporate bodily movement and make use of the speaker's surrounding environment to communicate, often physically acting out messages (Inoue, 2006). Although sign languages follow the same structural framework as any spoken language, their inherently physical nature changes the format of information received and expressed in conversation. Recent advancements in imaging technology have enabled researchers to compare cognitive processing of auditory and visual languages in detail. Machines like functional magnetic resonance imaging (fMRI) scanners are able to examine brain connectivity in subjects presented with visual linguistic stimulus (Wang et al., 2018). These studies have provided evidence for neural plasticity's link to the incorporation of visuospatial language in the areas typically dedicated to engaging with auditory speech (Fine et al., 2005). Embodied cognition, a growing field in cognitive science, explores the body's role in cognition, extending the scope of study beyond the mind to examine the role that the body's interactions with the environment play in cognitive processes occurring in the mind. Furthermore, it proposes that physical interactions throughout the body are able to influence cognitive processes in the mind, and that representations used in cognition can be externally located in the environment (Goldinger et al., 2016). Wilson (2002) emphasizes that embodied cognition supports the use of environmental symbolic off-loading and bodily sensorimotor representations reducing cognitive workload for the mind. Sign language's influence on neural connectivity and memory supports embodied cognition. After all, it is the physical nature of

visuospatial communication that affects the cognitive processing of the language. This use of physical space to communicate includes offloading information onto the environment, which reduces cognitive workload and has resulting implications for memory (Inoue, 2006). Sign language can be shown to impact both short and long-term memory in different ways (Craig et al., 2022; Malaia & Wilbur, 2019). These various cognitive impacts contribute to a better understanding of how an individual's embodied interactions with the environment enhance cognitive processes.

Sign language's influence on cognitive processes serves as a demonstration of embodied cognition and its capacity to enhance cognition. In this paper, I will explore the visuospatial features of sign language in comparison with its spoken language counterparts. I will then provide an in-depth comparison between the cognitive processing of auditory and visual language on a neurological level, exploring auditory deprivation and resulting neural plasticity. Subsequently, I will discuss the embodied nature of sign language and its implications on working and long-term memory through cognitive offloading. Lastly, I will explore and ultimately disagree with a critique of embodied cognition that discusses the location of lexical representations. I propose that sign language and the locations of its lexical representations exists as evidence of embodied cognition in practice.

### **Features of Sign Language**

While sign language does not utilize the same modal means of communication as auditory languages, it nevertheless shares many structural features. For example, in place of a verbal language's phonemes as linguistic units, sign languages are broken into cheremes, whose classification depends on the location of the sign, the hand configuration used, and the movement of the signing hand (Inoue, 2006). In this way, visual perception is playing an instrumental role

in shaping the phonology of the language. The location of a sign is of particular importance, as a sign's proximity to the face affects its discernability. Sign frequency is correlated with its distance from the lower part of the face, as this is where people primarily look to for visual cues in conversation. The further a sign is from this optimal zone, the more it relies on peripheral vision, making it more difficult to perceive (Caselli et al., 2022). Facial expressions also play an important role in sign language, acting as essential semantic cues that modify meaning through displays of emotion (Inoue, 2006). While sign language shares structural features including phonological units and semantic cues with many verbal languages, their unique characteristics arise from sign language's visuospatial mode of communication.

Visual information and perception play fundamental roles in sign language, highlighted by the importance of features such as iconicity. In this context, iconicity is defined as "visual resemblance between a sign and its referent" (Inoue, 2006, p. 223). Kanazawa et al. (2017) emphasizes that sign language is inherently visuospatial, employing its own distinct grammatical structures that differ from those of spoken verbal languages. The visually focused nature of this language necessitates adapted research tools, such as the one used by Enireddy et al. (2023), who employed neural networks to extract salient features from visual sign information. These features' characteristics were then classified with programming tools like Python. Despite the modal differences discussed, sign languages and spoken languages can still be compared due to their shared underlying structural similarities. These comparisons highlight the implications of visual processing in communication.

### **Comparing Sign and Speech Processing on a Neurological Level**

Various imaging technologies, such as fMRI and functional near-infrared spectroscopy (fNIRS) have been used to study the neural activations that occur during sign and speech

processing in both deaf and hearing participants (Kovelman et al., 2014; Fine et al., 2005). The findings from these studies support neural plasticity in language processing areas of deaf individuals' brains, those who are deprived of auditory stimulus, and use sign language to communicate. Fine et al. (2005) found that deaf signers, unlike their hearing counterparts, have their auditory cortex activated by visual information. Seeing as deaf individuals who communicate through sign language have been deprived of auditory stimulus over an extended period of time, their brains adapt to this lack of stimulus. This study suggests that this extended auditory deprivation triggers a neural rewiring process that encourages the brain to treat visual signed information as though it were auditory speech (Fine et al., 2005). This is further supported by Wang et al. (2018), who also used fMRIs to compare cross-modal neural activity and connectivity in deaf participants viewing general visual stimuli and linguistic visual stimuli. The linguistic information presented included sign language, words, and lip reading. The results support the neural plasticity phenomenon and the brain's ability to utilize areas typically reserved for processing of auditory stimuli for the processing of any linguistic stimuli, regardless of modality.

