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The Effect of Iconicity on Production in American Sign Language: An Electrophysiological Investigation

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The Effect of Iconicity on Production in American Sign Language: An Electrophysiological Investigation

A dissertation submitted in partial satisfaction of the requirements for the degree Doctor of Philosophy

in

Language and Communicative Disorders

by

Meghan Elizabeth McGarry

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2022

The dissertation of Meghan Elizabeth McGarry is approved, and is acceptable in quality and form for publication on microfilm and electronically.

Co-chair

Chair

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San Diego State University

2022

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Chapter 1, in full, is a reprint of the material as it appears in Language, Cognition and Neurocience. McGarry, Meghan E.; Mott, Megan; Midgley, Katherine J.; Holcomb, Phillip J.; Emmorey, Karen. The dissertation author was the primary investigator and author of this paper.

Chapter 2, in full, is currently being prepared for submission for publication of the material. McGarry, Meghan E.; Midgley, Katherine J.; Holcomb, Phillip J.; Emmorey, Karen. The dissertation author is the primary investigator and author of this material.

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Professors Karen Emmorey, Phillip Holcomb, Katherine Midgley

ABSTRACT OF THE DISSERTATION

The Effect of Iconicity on Production in American Sign Language: An Electrophysiological Investigation

by

Meghan Elizabeth McGarry

Doctor of Philosophy in Language and Communicative Disorders

University of California San Diego, 2022

San Diego State University 2022

Dr. Karen Emmorey, Chair

Dr. Phillip Holcomb, Co-Chair

Iconicity refers to the structured mapping between a lexical form and the conceptual representation of what it means. In this dissertation, I present data from a set of three experiments using Event-Related Potentials (ERPs) that investigate the potential role of iconicity in sign production. In Study One, I present the findings from a picture-naming paradigm, which found the iconic signs were retrieved more quickly than non-iconic signs, particularly when there was a strong visual overlap between picture and sign. The production of iconic signs was additionally associated with increased N400 amplitude, indicating additional semantic processing, though this was reduced for the trials with the greatest visual overlap. In Study Two, I compared the effects of iconicity in a picture-naming task to that in an English-to-ASL translation task to explore whether the faciliatory effect of iconicity was general or task-specific. I found reduced response latencies and N400 amplitudes for iconic signs only in the picture-naming task, with no differences in the translation task, indicating that the effect of iconicity was task-specific. In Study Three, I extended the investigation of iconic signs in picture-naming paradigms by exploring the effects on two distinct manners of iconic mapping: perceptual vs. motoric iconicity. As in Study Two, reduced N400 amplitudes were observed compared to non-iconic signs, but there were no differences in response latencies. Through the use of Laplacian transformations, I compared the distribution of effects for perceptually-iconic signs, which map onto how the referent is perceived, and motorically-iconic signs, which map onto how the referent is handled. I found increased activation at frontal and central electrode sites for perceptually-iconic signs, and increased activation at parietal sites for motorically-iconic signs. These findings suggest that perceptually-iconic mappings engage the ventral stream, while motorically-iconic mappings engage the dorsal stream. Overall, this dissertation finds evidence that iconicity facilitates sign retrieval when features encoded in the sign form map to visual features of the picture stimulus, and that the type of iconicity impacts the neural regions involved in the mapping between sign form and picture stimulus.

Introduction

Language has historically been viewed as arbitrary, with little structure between phonological forms and the meanings they express, which allows for greater abstractness in communication. Iconicity refers to the contrasting phenomena, where there is a motivated mapping between conceptual and linguistic representations. The assumption of arbitrariness stemmed from spoken languages, as iconicity is not prevalent in many Indo-European languages. However, more recent investigations have found that some spoken language families employ iconicity regularly (Dingemanse et al., 2015; Imai et al., 2015; Perniss et al., 2010). Although the use of iconicity varies across spoken languages, all sign languages studied to date are known to have significant numbers of iconic signs (e.g., Aronoff et al., 2005; Bellugi & Klima, 1976; Dingemanse & Thompson, 2020; Östling et al., 2018; Padden et al., 2015).

The consistent use of iconicity across sign languages, in contrast to the more variable presence in spoken languages, may be due to the difference in articulators. Sign languages use visible, three-dimensional manual articulators, which through shape and movement are able to easily map onto the visible and sensory-motoric elements of referents and events in the world (Taub, 2001). As the spoken language articulators are concealed within the mouth and the throat, they are not able to perform this same type of visual mapping, and instead tend to map acoustic forms onto the sounds emitted by referents or events in the world. The prevalence and the types of iconicity are a unique property of sign languages, which could affect linguistic or cognitive processes during signing. The manner in which they do that is at the heart of this dissertation.

In the first chapter, I describe a behavioral and electrophysiological investigation of iconic sign production (**Study One**). In a picture-naming task, participants viewed a set of pictures, half targeting iconic ASL signs and the other half targeting non-iconic signs. As a control, non-signers viewed the same pictures, which they named in English. Response latencies were recorded to assess whether iconicity facilitated ASL sign production, and whether the degree of structured overlap (‘alignment’) between the picture and the targeted iconic sign modulated this effect. Event-Related Potentials (ERPs) were also analyzed in order to investigate the effects of iconicity and of alignment on the N400 component, which indexes semantic processing during lexical access.

In the second chapter, I describe a follow-up investigation that explores whether the effect of iconicity is specific to the picture-naming paradigm (**Study Two**). Participants performed both a picture-naming task and an English-ASL translation task, targeting the same set of iconic and non-iconic signs as in Study One**.** Response latencies and ERPs were once again recorded to assess whether the effects of iconicity found in Study One were specific only to the picture-naming condition or whether they occurred regardless of the task at hand.

In the last chapter, I describe a third study that extends the investigation of the role of iconicity in sign production to explore specific types of iconic signs (**Study Three**). In this study, I explore whether the nature of the effect of iconicity depends on the nature of the iconic mapping between the form of the sign and the mental concept. Half of the targeted iconic signs were perceptually-iconic (the mapping exists between the articulators and a salient visual feature of the referent) and the other half were motorically-iconic (the mapping exists between the articulators and the way one would hold and manipulate an object).

Taken together, these studies explore the way in which iconicity impacts lexical access during sign production. The behavioral and electrophysiological results of these studies reveal how the nature of the mapping between a sign’s form, its meaning, and properties of the eliciting stimulus influence lexical retrieval latencies and neural activity during sign production through a variety of experimental methods.

Chapter One

Picture-naming in American Sign Language: an electrophysiological study of the effects of iconicity and structured alignment

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Abstract

A picture-naming task and ERPs were used to investigate effects of iconicity and visual alignment between signs and pictures in American Sign Language (ASL). For iconic signs, half the pictures visually overlapped with phonological features of the sign (e.g., the fingers of CAT align with a picture of a cat with prominent whiskers), while half did not (whiskers are not shown). Iconic signs were produced numerically faster than non-iconic signs and were associated with larger N400 amplitudes, akin to concreteness effects. Pictures aligned with iconic signs were named faster than non-aligned pictures, and there was a reduction in N400 amplitude. No behavioral effects were observed for the control group (English speakers). We conclude that sensory-motoric semantic features are represented more robustly for iconic than non-iconic signs (eliciting a concreteness-like N400 effect) and visual overlap between pictures and the phonological form of iconic signs facilitates lexical retrieval (eliciting a reduced N400).

Key words: Iconicity, ERPs, American Sign Language, N400, picture-naming

Psycholinguistic models of language processing typically separate semantic and phonological levels of representation (e.g., Dell & O'Seaghdha, 1992; Levelt et al., 1999). However, iconic lexical items, in which there is a motivated relationship between phonological form and meaning, challenge the degree of separation between phonology and semantics. Historically, iconic words in spoken languages were considered to be rare and limited to onomatopoeia (e.g., Assaneo et al., 2011). More recently, it has become clear that iconicity is more pervasive in spoken languages than previously thought (e.g., Imai et al., 2015; Perniss et al., 2010; Perry et al., 2015). For example, ideophones depict sensory images and are found in many of the world's languages (see Dingemanse, 2012 for review). In addition, a recent analysis of over 4,000 languages revealed that sound and meaning were not completely independent, and unrelated languages often use the same sounds for specific referents, e.g., words for *tongue* tend to contain an *l* sound and words related to smallness contain an *i* vowel (Blasi et al., 2016). Unlike spoken languages, iconicity has long been known to be widespread across the lexicon in sign languages. Iconic signs may be more prevalent than iconic words because of the affordances of visible, manual articulators that allow the creation of iconic expressions that depict objects and human actions, movements, locations, and shapes (e.g., Taub, 2001).

