Sign and Spoken Language Processing Differences in the Brain: A Brief Review of Recent Research

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Abstract

Background: It is currently accepted that sign languages and spoken languages have significant processing commonalities. The evidence supporting this often merely investigates frontotemporal pathways, perisylvian language areas, hemispheric lateralization, and event-related potentials in typical settings. However, recent evidence has explored beyond this and uncovered numerous modality-dependent processing differences between sign languages and spoken languages by accounting for confounds that previously invalidated processing comparisons and by delving into the specific conditions in which they arise. However, these processing differences are often shallowly dismissed as unspecific to language.

Summary: This review examined recent neuroscientific evidence for processing differences between sign and spoken language modalities and the arguments against these differences' importance. Key distinctions exist in the topography of the left anterior negativity (LAN) and with modulations of event-related potential (ERP) components like the N400. There is also differential activation of typical spoken language processing areas, such as the conditional role of the temporal areas in sign language (SL) processing. Importantly, sign language processing uniquely recruits parietal areas for processing phonology and syntax and requires the mapping of spatial information to internal representations. Additionally, modality-specific feedback mechanisms distinctively involve proprioceptive post-output monitoring in sign languages, contrary to spoken languages' auditory and visual feedback mechanisms. The only study to find ERP differences post-production revealed earlier lexical access in sign than spoken languages. Themes of temporality, the validity of an analogous anatomical mechanisms viewpoint, and the comprehensiveness of current language models were also discussed to suggest improvements for future research.

Key message: Current neuroscience evidence suggests various ways in which processing differs between sign and spoken language modalities that extend beyond simple differences between languages. Consideration and further exploration of these differences will be integral in developing a more comprehensive view of language in the brain.

Introduction

Despite involving a different modality, many believe SL processing shares significant commonalities to spoken language (SpL) processing.[1] Electroencephalography (EEG) evidence facilitates this claim as ERP components such as the N400, LAN, P600, and medial frontal negativity have shown some basic similarities between SL and SpL.[2–5] Additionally, many early imaging studies also corroborated this conclusion as they have shown that SL activates many similar prototypical language areas to SpL, such as perisylvian areas and frontotemporal networks.[6–10]

Despite later studies finding similar results,[11,12] various studies had found differences in lateralization between SL and SpL, and this became the main argument for those who initially contested that SL and SpL are processed similarly.[1,13]

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However, lateralization differences, like other early discovered differences, have since been explained by similar activation patterns occurring in SL and SpL in non-native participants and in situations of complex syntactic discourse-level information requiring greater cognitive control.[14] Thus, the following review will predominantly involve evidence from native and proficient SL users.

However, hope is not lost for those who oppose the of over-assertion SL and SpL's significant processing commonalities. Recent evidence has found processing differences even between different SpLs[15]; therefore, one could assume there are possibly even greater processing differences between languages of different modalities, especially when SLs can use spatial cues for syntax. Luckily, one does not have to assume this as many recent studies have found evidence for modality-specific processing.[1,16,17] Recent evidence even points to a greater complexity beyond these previously established beliefs of identical processing with changes being observed in the activation of modality-independent areas (e.g., perisylvian) in new SL learners that is unique to cross-modal language learning.[18] Additionally, while Trettenbrein et al.'s[19] recent meta-analysis of the functional neuroanatomy of SL found substantial overlap between activation during SL and SpL comprehension, this approach cancelled out the integral unique activity from the studies' specific manipulations that potentially differentiate these modalities. Additionally, without considering the production mechanisms of these languages, discussions about their processing are incomplete. Thus, this brief narrative review aims to highlight recently discovered processing differences between language modalities, discuss the attempts to disprove these differences, and encourage greater consideration of these differences within the language field. While commonalities do exist between SL and SpL processing, their significant differences should not be overlooked if researchers wish to accurately understand language processing in the brain.