Kanazawa et al. (2017), on the other hand, used fMRI studies to examine hearing sign language users. These participants exhibited modal-specific neural connections, segregating auditory information from visuomotor signs. Similarly, a study using fNIRS to study bilingual hearing signers supported "that brain regions cluster or work together differently for signers vs. non-signers during [a sign] language task" (Kovelman et al., 2014, p. 9). Considered together, these studies support the conclusion that, as a result of auditory deprivation, the brains of deaf individuals reorganize to receive sign language as linguistic information, processed through areas of the brain typically reserved for auditory information. This same neural plasticity, the

redirection of visuomotor information, does not occur in sign language users who are hearing. Conversely, Salverda (2016) critiques the accuracy of eye-tracking fixation patterns in the study of sign processing; however, Lieberman et al. (2016) maintains that late learners of sign language do not visually track sign language stimuli the same as native signers do. This adds to the evidence that it is auditory deprivation that leads to neural plasticity. These various studies demonstrate that there is an innate physical difference at the neurological level between the processing of auditory and visual languages. In particular, the processing of visual languages has the potential to influence organization and connectivity of the brain. That is to say, visual information presented through spatial use of the body has a significant role in communication and neural activity. While this is a unique feature of sign language regarding information reception and processing, this visuospatial feature also plays an important role in the production of information. This additional aspect of sign language can be explored as a concrete example of embodied cognition.

### **Embodied Cognition and Sign's Effects on Memory**

Wilson (2002, as cited in Inoue, 2006) highlights that sign language, through its bodily interactions with the speaker's environment, is an example of embodied cognition. Many signs across various sign languages involve physically acting out and imaging the thing that is being described, making use of the space in the speaker's immediate environment (Inoue, 2006). For example, the Japanese Sign Language (JSL) signs for the different forms of the verbs "give" and "take" involve the signer acting out the motion of transferring an imaginary object. This movement is respective to the speaker's body and the direction they wish to motion towards, the external environment influencing the meaning of the word. This physical depiction of an action is utilizing sensorimotor embodiment and simulation to assist the mind in processing and

understanding information (Inoue, 2006). Sign language also represents verb tense with forwards or backwards gesture motion and direction of signs. This in turn creates a physical timeline for conveying meaning by use of the speaker's surrounding environment (Inoue, 2006). After all, there is evidence that physically acting things out improves memory. This would suggest that signers benefit from the visuospatial language's practice of acting out its messages (Wilson, 2002, as cited in Inoue, 2006).

The embodied nature of this language has the advantage of offloading preloaded representations onto the environment. To reduce cognitive workload, preloaded representations carry additional information by referring to information not present, or carrying additional meaning not explicitly expressed (Wilson, 2002, as cited in Inoue, 2006). As preloaded representations, signs make use of the environment to carry additional information. For example, facial expressions carry semantic information that would otherwise need to be accessed cognitively (Inoue, 2006). In the same way, sign language takes advantage of environmental sign proximity from the lower region of the face for common words in order to reduce perceptive effort (Caselli et al., 2022). Effectively, this embodied offloading of information onto the environment reduces cognitive workload. Sign language's ability to make use of space, such as the region of the speaker's face, to ultimately ease cognitive effort, is an example of scaffolding the environment to enhance cognition (Caselli et al., 2022). The resulting improvement of memory is supported by a study conducted wherein deaf signers demonstrated superior long-term memory performance in a visual memory test compared to non-signers, suggesting improved visual cognition (Craig et al., 2022). It is sign language's embodied nature and use of the environment that impacts cognitive processes such as memory.

In order to explore sign language's effects on memory, it is important to examine the differences in working memory between individuals who communicate with different language modalities. Working memory, the maintenance of short-term information, consists of two subsystems as theorized by Baddeley & Hitch (1974, as cited in Inoue, 2006). The first subsystem, the phonological rehearsal loop, maintains auditory information while the second, the visuospatial rehearsal loop, maintains visual and spatial information (Inoue, 2006). Wilson & Emmorey (1997) emphasize that these rehearsal loops are structurally very similar, attributed to the shared universal structural properties of language. Due to this structural similarity in both visual and phonological working memory, a comparison can be made between the processing of visual and verbal words (Wilson & Emmorey, 1998). One notable feature that emerges from such a comparison is that signed words contain both simultaneous and sequential components, unlike spoken words. As a result of these compounded elements, the temporal duration of a sign is shorter than that of a spoken word (Geraci et al., 2008).