Emmorey (2014) has proposed that iconicity should be viewed as a structured mapping between two mental representations, a conceptual representation and a phonological representation. This proposal draws heavily on the structure-mapping theory proposed by Gentner and colleagues (Gentner, 1983; Gentner & Markman, 1997) and the analogue-building model of linguistic iconicity proposed by Taub (2001). Taub (2001) argued that the cognitive process of comparison is key to the concept of iconicity, and Gentner (1983) provides evidence that comparison processes crucially involve creating structured correspondences between two mental representations. Figure 1.1 illustrates how Taub's model applies to the iconic signs denoting 'bird' in American Sign Language (ASL) and Turkish Sign Language (TİD). These two unrelated sign languages exhibit different iconic mappings because different representations have been selected to represent the concept 'bird'. In ASL, the representative image highlights the bird's beak, and this aspect of the image can be mapped to the thumb and index finger of the phonological form; whereas in TİD, the bird's wings are prominent in the selected image and can be mapped to the two hands. We refer to this type of structured mapping between an image and a phonological form as 'alignment.' In this study we used a picture-naming task to investigate the effects on lexical retrieval of both sign iconicity (comparing iconic vs. non-iconic signs) and picture-sign alignment (comparing pictures that are aligned vs. non-aligned to a targeted iconic sign).

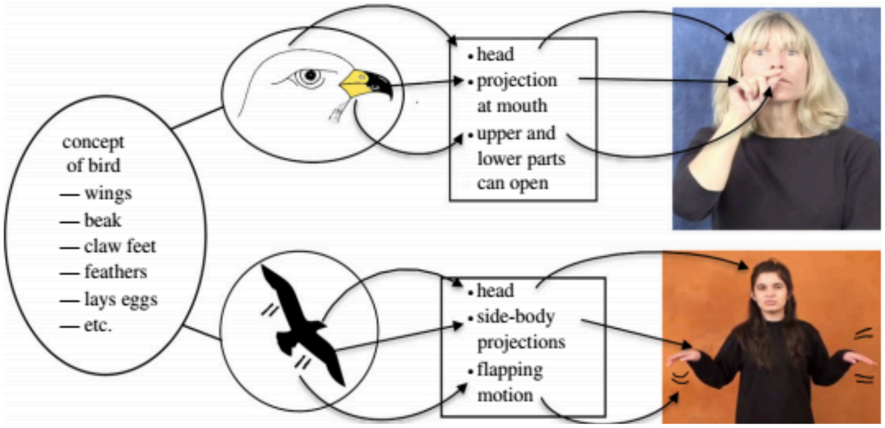

Figure 1.1. Illustration of the analogue-building process for the iconic signs for 'bird' in American Sign Language (top) and Turkish Sign Language (bottom). A representative image is selected for a concept, and the schematized image is mapped onto the phonological units in the language. Reprinted from Emmorey, K. (2014). Iconicity as structure mapping. Phil. Trans. R Soc B, 369,1651.

There is growing evidence that iconicity may play a role in lexical retrieval and production for signers, but whether these effects are strategic or reflect lexical processing effects is unclear. Vinson, Thompson, Skinner, and Vigliocco (2015) found that picture-naming times in British Sign Language (BSL) were faster for iconic than non-iconic signs, but this effect was limited to signs that were rated as having a later age of acquisition (Vinson et al., 2015). Vinson et al. (2015) speculated that iconicity may not have facilitated retrieval of early-acquired signs because a) their study may not have included a sufficient range of early-acquired signs or b) iconicity may only facilitate naming when there is some degree of difficulty in lexical retrieval, as occurs for late-acquired signs. However, Vinson et al. (2015) did not include a control condition in which non-signers named the same pictures in English. Such a control would help confirm that the observed effects were due to sign iconicity and not to uncontrolled aspects of the different pictures that were used to elicit iconic and non-iconic signs. Navarrete et al. (2017) carried out just such a control analysis with 70 of the 92 pictures used by Vinson et al. (2015) for which spoken naming latencies were available in Szekely et al. (2004). The authors found that pictures with iconic signs were named faster than those with non-iconic signs by non-signing speakers, highlighting the need for this type of control.

Navarrete et al. (2017) also found effects of iconicity on picture naming for Italian Sign Language (LIS). This study used a picture-picture interference task to investigate whether picture distractors with iconic signs interfere less with naming target pictures. The authors hypothesized that iconic signs become activated more quickly and robustly than non-iconic signs because iconic signs receive additional activation from the perceptual and action-related features that they encode. Navarrete et al. argued that if iconic distractor signs become activated more quickly, then they can be discarded more quickly as possible responses, which leads to faster responses when naming target pictures. Previous studies using this paradigm report a similar effect with lexical frequency; that is, target pictures were named faster when the distractor pictures had more frequent names (e.g., Dhooge & Hartsuiker, 2010; Miozzo and Caramazza, 2003). Two experiments confirmed Navarrete et al.'s prediction: naming times were faster when distractor pictures had iconic signs compared to non-iconic signs, and this effect held only for LIS signers and not for speakers performing the same task in Italian. In addition, a third experiment found that pictures with iconic signs were named faster than those with non-iconic signs for LIS signers, but not for Italian speakers. Pretato, Peressotti, Bertone, and Navarrete, (2018) found similar effects of iconicity on picture-naming times for hearing LIS signers.

These studies suggest that iconic signs may be easier to retrieve than non-iconic signs during production, but response time data can only reveal the summation of processing. The use of event-related potentials (ERPs) can track the time course of processing and reveal whether effects of iconicity occur during early picture processing, during lexical access, or at a later stage. Baus and Costa (2015) used ERPs and picture-naming to investigate the effects of iconicity and frequency on lexical retrieval in hearing bimodal bilinguals fluent in Catalan Sign Language (CSL) and Spanish/Catalan. Naming latencies were faster for pictures with iconic signs (particularly for low frequency items), and this effect was only observed when the bilinguals named the pictures in CSL and not in Spanish/Catalan. Baus and Costa found a very early effect of iconicity in a 70-140ms time window post picture onset: pictures named with iconic signs elicited a more positive response than those named with non-iconic signs, and this effect was only observed when naming pictures in CSL. Within the N400 time window (350-500ms), an effect of iconicity was again observed (greater positivity for iconic than non-iconic signs), but only for low frequency signs. In a later time-window (550-750ms), an interaction between iconicity and frequency was again observed, but now the effect of iconicity was only observed for high frequency signs. However, the same iconicity and frequency interactions were also observed when bilinguals named the pictures in Spanish/Catalan, which makes the iconicity effects difficult to interpret. In addition, the majority of the hearing bilinguals (23/26) learned CSL as a late L2 and had been exposed to CSL for an average of only 2.6 years. Iconicity is known to play a larger role in second compared to first language acquisition (for review see Ortega et al., 2017). Thus, it is unclear whether the observed iconicity effects only occur when a sign language is recently learned by hearing adults.

In the present study, we investigated the possible effects of iconicity on ERPs when deaf highly proficient signers name pictures in ASL. Of particular interest is the N400 ERP component, which has been shown to be sensitive to lexico-semantic processes (for review see Kutas & Federmeier, 2011). There are several possible hypotheses for how iconicity could modulate the N400 response. One possibility is that iconicity might pattern like lexical frequency, such that iconic signs are activated more rapidly and more easily compared to non-iconic signs. In this case, we should observe a smaller N400 (less negativity) for iconic than non-iconic signs, just as high frequency words elicit faster response times and smaller N400 amplitudes compared to low frequency words (Kutas and Federmeier, 2011). For picture-naming, ERP effects of lexical frequency (greater positivity for low frequency words) have also been found to emerge 150–200ms after picture onset for speech production (Strijkers, Costa, & Thierry, 2010; see also Baus, Strijkers, & Costa (2013) for typed naming). Strijkers et al. (2010) argued that this early frequency modulation reflects lexical access, rather than conceptual processing or phonological retrieval.