The Important Elements that Differ Between These Language Modalities

Comprehension Through ERP Components

Stroh et al.[14] claimed that syntactic processing in SL comprehension is only temporally similar to SpL. Recent research on the LAN when participants were exposed to syntactic violations in American Sign Language (ASL) has shown that its topography changes in certain contexts. When the syntactic violation was a verb reversed in direction, the LAN had a left lateralized topography similar to syntactic violations in SpL. However, when the violation was a verb disagreement, the LAN had a bilateral topography instead.[2,20] Although the LAN in SL appeared similar to that in SpL in other studies,[5] it's topographical inclusion of the right hemisphere is likely determined by the type of syntactic

violations, which is unique to SL processing. However, research on the LAN in SL is limited and minimally informative, likely because of the debate concerning the component's validity.[21]

The N400 is considered a lexical-semantic ERP component that modulates with violations of expectation with considerable similarity in SLs and SpLs.[3] However, other studies have found intriguing differences in SL processing to SpL across several SLs using the N400 and related components. A typical property in SpL is that the N400's amplitude is reduced when a word's phonological features overlap with that of primed words. However, the opposite pattern of a higher amplitude for signs with an overlapping location with primes has been observed in Spanish SL.[22] The authors determined that SL users resolve these conflicts differently as spatial location is a phonological tool for SL, akin to a word's first syllable in SpL, and hence process phonological information differently to SpL.[22] Researchers have also attempted to replicate the ERP responses that typically follow the identification of phonological rhyming pairs in SpL, in SL. Colin et al.[23] accomplished this by using similar sign locations in French Belgian SL to mimic phonological "rhymes" in SpL as these concepts serve analogous purposes in these language modalities.[23] While they observed a contingent negative variation after the first items of each pair—signifying that phonological encoding did occur—only in SpL was the N400 amplitude higher for rhyming than non-rhyming words. This lack of a rhyming effect in SL suggests that SL users do not associate static locations between signs like rhymes in SpL, despite space representing phonology in SLs. Even when Meade et al.[24] found evidence that priming sign location in SL did in fact increase the N400 amplitude, therefore increasing expectancy similarly to SpL, they also found that priming using handshape decreased the N400 amplitude instead. This hierarchical differentiation and inverse effects of priming techniques on sign expectancy are unique to SLs.

To expand on this, when Hosemann et al.[25] time-locked ERPs to the transition between signs in German SL, they found a reduced N400 amplitude for movements toward unexpected sign locations, as is typically observed in SpLs when time locking to the start of a word. This N400 onset occurring before sign onset potentially indicates that the transition phase between signs carries meaning in SL more than static location. They also further explored this novel aspect of SL processing through observing an increased N400 latency for non-action verbs compared to action verbs as the former involves a common transition phase before a second identifying transition. These results could reflect an SL modality-specific prediction mechanism that is not found in SpL, and potentially explain the variety of effects between the previously discussed results. If the pre-phonological information transition phase carries the phonological meaning in certain SL contexts, then this could explain why some studies found no priming or expectancy effects when time

locking to sign onset, as the phonological processing potentially occurred before sign onset. Further evidence for this can be found by Capek et al.'s[2] study that found an absence of the phonological mismatch negativity following a violation of phonological expectation in ASL. While the authors suggested that this type of phonological processing is specific to the auditory language domain, it could potentially be instead that in this context the phonological processing occurred prior to sign onset, so the violation after sign onset was no longer unexpected. The specific differentiating contexts in which phonological meaning is processed by the brain before or after phonological information is communicated directly should be investigated further by expanding temporal windows for analyses. Regardless, this characteristic of phonological access timing remains a processing aspect unique to SL.

Less evidence exists for modality differences than similarities in semantic processing. These later semantic stages could potentially be where the processing of these languages converge as the brain gradually abstracts language further from its sensory constituents. Even still, Gutiérrez et al.[22] found early, in contrast to SpL, semantic pre-activation (150–250 ms) of plausible signs among those that violated contextual expectations. They additionally found an increased latency for the N400 only when signs were either phonetically or semantically related, but not when they were related in both or neither ways to the expected sign. This suggests the presence of a form-meaning mapping distinct to SL that is processed at different time points, depending on the violation type and combinations of such. However, direct comparisons to SpL are still required to determine the precise mechanisms of this different processing. Regardless, the studies in this section highlight key ERP component modulations that reflect processing differences between these language modalities beyond the initial processing of their sensory components.

Modality-Dependent Activation During SL Comprehension

Although there are various common linguistic areas activated during SpL and SL comprehension, modality-specific processing is strongly reflected through other activation differences.[26] In various language tasks performed by bimodal bilinguals native to both British Sign Language (BSL) and SpL English, there was greater left-hemisphere activation for BSL comprehension compared to English comprehension. However, this lateralization difference was not reflected in non-signing, hearing controls.[27,28] While, they claimed that this reflects modality-specific processing, a more detailed investigation of activation in specific locations and networks would provide greater evidence.