The comparison between visual and auditory rehearsal loops is also important for understanding implications of sign language use on both short and long-term memory. As has been established, deaf sign language users are able to process visuospatial sign information as though it were auditory information. The auditory deprivation experienced by deaf individuals encourages neural plasticity, which treats visual information as if it were auditory language (Fine et al., 2005). This is also facilitated by the fact that visuospatial sign language information shares many structural properties with phonological auditory information due to the underlying universal language frameworks. As a result, sign information in deaf individuals may be using the auditory loop of working memory that it has been rerouted to in addition to the visual loop.

Therefore, sign language is making use of multiple substructures of working memory, employing the additional structures to enhance visual processing capacities (Inoue, 2006).

Nevertheless, this dualistic nature of sign may be a hinderance to working, or short-term, memory. Malaia & Wilbur (2019) argue that the use of sign language leads to less working memory capacity. This is possibly due to the fact that sign information is using up working memory's visuospatial resources in addition to auditory resources. James & Gabriel (2012) also found that the memory strategies interpreters employ specific to American Sign Language (ASL) led to less recall of words than the recall of auditory speech. However, this study's use of interpreters means that results were based on bilingual hearing signers. It is important to keep in mind that there are neurological differences between hearing signers and deaf signers, as deaf individuals have undergone auditory deprivation, a key factor in neural plasticity (Fine et al., 2005). All this is to say, sign's structural similarities and modal differences to verbal languages lend it an embodied nature that is able to enhance long-term while hindering short-term memory capacities.

### **Criticism of Embodied Cognition**

This concept of embodied cognition, as exemplified by sign language, has been critiqued. These critiques highlight examples of cognitive processes isolated to the mind, such as the location of lexical representations. Goldinger et al. (2016) first argue that embodied cognition is a faulty idea to rely on in cognitive science as it does not offer insights about behaviour, rather a description of phenomena. They continue by adding that embodied cognition as a theory relies on trivial arguments when attempting to explain human behaviour. That is to say, embodied cognition as an idea is being used as a replacement for psychological explanations that are sufficient as they are. They argue that cognition cannot be rooted in bodily processes, as a set of

connected phenomena should not replace more comprehensive cognitive explanations (Goldinger et al., 2016). Particular to linguistic embodied cognition, they discuss word frequency effects that arise in word perception and recognition. Words that are repeatedly presented are easy for study participants to perceive, while participants develop stronger recognition for words that are rarely shown. The rare words appeal to memory capacities in order to be recognized among the other repeated and easily perceived words. As a result, word frequency memory is assumed to correlate with distinctiveness (Goldinger et al., 2016).

Goldinger et al. (2016) support their critique of embodied cognition by pointing out that word frequency effects, a cognitive perception and recognition process, cannot be explained by embodied interactions. They reject the embodied cognition premise that language located outside of the mind can actively affect perception. They claim that semantics, wherein rules regarding the likelihood of words affects information processing, are found in the brain's memory, rather than other parts of the body or environment. The prediction and recognition of a word's frequency relies on information stored in the mind, as semantic rules are proposed to be located there, rather than in the environment of a conversation. Goldinger et al. (2016) argue that this semantic cognitive process is dependent on lexical representations stored inside the mind, not in the body. This strengthens their argument against embodied cognition in highlighting that lexical representations, a part of cognitive processing, are solely located in the mind. Therefore, the environment and body play no role in this process.

Nevertheless, cognitive research in sign language refutes this argument. Sign language utilizes embodiment and environment to enhance stored representations with preloaded ones. For example, the ASL expression of tense utilizes forwards or backwards motion to communicate past and future, an embodiment that reflects the body's physical movement towards future events

(Inoue, 2006). In this case, language is relying on the body's representations of time to more easily access the mind's representations for various auditory temporal words. In the same respect, sign language relies on socio-conventional facial expressions to express semantics (Inoue, 2006). These lexical representations containing semantic information are actively accessed through the environment, or the conversation partner's expressions. This cognitive process is relying on bodily movement and environment as a source of rules rather than performing additional computation in the mind. It is the physically embodied nature of the language that is directly playing a role in engaging cognitive memory processes. Therefore, key linguistic and cognitive features of sign language arise from physical factors rather than solely information stored in the mind, as Goldinger et al. (2016) suggest.

## **Conclusion**

To conclude, sign languages use a different mode of communication than spoken languages. While this visuospatial information is processed differently than auditory information, the two share many linguistic structural similarities. The differences in processing can be examined at a neurological level with imaging technology, revealing how auditory deprivation and use of sign language as a means of communication influences neural plasticity in deaf individuals. This arises from the embodied nature of sign language, and the language's use of the environment and speaker's body to convey information such as tense and action. The embodiment of this cognitive process also entails cognitive offloading onto the environment that reduces memory workload. While the language's visuospatial nature may be a hinderance to working memory, it is suggested to have enhancing effects on long-term memory. These implications of embodiment's role in memory are important topics in the field of cognitive science, supporting embodied cognition's ability to reduce cognitive workload in the mind.

Despite criticisms of the embodied cognition's validity and benefits, sign language exists as evidence in direct opposition of such arguments. Further exploration of this developing topic is key to understanding the emerging field of embodied cognition and modal factors in information processing.

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