Another possibility is that iconicity might pattern more like concreteness because iconic signs more strongly encode perceptual and action features of the concepts they denote compared to non-iconic signs. Concrete words are typically responded to faster than abstract words and also elicit a larger N400 (greater negativity) compared to abstract words (e.g., Holcomb et al., 1999; Kounios & Holcomb, 1994; van Elk et al., 2010). One explanation for the larger N400 amplitude for concrete words is that they have stronger and denser associative semantic links than abstract words, and concrete words may activate more sensory-motor information (see Barber et al., 2013).

In the present study, we also investigated the possible effect of alignment between a picture and the targeted iconic sign. Two previous studies have manipulated alignment in a picture-sign matching task with ASL signers (Thompson Vinson, & Vigliocco, 2009) and BSL signers (Vinson et al., 2015). In these studies, participants judged whether a picture and a sign matched, and the alignment between the form of the iconic sign and the picture was manipulated. For example, the iconic ASL sign BIRD depicts a bird's beak (see Figure 1), and an aligned picture would show a prominent bird's beak (e.g., top picture in Figure 1), whereas a non-aligned picture would show a bird in flight where the beak is not salient (e.g., bottom picture in Figure 1) (see also Figure 2 below). Both Thompson et al. (2009) and Vinson et al. (2015) found that native signers had faster RTs for iconic signs preceded by aligned than non-aligned pictures, and speakers performing the task with audio-visual English words showed no RT difference between the two picture-alignment conditions. We investigated whether picture-alignment impacts naming latencies and ERPs for iconic signs. We hypothesized that picture-alignment makes signs easier to retrieve due to the visual mapping between the picture and the form of the iconic sign. Therefore, we predicted faster naming times and a reduced N400 amplitude for iconic signs in the picture-aligned condition compared to the non-aligned picture condition.

In sum, the present study constitutes a two-part analysis of both iconicity and structured alignment between a picture and a sign. In our investigation, we explored 1) whether deaf ASL signers would be faster to name pictures using iconic signs than non-iconic signs and 2) whether for iconic signs, naming latencies are faster when the picture is aligned vs. non-aligned to the target sign. In addition, we investigated whether iconicity and/or picture alignment impacted the N400 response for sign retrieval and production.

Methods

Participants. Twenty-three deaf signers were included in our analyses (11 female; mean age = 33.65 years, *SD* = 6.11 years). Thirteen were native signers born into deaf signing families and ten were early ASL signers, exposed to ASL before age 6 years (mean age of ASL exposure = 2.9; SD = 1.76 years)[1]. All participants had normal or corrected-to-normal vision, and had no history of any language, reading, or neurological disorders. Two participants were left-handed. Two additional participants were run but were excluded from the analyses. One was excluded due to a large number of skipped trials ("don't know" responses), and the other due to an excessive number of artifacts in the ERP recording.

Control participants were 27 monolingual English speakers (13 female; mean age = 30.95 years, *SD* = 8.97 years) who had normal or corrected-to-normal vision, and had no history of any language, reading, or neurological disorders. Two participants were left-handed to match the deaf participants. Control participants had no exposure to ASL beyond knowing a few signs or the fingerspelled alphabet. These participants underwent the same experimental procedures as the deaf participants, but due to extensive speech-related ERP artifacts, only reaction times are compared for analysis.

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[1] When analyzed separately, native and early signers exhibited the same pattern of behavioral and ERP results, indicating that our findings were not driven by the native signers.

All participants received monetary compensation in return for participation. Informed consent was obtained from all participants in accordance with the Institutional Review Board at San Diego State University.

Materials. Stimuli consisted of digitized black on white line drawings. A total of 176 different pictures were presented representing 88 different concepts. Half of the 176 pictures (88) were named with iconic signs and half (88) were named with non-iconic signs. Descriptive statistics for the ASL signs are given in Table 1. Iconicity ratings and subjective frequency ratings were retrieved from the ASL-LEX database (Caselli et al., 2017; Sevcikova Sehry, Caselli, Coehn-Goldberg, & Emmorey, submitted), and videos of all targeted ASL signs can be found in this database (http://asl-lex.org). For this database, hearing non-signers rated sign iconicity on a scale from 1 (not iconic at all) to 7 (very iconic). Signs were considered iconic and included in the present study if they received a rating of 3.7 or higher, while non-iconic signs were included if they received ratings of 2.5 or lower. Iconic and non-iconic signs were matched for ASL frequency based on ratings from ASL-LEX; deaf signers rated the frequency of ASL signs on a scale from 1 (very infrequent in everyday conversation) to 7 (very frequent in everyday conversation). Iconic and non-iconic signs were also matched for the number of two-handed signs and for phonological neighborhood density (PND) using the Maximum PND measure from ASL-LEX. Age of acquisition (AoA) norms are not available for ASL, and therefore as a proxy, we matched the English translations of the iconic and non-iconic signs using English AoA norms from Kuperman et al. (2012). Both the iconic and non-iconic sign translations were early-acquired (see Table 1), suggesting that the ASL signs in the present study were all acquired early (only two items had an AoA above age 7.0 years).

Table 1.1. Descriptive statistics for the ASL signs.

	Iconicity *M(SD)*	Frequency *M(SD)*	# of two-handed signs	PND *M (SD)*	AoA (in years) *M (SD)*
Iconic signs	5.31 (0.94)	3.90 (1.24)	16	37.95 (27.02)	4.67(1.11)
Non-Iconic signs	1.86 (0.39)	4.17 (1.11)	17	31.23 (28.25)	4.66(1.22)

Note: PND = phonological neighborhood density, AoA = Age of Acquisition.

Of the 88 pictures that were named with iconic signs, 44 pictures were aligned with the ASL sign and 44 pictures were non-aligned with the same target ASL sign (see Figure 1.2). The other 88 pictures for non-iconic signs represented 44 different concepts, each of which was depicted by two different pictures (see Figure 1.2). Each participant saw all 176 pictures, and the order of the aligned and non-aligned pictures (iconic signs) was counterbalanced across participants in two pseudorandom lists; similarly for the non-iconic signs, the order of picture 1 and picture 2 was counterbalanced within these two lists.

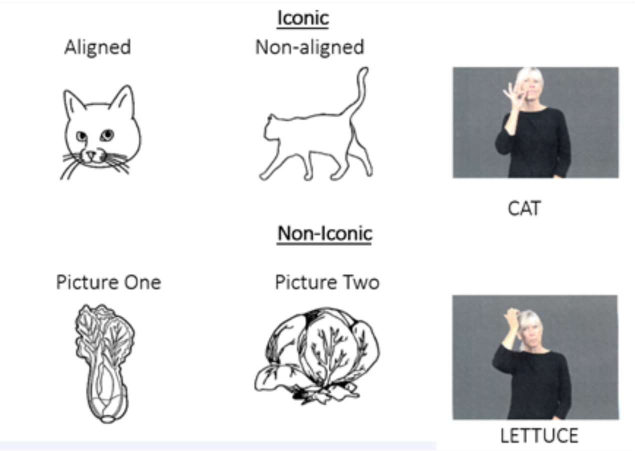

Figure 1.2. Example of stimuli illustrating an iconic and non-iconic target sign, as well as the aligned and non-aligned pictures for the iconic target sign. Non-iconic target signs are not aligned or non-aligned to the pictures because there is no clear mapping between form and meaning for these signs.

Because two different pictures were used for each concept, there are inevitable differences between the two pictures. Thus, it is possible to inadvertently have selected pictures such that one is a more prototypical example of the concept than the other which would lead to easier recognition and faster naming times. In order to avoid this potential confound, thirty MTurk workers rated all the pictures for prototypicality through an online Qualtrics survey. Each participant was given the English word and was asked to mentally imagine the concept. When they had a mental image in mind they clicked "Continue" and were shown a target picture. This target picture was rated on a 5-point scale for how well the picture represented their mental image for that concept, where 1 was a 'poor match' and 5 was a 'very close match'. All pictures were matched on their prototypicality ratings. Ratings did not differ between pictures targeting iconic signs (mean = 4.50, *SD* = 0.27) and pictures targeting non-iconic (mean = 4.53, *SD* = 0.23), *p* = 0.22. Prototypicality ratings also did not differ between aligned pictures for iconic signs (mean = 4.67, *SD* = 0.33) and non-aligned pictures (mean = 4.50, *SD* = 0.33), *p* = .24.