It is considered by some that written language and SL are processed in similar ways as they are both a visual form of language, and that the processing differences between SpL and SL simply reflect the differences between SpL and written

language.[29] However, often when these similarities between written and SL are observed, the study only compares hearing non-signers to deaf signers who both experience inferior temporal activation in the visual word form area for words and signs, respectively.[30,31] When investigating proficient bimodal bilinguals with within-subject designs instead, the confounding effects of hearing status are avoided. These within-subject designs demonstrate that written, spoken, and signed words activate mostly similar frontotemporal language areas in later time windows. However, in these same participants, differences manifest in earlier time windows where only spoken and written words activate left superior temporal and ventral occipitotemporal areas, while signed words uniquely elicit right intraparietal sulcus activity.[17] Emmorey et al.[32] also found, even when comparing deaf signers to hearing non-signers, that while inferior temporal regions were activated by both printed and fingerspelled words (single letter signs in SL, often considered analogous to SpL orthography), fingerspelling and ASL had more overlapping activation than fingerspelling and written words. Thus, through eliminating the confounding effects of hearing status, separately studying fingerspelling, and directly comparing written language and SL, the evidence posits that the processing of these visual forms of language have distinct properties.

To expand on the distinct activation during SL comprehension, some research has observed that the involvement of temporal regions is conditional in SL processing.[33] Capek et al.[6] found that speech-like mouth actions in BSL (which can be used to indicate information such as morphology) modulated activation in inferior temporal regions in SL. Specifically, they observed that an absence of these mouth actions did not induce any activity in temporal areas, except for the bilateral temporo-parietal-occipital junction. This selectivity of temporal area activation for morphological information is unique to SL processing. Researchers have also unsurprisingly found that larger movements of the hands and arms during SL comprehension, when phonological information was location-dependent, activated occipital (V5) areas, and thus its posterior temporal output regions, for biological motion perception.[34–36] Thus, a wider array of modality-dependent areas are recruited to assist SL processing, even in early learners.[36] While some may argue that these modality differences merely reflect early sensory processing unspecific to language, these spatial and visual properties express information that is vital for SL comprehension and the processing of these is intertwined with such. Therefore, these differences should not be dismissed when studying language.[5]

Further, differences have been displayed when investigating the brain's activation involved in participants rapidly switching between different language modalities, compared to rapidly switching between different SpLs. Unlike unimodal SpL code-switching, bimodal code-switching does not engage frontal lobe control regions.[26] The

omission of higher executive functions during the complex task of bimodal code-switching could be argued to be because of the bimodal bilinguals' mastery at code-switching; however, this does not explain why this frontal lobe activation was present in unimodal bilinguals with similar mastery levels. Instead, it likely suggests that bimodal bilinguals solve this motor-articulatory competition in a unique way and with different mechanisms.[26] This serves as more evidence that SL is processed differently to SpL.

The Addition of the Parietal Lobe During SL Comprehension

Moving from these less-investigated differences, one should also address the more commonly reported areas which are additionally activated during SL processing. Various recent studies have found that left inferior and superior parietal areas are heavily involved in SL comprehension in both native and non-native signers.[18,37–41] However, the parietal lobe's role in SL processing has been widely debated.

Some studies have found that when viewing SL signs, even non-signers have similar activation patterns to signers in a premotor-parietal circuit, the Action observation network (AON).[42–44] They propose that because the AON is unrelated to language processing and is similarly activated in signers watching SL and other communicative gestures like pantomime acts, this explains away the parietal activation seen in signers during SL comprehension.[45–47] However, parietal AON activation has actually been observed to be distinct from the language-specific processing of SL in parietal regions. Specifically, the left supramarginal gyrus (SMG) is only activated in signers during SL comprehension, and not when their non-signing counterparts view the same signs.[38,39] Further evidence for this language-specific parietal activation is that Cardin et al.[30] found that non-signs elicited AON activation in signers and non-signers, but only signers had increased SMG activation when viewing non-signs. Therefore, this provides evidence that AON activation is separate from the documented SMG activation. Instead, the AON activation in non-signers likely results from non-language processes of recognizing the signs' communicative intent and the viewer's attempts to process the complex motion information of SL.[42,48] This is concurrent with recent evidence suggesting that gesture-similarity is a common early strategy for new SL learners.[49,50] Thus, this evidence points toward the SMG having a unique role in SL processing.

