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Examining Differences in Working Memory Between Signed and Spoken Language

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Abstract
Signed language poses an interesting puzzle to cognitive science, as it appears to differ from spoken language on such a fundamental level. Experiments have sought to examine the nature of signed language in the context of working memory, but overall results remain inconclusive, partially because each of these experiments included some methodological flaws. In this paper, a potential experimental paradigm based on a serial-recall task is suggested, which avoids these methodological pitfalls. An additional experiment is purposed, also based on this serial-recall task, that utilizes brain imaging techniques to examine the cognitive processing of signed language.

Introduction

Signed language presents interesting challenges and questions for the field of cognitive psychology because it defies normal categorization in terms of cognition. It doesn't fit with the standard conception of language, yet it parallels spoken language and diverges from motor processing in unexpected ways. For example, the process of learning a signed language activates the same areas of the brain that are activated when learning a spoken language (Newman-Norlund, Frey, Petitto, & Grafton, 2006). Production of signed language also appears to use language-oriented brain structures situated in the left hemisphere of the brain, not right-brain motor-oriented ones. In fact, damage to language-oriented areas manifests in identical language deficiencies in deaf signers and hearing non-signers, while right-brain damage disrupting spatial tasks appears not to affect signed language production or reception at all (Lane, Hoffmeister, & Bahan, 1996)

Extensive research has been done on signed language and how it relates to spoken language. One study (Pyers, Shusterman, Senghas, Spelke, & Emmorey, 2010) observed groups of signers who learned an emerging sign language (Nicaraguan Sign Language) at different times in the language's evolution. Results showed that spatial cognition required the support of language. Further, learning a signed language causes patterns of brain activity similar to those found in learning of a spoken language; however, participants learning the signed language also showed activity in areas of the brain concerned with sensorimotor tasks in a manner inconsistent with learners of the spoken language (Newman-Norlund et al., 2006). However, research examining working memory (short-term memory) has also shown differences in recall ability between users of signed versus spoken language (Bavelier, Newport, Hall, Supalla, & Boutla, 2006; Boutla, Supalla, Newport, & Bavelier, 2004). Thus, the degree to which signed and spoken languages are similar, and the degree to which they are different, is still unclear.

Working memory is a valuable domain in which to examine signed language because the process of rehearsal is handled in two different ways, depending on the input. These manners of rehearsal are called the phonological loop and the visuospatial sketchpad. The phonological loop is used to rehearse and remember auditory input, including language, while the visuospatial sketchpad is used for visual or motor-oriented information. Conceptually, signed language is not exclusively processed with either of these methods of rehearsal. It is both linguistic and spatial in nature, suggesting it utilizes both the phonological loop and the visuospatial sketchpad. Fortunately for the process of research, the phonological loop is capable of holding significantly more pieces of information at once than the visuospatial sketchpad (Bavelier et al., 2006). Therefore, it is possible to examine the duality between signed language's visual and linguistic components through experimentation. However, previous research into whether signed language is processed as linguistic or visuospatial input has yielded mixed results.

Recall tasks are a valuable tool for comparing working memory between spoken and signed language. Signed and spoken recall can both be hindered by similar factors. Spoken language recall is hindered by similar-sounding (phonologically similar) words. Similarly, short-term recall of lists of signed words is hindered by similarity of hand shape or motion (cheremic similarity) (Mills & Weldon, 1983; Poizner, Bellugi, & Tweney, 1981). However, unlike spoken language, signed language recall is not affected by similarity of meaning or other forms of semantic similarity (Poizner, et al., 1981). This disparity conflicts with the evidence supporting the idea that signed and spoken languages are cognitively identical, which raises questions about whether signed language is processed differently than spoken language in working memory. Attempts to resolve these questions have had conflicting results; some experiments (Bavelier et al., 2006; Boutla et al., 2004) have found consistent differences in working memory span between sign and speech, while others (Wilson & Emmorey, 2006), using similar methods, have found no such differences. Thus, controversy on this topic remains, and the question stands: In the context of working memory, are spoken and signed language processed the same way?