Procedure. Each trial began with text advising the signer to prepare for the next trial by pressing and holding down the spacebar (with their dominant hand) on a keyboard placed in the participant's lap. As soon as the space bar was pressed down, a fixation cross appeared in the center of the screen for 800ms followed by a 200ms blank screen and then the to-be-named picture which remained on screen until the spacebar was released. The release of the spacebar marked the response onset, i.e. the beginning of signing. Reaction times were calculated as the amount of time elapsed from when the picture appeared on screen to spacebar release. After signing the participant again saw the text asking them to press the spacebar. Participants were told that they could blink and move prior to replacing their hand on the keyboard or during the longer blink breaks that came about every fifteen trials. Participants were also provided with two self-timed breaks during the study, which gave them the opportunity to take a break for as long as they desired before resuming the study. Participants were instructed to name each picture as quickly and accurately as possible. They were also asked to use minimal mouth and facial movements while signing in order to avoid artifacts associated with facial muscle movements in the ERPs. In the event that a participant did not know what the picture represented or the sign to name it, they were instructed to respond with the sign DON'T-KNOW, thereby skipping the trial.

For hearing participants, each trial began with a purple fixation cross appearing in the center of the screen for 800ms followed by a gray fixation cross for 800ms. The second fixation cross was followed by 200ms blank screen and then the to-be-named picture which remained on screen for 300ms. A blank screen was then presented until the picture was named aloud, after which the experimenter pressed a key to begin the next trial. Headphones worn by the participants included a microphone which recorded the naming of the picture. The time elapsed between the picture's presentation and the onset of speech was used as a measure of reaction time. Participants were told that they could blink during the purple fixation cross or during the longer blink breaks that came about every fifteen trials, as well as during the self-timed breaks. As with the deaf participants, the hearing participants were instructed to name the pictures as quickly and accurately as possible, and to tell the experimenter if they did not recognize the picture or could not name it. As noted above, due to speech artifact that overlapped temporally with the components of interest the ERP data from the hearing participants could not be used for analysis.

To familiarize all participants with the task, a practice set of 15 pictures that were not included in the experimental list was given to participants before the experiments. Participants were not familiarized with the images prior to the experiment.

EEG recording and analysis. Participants wore an elastic cap (Electro-Cap) with 29 active electrodes (see Figure 1.3 for an illustration of the electrode montage). An electrode placed on their left mastoid served as a reference during the recording and for analyses. Recordings from electrodes located below the left eye and on the outer canthus of the right eye were used to identify and reject trials with blinks, horizontal eye movements, and other artifacts. Using saline gel (Electro-Gel), all mastoid, eye and scalp electrode impedances were maintained below 2.5 kΩ. EEG was amplified with SynAmpsRT amplifiers (Neuroscan-Compumedics) with a bandpass of DC to 100 Hz and was sampled continuously at 500 Hz.

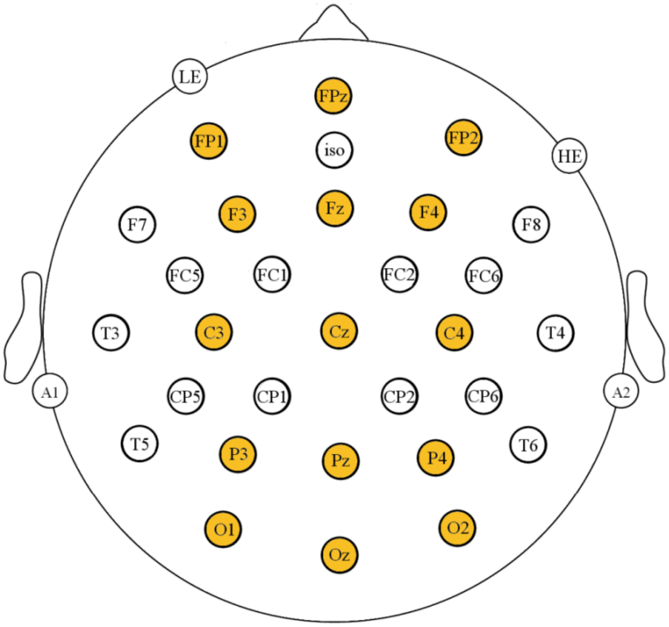

Figure 1.3. Electrode montage used in this study. Highlighted sites were used in the analysis.

ERPs were time-locked offline to the onset of the picture, with a 100ms pre-stimulus baseline. Trials contaminated with artifact were excluded from analysis, as were trials with reaction times shorter than 300ms or longer than 2.5 standard deviations above the individual participant's mean RT.

Mean amplitude was calculated for the N400 window (300-600ms after picture presentation).[2] The selection of this window was based on visual inspection of the grand means, which showed an N400 component with activity continuing to 600ms after picture presentation. For this time window, two repeated-measure ANOVAs were conducted. One ANOVA with two factors of Iconicity (Iconic, Non-Iconic), three of Laterality (Left, Midline, Right) and five of Anteriority (FP, F, C, P3, O). The other ANOVA was conducted only with the iconic sign targets and included two factors of picture alignment (Aligned, Non-Aligned), three of Laterality, and five of Anteriority. These ANOVAs were used to assess the effect of iconicity and alignment on sign production during the N400 window.

Image Complexity Analysis

During the early stages of behavioral analysis, it became apparent that there were some images with significantly and consistently slower response latencies. As the pictures were controlled for prototypicality and several other variables described above, the complexity of the pictures was explored as a potential previously-unidentified variable. To assess this variable, the pictures were all processed through Matlab's Entropy function, which returned a numerical value to represent the complexity of an image. Through this function, an image of entirely white pixels will receive a low complexity score, while an image with a lot of detail will receive a high complexity score. Higher image complexity scores may be associated with more effortful

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[2] Given the results of Baus and Costa (2015), we compared ERPs for iconic and non-iconic signs in the 70–140ms window post picture onset. There were no significant effects of iconicity in this early time window (all *p*s > .1)

recognition, and therefore changes in reaction time and brain response. Four pairs of pictures targeting iconic signs were determined to have unusually different entropy values between the aligned and non-aligned pictures, and thus were excluded from all analyses. For matching purposes, the four most dissimilar pairs in the non-iconic condition were also excluded.

Results

Iconic vs. non-iconic sign production

For deaf signers, naming latencies and accuracy, as well as ERPs, for the 80 pictures targeting iconic signs were compared to the 80 pictures targeting non-iconic signs. As a control, naming latencies and accuracy for English speakers responding to the same pictures were also compared. Trials with RTs shorter than 300ms or longer than 2.5 standard deviations above the individual participant's mean RT were excluded from analysis (3% of the data). Trials with incorrect responses (7 trials or 4%, on average) were excluded from ERP analyses and the naming latency analyses.

Naming accuracy. Mean accuracy was similar for the signing participants and the English-speaking participants (3% of all trials and 5% of all trials, respectively) with no significant difference in accuracy for iconic and non-iconic trials for either group (p=.23 and p=.43 respectively).

Naming latencies. The mean overall naming latency for ASL and English was similar (M = 806ms, SD = 167 and M = 827ms, SD=109, respectively). However, we conducted separate analyses for manual (ASL) and vocal (English) naming latencies due to the potential articulatory differences in response type (see Emmorey et al., 2012). To statistically compare naming latencies between iconic and non-iconic signs, we used a linear mixed effects model, with items and participants as random intercepts, and iconicity, sign frequency, picture prototypicality, and picture complexity as fixed effects for both groups. For signing participants, a marginal main effect of iconicity was found, $t = -0.502$, $p = 0.055$, such that iconic signs ($M = 798$ms, $SD = 165$) were produced faster than non-iconic signs ($M = 830$ms, $SD = 160$). For the English speakers, the production of English words with iconic ASL translations ($M = 824$, $SD = 109$) vs. non-iconic translations ($M = 834$, $SD = 113$) yielded no significant effect of iconicity, $t = -1.283$, $p = 0.14$.

Electrophysiological effects of iconicity. There was no main effect of Iconicity, $F(1,24) = 0.78$, $p = .39$, but there was a significant interaction between Iconicity x Laterality, $F(1,24) = 5.89$, $p = .009$, indicating that the production of iconic signs was associated with greater left-sided negativity across the N400 window. Additionally, production of iconic signs elicited greater negativities at frontal electrodes sites, as evidenced by an Iconicity x Anteriority interaction, $F(1,24) = 4.76$, $p = .02$ (see Figure 1.4).