Nevertheless, some suggest that this still does not adequately counter the possibility that SMG activity is a part of non-language sensory processing because of an increased relevance to signers.[14] However, this argument still cannot invalidate that SL is processed differently to SpL as processing the sensory constituents of language is still a crucial component of language comprehension.[5] Even without this, ample recent evidence exists to implicate the SMG in complex and unique SL comprehension mechanisms. Unlike in SpL, the addition of the SMG for SL comprehension is likely involved in establishing representations of abstract phonological information from the spatial elements of SL. The SMG has shown increased activation when participants make phonological similarity judgements during SL comprehension.[51,52] Additionally, Cardin et al.[30] found that non-signs elicited more SMG activation than signs from both known and unknown languages. This corroborates the SMG's role in phonological functions within the brain as the neural pressures for linguistic processing were greater for these non-sign stimuli that violated phonological SL rules.[30] In another study involving semantic judgements of fingerspelling, signs, written words, and spoken words, only ASL-English bilinguals, not non-signers, displayed greater left SMG activity for signs than fingerspelling.[52] Therefore, as ASL fingerspelling is done in a single space, this can be taken as evidence supporting the SMG's involvement specifically in assigning phonological meaning to spatial information in SL. Activation of the SMG for phonological processing is found in early and new learners of SL, mere months into learning, and is correlated with greater SL proficiency.[18,37,41] Emmorey et al.[34] even found evidence that signers may differentially recruit the SMG in their forward models when predicting upcoming signs during SL comprehension. From this evidence, it is clear that the SMG is uniquely recruited for the processing of SL to appropriately deal with the spatial elements for which the SMG has a pre-existing evolutionary propensity.

Still, some argue against parietal activation being a valid difference in SL comprehension. Stroh et al.[14] contended that the SMG activation that previous studies had observed during sign movement violations was actually caused by a reorientation of spatial attention, akin to that seen during the Posner cueing task. They argue that parietal involvement following these violations is instead purely spatial processing that merely temporally coincides with language processing. However, this explanation fails to account for evidence showing increased SMG activation in bimodal bilinguals when they read written words with SL translations.[52,53] Regardless of whether this parietal activation reflects participants converting the written words to their preferred processing method or activation spreading to specific SL methods of word processing, this SMG activation is void of reorientation, or spatial input entirely. Also, SMG activation is present even in SLs where syntax is less spatially dependent, like BSL, as well as the more spatially dependent SLs like ASL.[30,34,37] Thus, the SMG is not just an anatomical substrate for mere non-language spatial processing in SL. Rather, the SMG is additionally involved in the processing of complex syntactical and phonological information for the comprehension of SL. Further evidence to support this argument can be found from studies investigating SL production.

The Uncontested Anatomy of Production

Despite fewer studies investigating SL production, they generally agree on the different anatomical areas involved in SL and SpL production.[54] An early cortical EEG study conducted on a proficient SL speaker saw increased activation in their brain's parietal areas during SL production.[55] Various later studies have further substantiated these results using more modern brain-imaging techniques. MacSweeney et al.[38] found that although regular spatial processing and general sign production require the left parietal lobe, the complex mapping of space to internal representations of signs during SL production requires more activation in the right parietal lobe. Emmorey[56] suggests that this additional right superior parietal lobe (SPL) activation is unique to SL and specifically responsible for producing classifier information for objects using iconic sign location and movements. Other studies have corroborated this observation of bilateral SPL activation during SL production when bimodal bilinguals and deaf signers named pictures and produced sentences.[34,57] Even more specifically, Emmorey et al.[58] found evidence to suggest that while handshape components rely on similar frontotemporal networks to SpL, the locations and movement components of sign classifiers are processed by the bilateral SPL, instead. This is supported causally by a transcranial magnetic stimulation study where inhibiting the left SPL was found to decrease detection and correction of spatial errors but did not alter participants' fine-motor control during signing. Therefore, this suggests that the SPL is specifically involved in language processing beyond simply creating sign movements.[59] This parietal lobe recruitment and bilateral activation during SL production is a great disparity to that observed in SpL production.

The role of the SPL and SMG in SL processing is further distinguished by Weisberg et al.'s[51] study which saw that SPL activation was similar for fingerspelling and ASL production, but SMG activation was greater when producing ASL. This suggests that the SMG is the neural substrate for phonological retrieval and encoding processes, and the SPL is instead a substrate for the general and fine-grained aspects of spatial configurations from memory.[51] These are both unique processes to SLs being processed in distinctive regions from SpL during production. This additionally supports the argument against the SMG activation in SL only reflecting spatial reorienting, as the SMG is activated in SL production where reorienting of attention does not occur.