The existing literature addressing this question consists chiefly of three experiments (Bavelier et al., 2006; Boutla et al., 2004; Wilson & Emmorey, 2006) using very similar methods. In these experiments, participants were presented with series of digits or letters in spoken English or American Sign Language (ASL) and asked to recite them from memory. Working memory span was measured using two metrics: the length of the longest list recalled, and the total number of elements correctly recalled over all trials of the testing session. The overall results between these studies are contradictory, with some experiments showing a significantly shorter working memory span for users of sign language (Bavelier et al., 2006; Boutla et al., 2004), and others finding no such difference (Wilson & Emmorey, 2006).

One explanation for these inconsistencies is that these experiments suffer from some methodological faults. For example, the studies mentioned did not use lists of words: each paradigm used lists of signed letters for deaf subjects and lists of either spoken letters or spoken digits for hearing subjects. Signed digits were not used due to their potential for confusion, given how similar they are to each other. However, even though the lists were tightly controlled for phonological and cheremic similarity and presented a consistently meaningless order, lists of ASL letters are not comparable to lists of spoken letters or digits (Wilson & Emmorey, 2006). Signed letters and spoken digits are not comparable because there are fewer digits than letters, which may lead to differences in short-term recall (Wilson & Emmorey, 2006). This observation compromises the results of the first study (Boutla et al., 2004), which used this type of comparison. Wilson and Emmorey (2006) argue that a better option would be to compare English letters with ASL letters. However, this could be problematic because English letters and ASL letters have differing roles in language. In spoken English, letters represent sounds that are combined to make words, while ASL words are made with gestures, not letters (Lane, Hoffmeister, & Bahan, 1996). Thus, English letters and ASL letters are incomparable because ASL letters are unlikely to be processed phonologically (Bavelier et al., 2006), the way spoken letters are. Using words instead of letters or digits would provide more consistent and comparable results, because words have the same linguistic role in both spoken English and ASL (Lane et al., 1996).

Another methodological issue with the studies mentioned is that the only groups compared are deaf signers and hearing non-signers. This could be problematic because certain cognitive processes require language as support (Pyers et al., 2010). Thus deaf people may not use the same memory processes as hearing people do (Lane et al., 1996). This uncertainty can be accounted for by comparing deaf signers to both hearing non-signers and to hearing people who know signed language.

Brain imaging techniques can provide another valuable perspective in the study of signed and spoken language and may prove especially useful in recall experiments. Although there is evidence supporting similarity in brain activity when learning spoken and signed language (Newman-Norlund et al., 2006), such testing has not been done in the specific task of short-term recall. Experiments using brain imaging would be best performed multiple times on hearing signers so that brain activity during signed and spoken recall tasks could be compared for each individual participant. The resulting images of brain activity could be compared for any differences in activity patterns in parts of the brain such as Wernicke's area (concerned with language reception) and Broca's area (concerned with language production), as well as differences in activity in areas of the brain concerned with visual or sensorimotor processing. This analysis would be best carried out in two experiments: one serial-recall experiment using hearing non-signers, deaf signers, and hearing signers, and one brain imaging experiment performed on hearing signers alone.

Methods: Experiment 1

Participants. 80 participants would be recruited: 20 deaf people proficient in American Sign Language (ASL), 20 hearing people without experience with ASL, and 40 hearing people proficient in ASL. Hearing signers would be divided into two groups of 20 divided by experience in both languages, each group having the same number of people who learned spoken English as their first language, ASL as their first language, and ASL and English simultaneously. There will be four groups in total: hearing non-signers presented with spoken lists; hearing signers presented with spoken lists; hearing signers presented with signed lists; and deaf signers presented with signed lists.

Materials. This experiment requires a video camera to record spoken and visual stimuli and a computer or television to present them. A research assistant fluent in both English and ASL would be required to record stimuli. The prerecorded stimuli would be lists of words presented either in spoken English or ASL. Lists would consist of three to nine nouns (two lists for each quantity) and would be identical in both signed and spoken conditions, exposing participants to the same words in the same order. Lists would be tightly controlled for minimal phonological, cheremic, and semantic similarity, and no word would be repeated. Lists would be spoken or signed at the rate of one word per second.