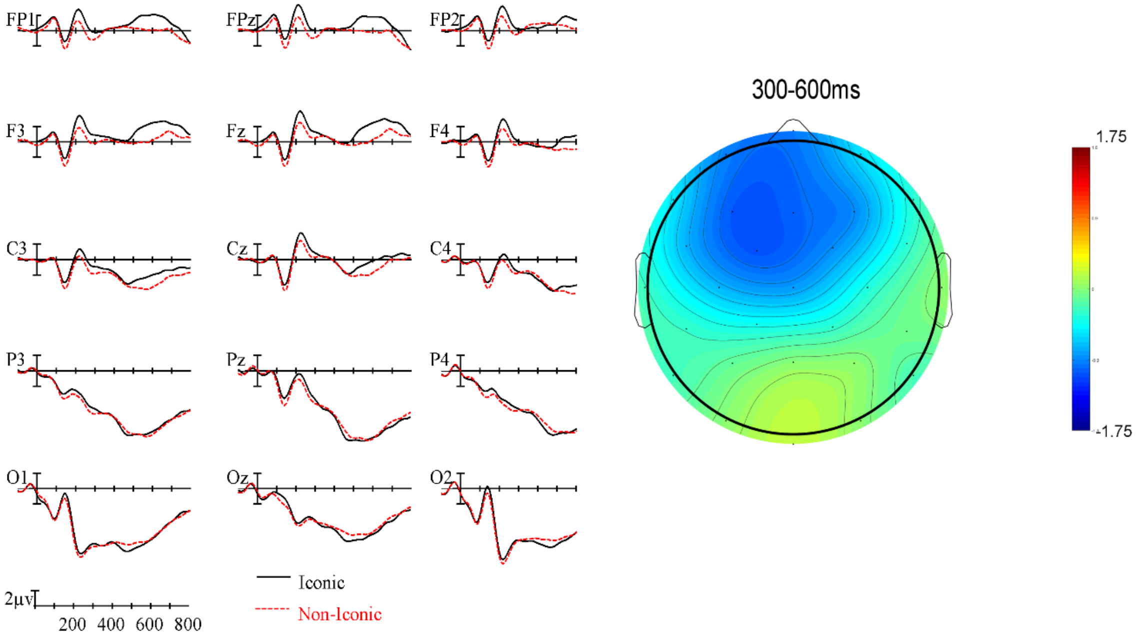

Figure 1.4. ERP results from the fifteen electrode sites included in analysis. The voltage map illustrates the greater frontal negativity for iconic compared to non-iconic signs in the N400 window.

Effects of picture alignment for iconic signs

To test the effect of alignment, we compared naming times and ERPs for the pictures that were visually aligned with the features of the target sign (N = 40) and the pictures that were non-aligned with the target sign (N = 40). Again, as a control, naming latencies and accuracy were compared for speakers naming the same pictures in English.

Naming accuracy. There was no significant difference in accuracy between aligned and non-aligned pictures for either ASL signers or English speakers (p=.19 and p=.14 respectively).

Naming latencies. A similar linear mixed effects structure was used as for the iconicity comparison, with alignment included as a categorical variable in the place of iconicity. For signers, there was a significant main effect of alignment, $t = 2.46$, $p = .02$. Signs with aligned pictures were named significantly faster than signs with non-aligned pictures, (*M* = 767ms, *SD* = 155 and *M* = 817ms, *SD* = 180, respectively). This effect was not found for English speakers, $t = -0.92$, $p = .35$, as aligned pictures and nonaligned pictures had similar reaction times (*M* = 827ms, *SD* = 109 and *M* = 820ms, *SD* = 108, respectively.)

Electrophysiological effects of alignment. There was no main effect of Alignment, $F(1,24)= 0.5$, $p = .83$, but there was a significant interaction between Alignment x Anteriority, $F(1,24)= 5.68$, $p = .01$. Pictures in the non-aligned condition generated a larger negativity at frontal electrode sites compared to pictures in the aligned condition. In addition, there was a three-way interaction between Alignment x Anteriority x Laterality, $F(2,48)= 3.87$, $p = .003$. The effect of alignment was strongest for the frontal electrodes over the right hemisphere (see Figure 1.5).

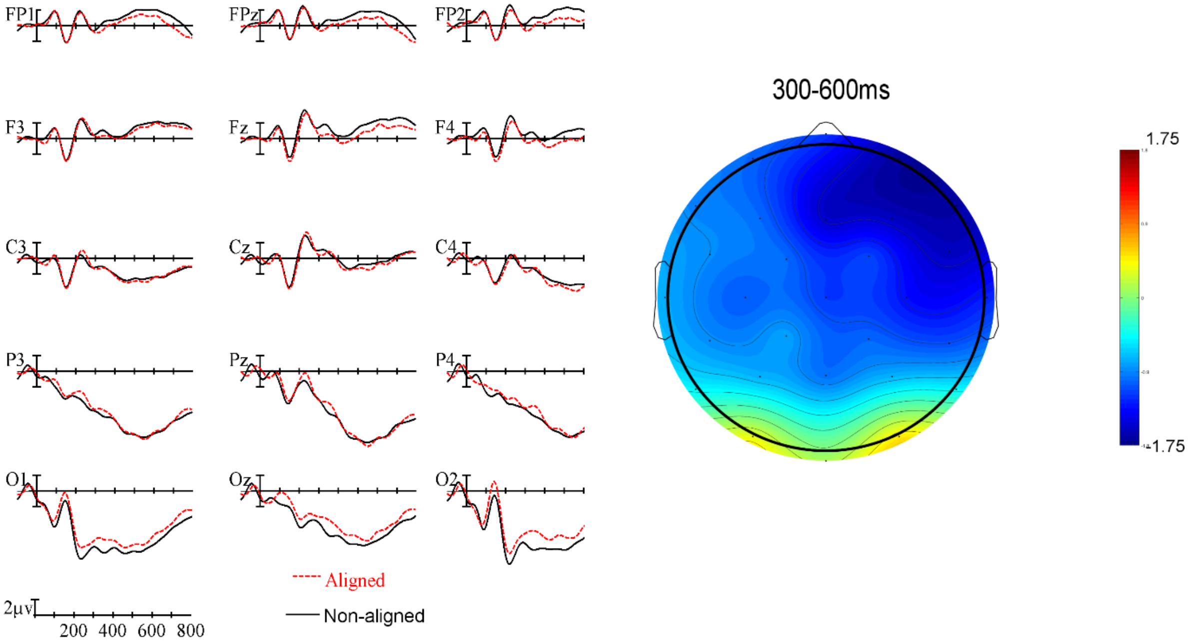

Figure 1.5. ERP recordings from the fifteen electrode sites included in analysis. The voltage map illustrates greater frontal right-sided negativity for pictures in the non-aligned condition compared to the aligned condition in the N400 window.

Discussion

The goals of this study were to investigate a) whether sign iconicity facilitates lexical retrieval and/or modulates the N400 ERP component during picture naming and b) whether picture-sign alignment (shared visual features between a picture and an iconic sign) speeds naming latencies and/or modulates the N400 response. We found behavioral and electrophysiological effects for both types of manipulations, and we address these findings separately below.

Iconic vs. non-iconic sign production

Iconic signs were produced marginally faster than non-iconic signs, but English speakers showed no effect of the iconicity manipulation when producing spoken English translations. These findings are consistent with several previous studies of iconicity and picture-naming in different sign languages (Baus & Costa, 2015; Vinson et al., 2015; Navarrete et al., 2017; Pretato et al., 2017). One possible explanation for these findings is that the link between semantic features and phonological representations for iconic signs facilitates production compared to non-iconic signs. Another possible (not mutually exclusive) explanation suggested by Navarette et al. (2017) is that the semantic features depicted by iconic signs are encoded more robustly at the semantic level, which could facilitate lexical retrieval and thus speed naming times for iconic signs.