A key mechanism for language production is how this information is fed back through the system to screen for errors. However, little research has investigated feedback mechanisms in SL compared to SpL as most assume that they are the same. The few studies that have investigated SL production feedback have shown that post-output monitoring is different between these language modalities. Crone et al.'s[55] cortical EEG study on a single proficient bimodal bilingual showed enhanced sensorimotor activation after picture naming in SL, sign reading, and sign repetition. But when this was repeated in SpL with auditory and written words, there was instead activation in temporal and occipital areas.[55] However, the generalizability of this study is questionable with its single-participant sample. Recent researchers have further investigated this sensorimotor activation as a different feedback mechanism for SL compared to SpL in multiple bimodal bilinguals. These studies have generally found greater activation in postcentral gyri and the SPL following SL production, superior temporal sulcus and frontal areas following auditory SpL production, and bilateral occipital cortex regions more after speaking SpL than signing SL.[34,60] This latter result initially seems surprising given that these visual regions had greater activation following an auditory modality (SpL) than a visual modality (SL). However, the suppressed occipital activation in SL production likely reflects cortical attenuation of participants to distinguish self from externally produced visual input, which is a mechanism not observed in SpL.[34] Moreover, the left and anterior SPL have also been implicated in the SL feedback system to be involved in proprioceptive monitoring, providing further evidence for its unique role in SL.[34,38] Overall, signers' brains tend to rely on somatosensory and spatial feedback, rather than the visual or auditory feedback used by SpL. This processing in modality specific regions and occipital attenuation translates into the brains of signers having unique feedback mechanisms with specialized neural substrates for SL production.

Production Through ERP Components

Fewer studies have investigated the ERP correlates of SL production, likely because motor movements generated by SL often impact EEG recordings. Despite this, Rès et al.[4] showed that pre-output monitoring was similar in SL and SpL through finding a similar error-related negativity ERP component in both modalities. However, they did not analyze any post-output ERP components to investigate past the point that modality has been shown previously to influence the mechanisms involved in language production. Baus and Costa[61] investigated lexical access in bimodal bilinguals performing picture signing in Catalan SL and picture naming in SpL. They believed that lexical access in SL would differ in time course from SpL as SLs have different articulators that alter lexical access timing and involve more language components that are related to words' meanings (i.e., iconicity). While the frequency effect that causes a higher amplitude P200 component for low-frequency compared to high-frequency words was still evident in both SpL and SL production, it was 150 ms later after SpL responses, even for SpL responses with high iconicity.[61] Some may argue that this latency difference is simply because of SpL being participants' second language; however, P200 latency differences have not been observed between people's first and second SpLs.[62,63] Therefore, this latency difference in processing can likely be attributed to a greater ease of lexical access in SL compared to SpL overall, because of its distinct linguistic properties, rather than those that it shares with SpL (e.g., iconicity).[61] This greater ease of lexical access suggests yet another

difference in language processing between SL and SpL. However, as the evidence for this P200 latency difference is scarce, more research is required to determine if all SL production processing occurs earlier, or if the order components are processed in is different.

Discussion

It is clear from this current research that comprehension and production processes are interweaved for SL, but in a different way than that of SpL because of its modality and unique syntactic properties.[34] SL processing is unique to SpL in that it recruits the right hemisphere for complex syntax comprehension, has context-dependent timing of expectancy effects on the N400, and involves earlier semantic and lexical access in comprehension and production, respectively.[2,22,56,61] In SL, temporal areas are seemingly conditionally activated in comprehension and are not crucial to feedback mechanisms, which are conversely key to SpL processing.[33,34] There are also modality-specific differences in early language processing, different mechanisms for bimodal compared to unimodal code-switching, and unique modality specific feedback mechanisms for SL.[26,34–36] Various parietal areas are exclusively activated in SL for language-specific processing such as phonology, syntax, and mapping internal representations to spatial information in comprehension and production.[51,52,56] Against popular arguments from those who oppose the significance of these findings, this research shows that processing differences cannot be explained by hearing status, language proficiency, interlanguage differences, non-language processes, and/or being similar to written language.[17,33,36,37]