Design and Procedures. Participants would be presented with a video list of three words, and then instructed to recite the words they remembered in order, saying or signing "blank" for any forgotten words. They would then be presented with the video of the other 3-word list and asked to recite back. Participants would then be presented with the four-word lists, and continue with two trials of each list length, in ascending order, until both lists of a given length cannot be correctly recalled. Participants would be scored on longest list correctly recalled and total number of words correctly recalled.

Analysis and Results: Experiment 1

Each participant will yield two pieces of data: the length of the longest list correctly recalled (recall length) and the total number of words recalled over all of the lists (total score). Participants' scores would be aggregated to find the mean recall length and total score for each of the four test groups, as well as the associated variances. Then, one-way analyses of variance (ANOVAs) would be run to compare both mean recall length and total score between each possible pair of groups.

Certain pairs of groups would likely be focused on in analysis, as differences between certain pairs of groups may be more significant. For example, any significant difference between deaf signers and hearing signers responding to signed lists could only be attributed to differences in working memory span, indicating that hearing and deaf people access linguistic memory differently. Meanwhile, a significant difference between hearing signers presented with spoken lists and hearing signers presented with signed lists could be attributed to differences in processing for spoken and signed language. In this case, the first result (given no significant difference in the second pair) would support the hypothesis that deaf people don't have the same access to the phonological loop as hearing people do; meanwhile, the second result (given no significant difference in the first pair) would support the hypothesis that the brain, whether hearing or deaf, rehearses signed language with the visuospatial sketchpad, not the phonological loop.

Methods: Experiment 2

Participants. At least 20 hearing people proficient in ASL would be gathered and separated into two groups of 10 stratified by relative proficiency in English and ASL (as described in Experiment 1).

Materials. Similar to Experiment 1, this experiment requires a video camera to record the stimuli, a screen to display them, and a research assistant to record stimuli in both English and ASL. Lists would be prepared in the same way as in Experiment 1, but in this case the spoken lists would contain different (but equivalent in length and phonetic/cheremic and semantic similarity) words than the signed lists, as each subject would be exposed to both sets of lists. In addition, an EEG reader would be used to record relative brain activity. EEG is the most useful method of brain imaging in this application because it is silent, and thus would not interfere with auditory stimuli or processing,. Its drawbacks in the area of spatial resolution are not an issue for this study because the areas of interest (Wernicke's area, Broca's area, and the motor cortex) all show activity on the sulci of the cortex and each area is discretely separated from one another.

Design and Procedures. The two groups of participants are presented with the same serial recall task described for Experiment 1. One randomly selected group would be exposed to the spoken stimuli, while the other would be exposed to the signed stimuli. Brain activity would be measured by EEG, focusing on activity in: Broca's area, Wernicke's area, and the motor cortex. After seven days, participants would repeat the task in the opposite condition. In this case, scoring recall length or total words recalled is unnecessary, as the brain activity imaging is the variable of interest.

Analysis and Results: Experiment 2

Each participant would have two brain activity images: one image taken during the spoken language task, and one during the signed language task. The two scans for each participant would be compared using statistical parametric mapping software (such as SPM 99, as used by Newman-Norlund et al. (2006)). The brain activity images would first be divided by time, into "listening" periods, "recall" periods, and "rest" periods.

Significant differences in brain activity during listening or recall periods would indicate differences in how signed language is processed in working memory, compared to spoken language. For example, increased motor cortex activity during either listening or recall periods for signed lists would indicate a relative increase in involvement of the visuospatial sketchpad portion of the working memory model, which in turn would support the hypothesis that the brain processes signed language differently than traditional language. Meanwhile, a lack of significant differences in brain activity would support the hypothesis that language is processed as language, regardless of language form.

Discussion

The first things to consider in the creation of the preceding experimental methods are any confounds that could compromise analysis of the data collected. For instance, it is possible that speakers of various languages think of their languages' component parts differently because of discrepancies in linguistic structure. If this were true, then the experimental method presented would be invalid because lists of spoken words would be fundamentally different from lists of signed words. This could undermine the experiment entirely, as the primary goal of using lists of words was to avoid this exact issue which arose in prior studies due to differences between signed and spoken letters and digits.