The electrophysiological results revealed that production of iconic signs elicited a more negative response than non-iconic signs. This effect was strongest over frontal sites. Behavioral facilitation is typically associated with reduced N400 amplitude, suggesting a different mechanism accounts for our facilitated naming latencies. When compared to abstract words, concrete words are typically responded to faster, as well as eliciting a larger N400 (e.g., Holcomb, Kounios, Anderson, & West, 1999; Kounios & Holcomb, 1994; van Elk et al., 2010). Several studies have established that this effect is generally anterior in distribution, resulting in greater negativities over frontal sites for concrete words (Kounios & Holcomb, 1994; Holcomb et al., 1999; Barber et al., 2013). Greater negativity for concrete words compared to abstract words has been interpreted to be the result of the simultaneous activation of both sensory-motoric conceptual features and linguistic features for concrete words. In the present study, the iconic signs all depicted specific perceptual and/or motoric features of the concepts they denoted (e.g., the form of an object; how an object is held), while the non-iconic signs did not depict any sensory-motoric features. If, as suggested by Navarette et al. (2017), the semantic features depicted by iconic signs are more robustly represented and activated, then this could give rise to greater activation of sensory-motoric features for iconic compared to non-iconic signs, which would result in greater frontal negativity for iconic signs. Thus, despite the fact that both iconic and non-iconic signs referred to concrete, picturable concepts, the sensory-motoric semantic features of iconic signs may be more robustly represented which facilitates lexical retrieval and also elicits a larger negativity that tends to be frontal in distribution.

Effects of picture alignment for iconic signs

For iconic signs, we manipulated the structural alignment between the signs and pictures and found that when the iconic features of the sign and the picture were aligned, naming times were faster than when the sign and picture were not aligned. This result is consistent with comprehension studies of picture-sign matching that found that structural alignment facilitated matching of signs and pictures (Thompson et al, 2009; Vinson et al., 2015). Crucially, there was no behavioral effect of alignment for our control group of English speakers.

Naming facilitation for iconic signs in the aligned vs. non-aligned picture condition was associated with a reduction in N400 amplitude for aligned pictures. This reduction in amplitude suggests less effortful retrieval as a result of priming between the picture and sign form. Both the reduced N400 and faster reaction times to aligned pictures indicate that the overlap between the picture and the sign form has a faciliatory effect on lexical retrieval and production. The priming effect during the N400 window was strongest over frontal, right hemisphere sites. We hypothesize that this distribution may be associated with form processing in ASL based on a similar distribution for implicit ASL phonological priming found by Meade, Midgley, Sehyr, Holcomb, and Emmorey (2017). In that study, deaf signers made semantic relatedness judgements on pairs of English words that had either phonologically-related or unrelated ASL translations (all pairs in the experimental condition were semantically unrelated). When signs were phonologically-related they were visually similar, sharing the same location, handshape and/or movement. Target words in the ASL phonologically-related trials elicited smaller N400 amplitudes than targets in the unrelated trials. Importantly, this effect was strongest over the right frontal electrode sites, and was interpreted as evidence for implicit phonological priming in ASL. As the effect of alignment in the present study has a similar distribution, this may indicate that the relationship between the phonological form of the sign and the visual features of the picture are being implicitly activated in a similar manner, thus resulting in the facilitatory priming effect.

To explore the relationship between alignment (iconic signs with aligned vs. non-aligned pictures) and iconicity (iconic vs. non-iconic signs), we visually inspected the relationship between these three conditions. As shown in Figure 1.6, regardless of picture alignment, production of iconic signs was associated with a more negative amplitude than non-iconic signs.[3] Thus, the priming effect for iconic signs in the aligned condition does not override the negativity associated with the concreteness-like effect for iconic signs. In addition, both effects extend after the typical N400 epoch and are visible 700ms after stimuli presentation.

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[3] An ANOVA revealed a significant difference between non-iconic and iconic aligned conditions, with a three-way interaction with anteriority and laterality, *F*(8,176) = 3.29, *p* = .02; the difference was strongest over frontal right-hemisphere sites. An ANOVA also revealed a significant difference between the non-iconic and the iconic non-aligned conditions, with an interaction between condition and anteriority, *F*(4,88) = 8.97, *p* = .002; the difference was strongest in the frontal sites.

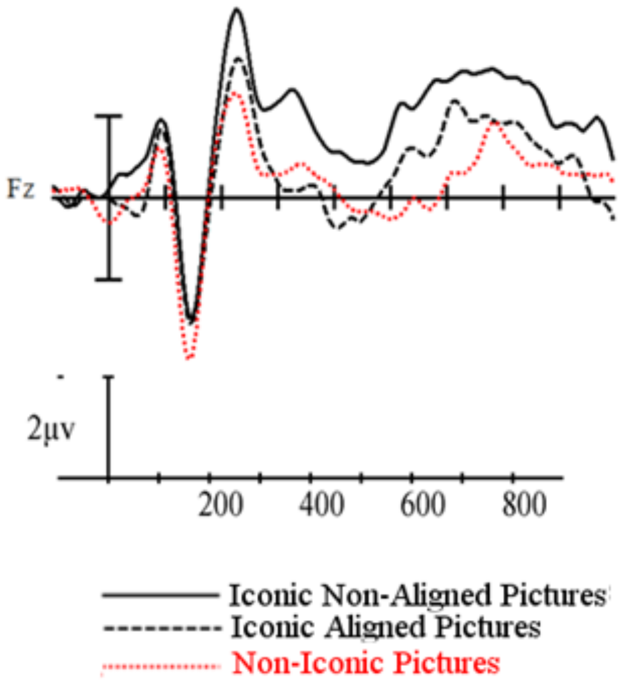

Figure 1.6. Single-site ERP recording comparing the iconic (both non-aligned and aligned shown separately) and non-iconic condition. The proposed N700 effect is highlighted by the box.

We suggest that the late concreteness-like effect for iconic signs may reflect the N700 component, which has been previously suggested to index the amount of resources required to form a mental image of a concrete concept (Barber et al., 2013; West & Holcomb, 2000). In a sentence reading task, West and Holcomb (2000) found greater frontal negativity for trials where participants needed to generate an image of the final word in order to determine whether the concept was imageable or not versus when participants read the sentence and answered questions that did involve imagery (e.g., about the spelling of the final word). This imageablity effect onset around the typical N400 epoch and continued to be visible more than 700ms after stimuli presentation. West and Holcomb proposed that this extended greater negativity may be due to activation of perceptual features of a concept when generating a mental image. Although both iconic and non-iconic signs in the present study referred to imageable concepts, iconic signs may facilitate image generation because these signs depict imageable features of the concept. Our finding that the production of iconic signs is associated with greater negativity in the N700 time window may reflect greater imageabilty of iconic than non-iconic signs. Greater negativities in both the N400 and N700 time windows for iconic signs may indicate greater activation of semantic and perceptual features that are depicted by these signs and that are emphasized by the picture-naming task.

Conclusions

Signed languages, unlike most spoken languages, have notable iconicity that is widespread across the lexicon, providing an opportunity to investigate the impact of form-meaning mapping on lexical retrieval. The present study replicates the faciliatory effect for production of iconic signs (faster naming times), particularly when the signs are structurally aligned with the picture being named. The electrophysiological results revealed that retrieval of iconic signs elicited greater frontal negativities than non-iconic signs which we interpreted as reflecting greater activation of sensory-motor semantic features for iconic signs. The amplitude of this effect was reduced for iconic signs in the picture-aligned condition. We interpreted this reduced negativity as a priming effect arising from the form overlap between semantic features depicted in the picture and in the iconic sign.

The targeted iconic signs in this study demonstrated multiple types of iconicity, including iconicity based on perceptual features (such as the handshape of the sign mimicking the shape of the bird's beak in Figure 1) and iconicity based on the way the object is handled or held (such as the handshape of the sign mimicking how an ice cream cone is held near the mouth). The perceptually iconic signs made up 77% of the target signs (39/44), while the handling type signs constituted only 23% of the target signs (5/44). Unfortunately, the number of handling iconic signs is too small for a separate analysis. However, the distinction between these two types of signs is worth exploring in future work because studies have suggested cross-linguistic differences in the distribution of these sign types (Padden et al., 2013), and object manipulability has been shown to speed picture-naming times (Lorenzoni, Peressotti, & Navarrete, 2018; Salmon, Matheson, & McMullen, 2014). In addition, children may acquire signs with perceptual iconicity later than those with motoric iconicity (Caselli & Pyers, 2020; Tolar et al., 2008), and these two sign types also give rise to different cross-modal priming effects (Ortega & Morgan, 2015).