Overall, the differences studies have so far observed between SL and SpL could potentially speak for a variety of overarching processing differences in the brains of their users. One key theme across many of the recorded disparities involves temporality. Broadly, it can be seen that late stages of language comprehension and early stages of production and feedback are somewhat similar between these language modalities. However, once one explores outside this narrow temporal window, several differences emerge because of brain's gradual abstraction away from the sensory components for language comprehension, then back toward sensory components for language production. Further investigation of this aspect of processing differences between language modalities could provide greater insight for general theories of language processing, especially concerning timing through observing exactly when these modalities converge and diverge. Not only are there differences in how these language modalities are processed during these stages, but also in the timing of certain mechanisms within them. Research has already alluded to lexical access via the P200 in SL production and modulations of the N400 in SL comprehension occurring earlier than in SpL.[25,61] However, these latency differences should be verified by future research. Additionally, what

remains to be found are whether these earlier latencies reflect a reordering of the steps of processing language information or a global latency shift for SL processing, as well as any further timing differences that may result from them. Determining the precise temporal dynamics and fluidity of SL compared to SpL processing will help evolve our current understandings the time course of language processing.

The modality-dependent anatomical mechanisms involved in SL and SpL processing provide another key theme of differences worth discussing. An argument can be made that the activation pattern differences seen between language modalities reflect analogous mechanisms merely located in modality-specific cortical regions. This could be true for some aspects of SL, such as phonological processing occurring in the parietal lobe in SL, instead of frontotemporal networks as in SpL;[34] however, the analogous mechanisms are still tailored to their specific modalities and may still potentially differ because of this. Therefore, future research needs to directly compare these mechanisms' characteristics through investigating them in different contexts to observe if they function similarly. Additionally, the evidence discussed above suggests that these modalities also have unique mechanisms without analogous counterparts in different cortical regions. Additional processes are recruited for SL that are not present in SpL, such as the recruitment of certain right hemispheric structures for specific syntactic violations and for classifier information during object naming. As well, key prediction mechanisms for SpL reflected in the N400 show dissimilarities with those used for SL, suggesting that these underlying mechanisms may be governed by different rules, determined by the language modality.

It is already known that the characteristics of the language/s one learns leads to the development of cortical structures and mechanisms in accordance with these characteristics, causing various processing differences between SpLs.[15] Therefore, if languages of the same modality are not processed identically, why would languages of a different modality be? Especially with SLs' many interlanguage structural variations and their minimal adherence to the structure of their region's SpLs. The dismissal of these nuances, both within and between language modalities, has various implications. Current theories of language processing, while they must be somewhat reductionist to maintain broad applicability, are still based almost solely on research from SpLs and their written formats. Basing theories on only one subset of languages limits our ability to accurately ascertain the core processes of language as a whole and leaves the field vulnerable to generalizing SpL-specific processes to all language types. This has further implications for clinical practice as these theories are used to determine the diagnosis and treatment of adverse cortical events, which for SL users would have inherent, yet neglected, differences. Therefore, for current theories and understandings of language processing to become more comprehensive of the entirety of language, more research and appreciation of the precise similarities and differences between language modalities is required.

While the specific areas requiring further exploration were identified above, the broader field also has limitations upon which it must improve before adequately addressing these areas. To distinguish the processing of these language modalities and to support the aforementioned differences further, future research must make more direct comparisons between SL and SpL, rather than making comparisons across studies, often with different designs. Explicit parallel observations of language processing between modalities in a variety of contexts will not only help our understandings of SL and SpL separately through exploring their differences, but also language as a whole through solidifying their similarities. Direct comparisons of language processing should also be made between different SLs to determine the characteristics that are global to the modality or specific to certain SLs. Researchers should also investigate SL production timing with measures that allow for detailed spatial and temporal resolution to consolidate these findings. Future studies must also differentiate exactly when these parietal language processes in SL occur in relation to similar SpL processes, and when and how these modality-specific processes in SpL and SL converge into the few general language processes they share. Lastly, when investigating SL, a field standard needs to be set to control for hearing status and language proficiency as previous studies have shown how incorrect interpretations can be reached in lieu of these controls.

Overall, despite the claims by some that SL and SpL processing differences are negligible, ample evidence can be found that suggests the differences are instead profound. Modality-processing differences manifest in a multitude of significant ways, particularly in earlier comprehension and later production stages. Modality-dependent differences range from variations in when certain information is processed, to distinct anatomical and electrophysiological mechanisms used to comprehend and produce language, leading to unique processing characteristics of these language types. Although cross-modality processing commonalities do exist and are important to consider when crafting theories about language processing, the often neglected differences are equally informative toward these goals. It is imperative that we continue investigating language modality processing differences to better understand the complexities of our communication system that extend beyond that of the typical SpLs. Only once these unique mechanisms have been identified, separately from the processing commonalities, will we be able to work toward a more comprehensive view of language in the human brain.

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Author's Contribution

Statement of Ethics

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