Another issue with prior studies that this method sought to correct was the fundamental difficulty in comparing deaf and hearing people, who may have differences beyond hearing status. This experimental method tries to bridge that gap by comparing deaf signers to hearing signers; however, it is still possible that these two groups interpret signed language differently, which raises the same issues as the prior comparison. In addition, individual differences in cognition are impossible to anticipate, and these differences could affect results significantly. Future research in this field could focus on finding better ways to compare signed and spoken language in deaf and hearing populations.

If the experiments' methods are internally valid and their results are unambiguous and statistically significant, the findings of these experiments are immediately applicable to a number of fields. One of the most immediate applications of this research is in deaf education. If deaf recall is significantly lower than hearing recall (indicating spatial processing of signed language), then this could further a deaf education paradigm based more on spatially-oriented information, which could help to mitigate the difficulties that deaf people face. Meanwhile, the opposite finding could pave the way for better accommodation for deaf individuals within standard education systems, as well as in occupational settings and other contexts.

The applications of the brain imaging experiment's results are even more interesting. No matter which hypothesis the results support, the findings could fuel innovations in the treatment of speech disorders. For example, if the experiment found that reciting signed lists causes significantly less activation in Broca's area, that result would suggest that patients with Broca's aphasia, which causes deficiencies in the production of language, may be better able to communicate using signed rather than spoken language.

The results of this study could also apply to other subfields of psychology. Differences or similarities in the use of working memory between signed and spoken language would shed new light on the existing model of working memory, and may even reveal new evidence about the ways that people use memory. Significant differences in memory ability also raise questions about existing theories of language, and could prompt further research not only into the differences between spoken and signed languages, but also between our conception of a "traditional" language (English) and tonal or melodic languages (such as Cantonese or Mandarin Chinese) or even tribal "click" languages (such as the Khoisan languages of South Africa).

Further research on working memory with respect to signed language could provide new insights into the needs of the deaf, helping us to understand the specific challenges they face. With this greater scientific understanding, education could be improved and new disability measures could be created to improve the lives of the deaf.

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References

Bavelier, D., Newport, E., Hall, M., Supalla, T., & Boutla, M. (2006). Persistent Difference in Short-Term Memory Span Between Sign and Speech. *Psychological Science*, *17*(12), 1090-1092. doi: 10.1111/j.1467-9280.2006.01831.x.

Boutla, M., Supalla, T., Newport, E., & Bavelier, D. (2004). Short-term memory span: insights from sign language. *Nature Neuroscience, 7*(8), 997-1002.

Lane, H., Hoffmeister, R., & Bahan, B. (1996). Form and Function in ASL. *A Journey into the Deaf-World* (pp. 78-123). San Diego: DawnSignPress.

Mills, C., & Weldon, L. (1983). Effects of semantic and cheremic context on acquisition of manual signs. *Memory & Cognition*, *11*(1), 93-100.

Newman-Norlund, R., Frey, S., Petitto, L., & Grafton, S. (2006). Anatomical Substrates of Visual and Auditory Miniature Second-Language Learning. *Journal of Cognitive Neuroscience*, *18*(12), 1984-1997.

Poizner, H., Bellugi, U., & Tweney, R. (1981). Processing of Formational, Semantic, and Iconic Information in American Sign Language. *Journal of Experimental Psychology*, *7*(5), 1146-1159

Pyers, J., Shusterman, A., Senghas, A., Spelke, E., & Emmorey, K. (2010). Evidence form an emerging sign language reveals that language supports spatial cognition. *Proceedings from the National Academy of Sciences*, *107*(27), 12116-12120. doi/10.1073/pnas.0914044107.

Wilson, M., & Emmorey, K. (2006). Comparing Sign Language and Speech Reveals a Universal Limit on Short-Term Memory Capacity. *Psychological Science*, *17*(8), 682-683. doi: 10.1111/j.1467-9280.2006.01766.x