While the present study cannot explore differences between perceptual and motor-iconicity and alignment due to the small sample size, it is possible that different forms of iconicity may lead to different degrees or manners of behavioral facilitation and/or EEG modulation. The type of iconicity for the perceptual iconic signs involves a structured overlap between the features of an object and the phonology of the sign, resulting in a wide variety of possible handshapes. When non-aligned, the picture does not depict physical features that are easily mapped onto the phonological features of the iconic sign. In contrast, the type of iconicity for the handling signs requires the signer to mentally imagine themselves interacting with the pictured object and configure the hands to manipulate the object. Pictures of objects do not show the hands, and thus the alignment for handling iconic signs does not rely on a clear overlap between phonological features (e.g., handshape) and visual features of the object. This difference in the nature of picture-sign alignment could potentially influence performance in a picture-naming task. The reaction-time benefit and/or the electrophysiological priming may be strongest for the perceptually iconic signs. Future research intentionally comparing cases of perceptual iconicity to other forms of iconicity may discover whether these different types of structural overlap affect lexical retrieval and/or sign production in different ways.

Acknowledgements

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Chapter Two

How (and why) does iconicity effect lexical access: an electrophysiological study of American Sign Language

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Abstract

Prior research has found that iconicity facilitates sign production in picture-naming paradigms and has effects on the N400 ERP component. These findings can be explained by two separate hypotheses: (1) a task-specific hypothesis that suggests the faciliatory effect of iconicity is specific to paradigms with picture stimuli – under this hypothesis, visual features of the iconic sign form can map onto the visual features of the pictures, thus priming lexical access – and (2) a task-general hypothesis that suggests that the retrieval iconic signs results in greater semantic activation due to the robust representation of sensory-motor semantic features (akin to a concreteness effect), which can facilitate lexical retrieval. The present study distinguishes between these two hypotheses by comparing the behavioral and electrophysiological effects of iconicity during a picture-naming task and an English-to-ASL translation task. There was evidence of priming only in the picture-naming task, which supports the task-specific hypothesis and provides evidence that iconicity only facilitates sign production when the eliciting stimulus and the form of the sign are able to visually overlap.

Key words: Iconicity, ERPs, American Sign Language, N400, picture-naming, translation

Iconicity refers to the presence of a perceived relationship between a lexical item’s phonological form and its meaning. Historically, iconic words were considered to be a rare phenomenon in otherwise arbitrary spoken languages, though documented in playful use such as onomatopoeia (Assaneo et al., 2011). More recently, it has become apparent that iconicity is in fact far more widely employed in spoken languages, though its degree of use varies considerably among language families as well as individual languages (Dingemanse, 2017; Imai et al., 2015; Perniss et al., 2010; Perry et al., 2015). In contrast, sign languages consistently employ iconicity in a widespread manner throughout the lexicon (Novogrodsky & Meir, 2020; Oomen, 2021; Perlman et al., 2018; Trettenbrein et al., 2021). The frequent use of iconic mappings may be due to the visual three-dimensionality afforded sign languages by the use of visible articulators, which more easily map onto visually-salient features of real world objects and the manner in which they move (Taub, 2001).

Iconicity can be characterized by analog mappings between imagistic representations, conceptual representations, and phonological form. Consider, for example, the iconic American Sign Language (ASL) sign for ‘cat’ (Figure 2.1). The iconicity of this sign can be seen in the mapping between the phonological form of the sign (the whisker shape of the fingers, which are located at the signer’s face) and the representation of the shape of a cat’s whiskers and their location on the cat’s face. Vinson, Thompson, Skinner, and Vigliocco (2015) found that pictures were named more quickly with iconic British Sign Language (BSL) signs than non-iconic BSL signs. Faster picture-naming for iconic signs has now been replicated across other signed languages, including Italian Sign Language (Navarrete et al., 2017) and Catalan Sign Language (Gimeno-Martínez & Baus, 2022).

In a previous study with ASL, we also replicated the finding of reduced response latencies for the production of iconic signs compared to non-iconic signs in a picture-naming paradigm (McGarry et al., 2020; Study 1). In this investigation, we included Event-Related Potentials (ERPs) to explore whether the faster response latencies found for iconic signs was due to facilitated lexical access, or due to strategic use of iconicity at a later stage of processing. We specifically investigated the N400 component, an ERP component that indexes lexico-semantic processes, because modulation of in its amplitude can provide insight into whether and how different lexical properties impact processing (for review see Kutas & Federmeier, 2011). The faster retrieval of iconic signs in picture-naming tasks could be explained by (at least) two different hypotheses.

The first hypothesis is that iconic signs are retrieved more quickly than non-iconic signs in picture-naming paradigms because the iconic mapping can be extended to visual elements of the pictures (i.e., visual elements of the picture map onto visual elements of the phonological form of iconic signs). This visual mapping primes the retrieval of iconic signs, reducing naming latencies compared to non-iconic signs (no picture-form mapping is possible for these signs). If this account is correct, then the recognition and comprehension of iconic signs may also be facilitated by the degree of overlap between a picture-prime and a sign-target in a picture-sign matching task, with increased visual overlap resulting in increased facilitation for iconic signs. For example, a picture of a cat highlighting the cat's whiskers (Figure 2.1a) has a stronger overlap with the form of the ASL sign CAT than a picture of a cat highlighting the cat's body and tail (Figure 2.1b). Most of the pictures included as stimuli in picture-naming studies are likely to have at least some visual overlap with the targeted iconic sign, though the degree of this overlap varies, e.g., for both pictures in Figure 2.1, the head of the cat can map to the head of the signer, but the additional mapping of the whiskers to the handshape of the sign provides a stronger picture-sign overlap for Figure 2.1A.

Sign comprehension studies using a picture-sign matching task have manipulated the amount of this visual overlap ('alignment') to investigate whether the degree of alignment between a picture and a sign facilitates sign recognition (McGarry et al., 2021; Thompson et al., 2009; Vinson et al., 2015). Results from these experiments indicate that aligned picture-sign pairs (e.g., Figure 2.1A) are responded to more quickly and accurately than less aligned pairs (e.g., Figure 2.2B). These findings suggest that the degree of mapping between visual features of the referent depicted by a picture and the phonological elements of an iconic sign can be capitalized on during lexical activation, which enables participants to access the meaning of iconic signs more rapidly and efficiently compared to when the picture is less aligned with the form of the sign.

Support for this task-specific hypothesis can be found in a lexical decision experiment by Bosworth and Emmorey (2010). In this study, deaf ASL signers were asked to determine whether the target sign in a prime-target pair was a real sign, and the semantic relationship between the prime and target signs and the iconicity of the signs were manipulated. Participants demonstrated semantic priming through reduced response times (RTs) when the sign-prime and the sign-target were related in meaning. However, there was no difference in this facilitation effect when the prime-sign was iconic, compared to when it was non-iconic. Further, RTs did not differ for iconic compared to non-iconic target signs. These findings support the task-specific hypothesis because iconicity did not facilitate lexical access during sign recognition when the task that did not involve picture stimuli.

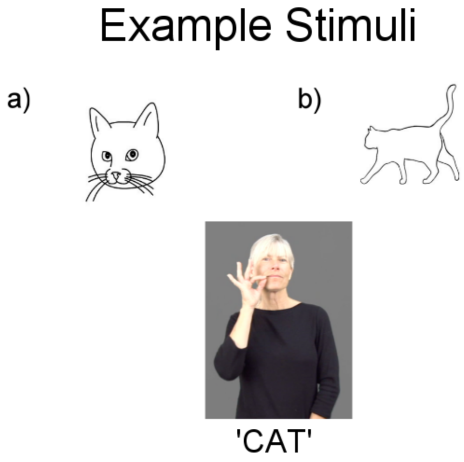

Figure 2.1. Examples of a) aligned and b) non-aligned picture stimuli. For aligned pictures, the pictures highlight a feature that maps onto the targeted sign (‘CAT’), while this feature is minimized in the non-aligned pictures.

The second hypothesis proposes that the facilitatory effect of iconicity is not driven by a mapping between the stimulus and sign, but rather by the inherent attributes of iconic signs. Navarrete et al. (2017) hypothesized that iconic signs are activated more quickly and robustly than non-iconic signs due to correspondence between the sign and the perceptual-motor features of the referent. This faster activation in turn cascades into faster exclusion of non-targeted signs, and therefore faster lexical retrieval and production of the targeted sign. If this account is correct, then iconic signs should be retrieved faster than non-iconic signs, regardless of the experimental paradigm. This view of iconicity is similar to the concept of lexical concreteness. Concreteness is known to facilitate response latencies and to also elicit larger frontal N400s for concrete items than abstract items. The larger N400 amplitude is hypothesized to be due to the stronger and denser network of semantic links for concrete words arising from the neural activation of more visual and sensory-motor information, compared to abstract words (see Barber et al., 2013;

Holcomb et al., 1999; Kounios & Holcomb, 1994; van Elk et al., 2010). If the existence of a mapping between form and meaning for iconic signs results in stronger coding of perceptual and action semantic features compared to non-iconic signs, then iconicity may give rise to behavioral and neural effects that are parallel to concreteness effects.

In McGarry et al. (2020; Study One), we found evidence consistent with both the task-specific and the semantic feature coding hypotheses. We found increased N400 amplitude (greater negativity) for iconic signs compared to non-iconic signs, particularly over frontal sites (as found for concreteness effects). This finding is consistent with the semantic feature coding hypothesis, suggesting that iconicity may be functionally similar to concreteness. However, we also included an alignment manipulation in our picture-naming paradigm and found that response latencies for the aligned trials were significantly shorter than for the non-aligned trials. Additionally, N400 amplitudes were significantly smaller for the aligned trials, and reduced N400 amplitudes are often interpreted as evidence of priming (Kutas & Federmeier, 2011; Luck, 2014). This finding is consistent with the task-specific hypothesis because the facilitatory effect of iconicity is modulated by the nature of the picture stimulus, i.e., priming occurs when the iconic features of the to-be-produced sign map onto visual features of the picture.

As we found some evidence for both hypotheses in McGarry et al. (2020; Study One), we needed to explore a different paradigm to untangle the two hypotheses. As many investigations of the role of iconicity on sign production have used pictures, the use of a different experimental paradigm may help untangle the two hypotheses. Therefore, Study Two compared effects of iconicity for a picture-naming task and a non-picture paradigm – specifically, an English-ASL translation task, where participants view printed English words, and produced the ASL translations. This design allows us to compare effects of iconicity across tasks using the same items.

Recently, Gimeno-Martinez and Baus (2022) conducted a similar study with Catalan Sign Language (LSC), comparing a picture-naming task with a Spanish-to-LSC translation task. Replicating McGarry et al. (2020; Study One), the production of iconic LSC signs in the picture-naming task was associated with reduced response times (RTs) and larger (more negative) ERP components (although in an earlier time window). However, no differences in RT or in the ERP waves were found between iconic and non-iconic LSC signs for the translation task. The lack of effect in the translation task provides support for the task-specific hypothesis. The present study (Study Two) investigates whether the same pattern of results will be found for ASL signers, and we also modified some of the methods used by Gimeno-Martinez and Baus (2022).

The effects of iconicity found by Gimeno-Martínez and Baus (2022) in their picture-naming paradigm occurred during an early (140-210ms) epoch rather than the N400 epoch, which is where effects were found in McGarry et al. (2020; Study One). The early onset of the effects found by Gimeno-Martínez and Baus may have occurred because participants were familiarized with all the stimuli prior to the study, unlike in McGarry et al. (2020; Study One). In the present study (Study Two) participants will not be familiarized with the stimuli, and therefore we expect that effects of iconicity on lexical access and retrieval should occur during the N400 window, but we will also examine the early time window for possible iconicity effects.

In order to maximize the relationship between the picture stimulus and the targeted sign, we chose to only present the aligned pictures from McGarry et al. (2020; Study One). This choice allowed us to maximize the potential for visual priming within the picture-naming task, creating a larger contrast with the translation task. As a result, for the picture-naming task we expect to see faster response latencies and reduced (smaller) N400 amplitudes for iconic than non-iconic signs, consistent with the priming effect found for aligned trials in McGarry et al. (2020; Study One). If this facilitatory effect is best explained by the task-specific hypothesis, then we predict there will be iconicity effects only in the picture-naming task, as only stimuli in this condition can visually map onto the targeted signs. If the semantic feature coding hypothesis is correct, then we predict reduced response latencies for iconic signs in both tasks and an increased N400 amplitude for iconic compared to non-iconic signs in the translation task. This pattern of results would indicate that participants automatically activate richer sensory-motor semantic features that are depicted by iconic signs, regardless of the task.

Methods

This study was pre-registered on the Open Science Framework (https://osf.io/4ufd3).

Participants. Twenty-six deaf signers were included in the analyses (11 female; mean age = 31.73 years, *SD* = 7.13 years). Participants were born into deaf signing families (N = 19) or were exposed to ASL prior to the age of six (N = 7; mean age of exposure = 3.25 years). All participants had normal or corrected-to-normal vision, and had no history of any language, reading, or neurological disorders. Two participants were left-handed. Four additional participants were run but were excluded from the analyses due to an excessive number of artifacts in the ERP recording (more than 30% of total trials).

All participants received monetary compensation in return for participation. Informed consent was obtained from all participants in accordance with the Institutional Review Board at San Diego State University.

Materials. Stimuli consisted of the aligned subset of digitized black on white line drawings from McGarry et al (2020; Study One), as well as the printed English word referring to the same concept (e.g. a picture of a bird, and the printed word ‘bird’). A total of 88 different drawings and 88 English words were presented. Both the set of drawings and words targeted the same 88 ASL signs. Half of the stimuli (44 pictures and their corresponding English words) were named or translated with iconic ASL signs, while the other 44 were named/translated with non-iconic signs. Descriptive statistics for the ASL signs are given in Table 2.1.

Iconicity ratings and subjective frequency ratings were retrieved from the ASL-LEX database (Caselli et al., 2017; Sehyr et al., 2021), and examples of all targeted ASL signs can be found in the ASL-LEX database (http://asl-lex.org). We also retrieved iconicity ratings provided by hearing non-signers who judged ASL signs on a 7-point scale (1 = not iconic at all, and 7 = very iconic). As in McGarry et al. (2020; Study One), signs were considered iconic if they received a rating of 3.7 or higher, while non-iconic signs were included if they received ratings of 2.5 or lower. The iconic and non-iconic signs were matched for ASL frequency ratings from ASL-LEX, the number of two-handed signs, and for phonological neighborhood density (PND) using the Maximum PND measure from ASL-LEX. English age of acquisition (AoA) norms were used as a proxy for ASL AoA (Kuperman et al., 2012). Picture stimuli were matched for name agreement (from McGarry et al., 2020; Study One), prototypicality (using ratings that were collected by McGarry et al., 2020; Study One), and image complexity as assessed through Matlab’s ‘entropy’ function (from McGarry et al. 2020; Study One).

Table 2.1. Descriptive statistics for the ASL signs.

	Iconicity *M(SD)*	Frequency *M(SD)*	# of two-handed signs	PND *M (SD)*	AoA (in years) *M (SD)*
Iconic signs	5.31 (0.94)	3.90 (1.24)	16	37.95 (27.02)	4.67(1.11)
Non-Iconic signs	1.86 (0.39)	4.17 (1.11)	17	31.23 (28.25)	4.66(1.22)

Note: PND = phonological neighborhood density, AoA = Age of Acquisition.

As noted above, we used the 44 aligned pictures with the greatest amount of structured overlap between picture and target sign from McGarry et al. (2020). To balance the number of stimuli, we randomly selected one picture for each of the non-iconic target signs. The order of picture presentation was counterbalanced across participants in two pseudorandomized lists. In the translation block, each participant saw 88 printed English words corresponding to the concepts in the picture-naming task in pseudorandomized order. The two lists were counter-balanced across participants.

Procedure. Participants were asked to prepare for each trial by pressing and holding down the spacebar of a keyboard placed in their lap. When the space bar was pressed, a fixation cross appeared in the center of the screen for 800ms, followed by a 200ms blank screen and then the to-be-named picture or to-be-translated English word (the stimulus). This stimulus was maintained on the screen for 300ms, followed by a blank screen. The spacebar release marked the response onset, i.e. the beginning of sign production. Reaction times were calculated as the amount of time elapsed from when the stimulus appeared on screen to spacebar release. After signing (space bar release), the blank screen disappeared and participants saw text asking them to press down the spacebar to move on to the next trial when ready. In this between-trial period, participants were able to take a break and blink, as the next trial would not begin until they replaced their hand on the keyboard. Participants were also provided with two self-timed breaks during the study, which gave them the opportunity to take a break for as long as they desired before resuming the study. Participants were instructed to name or translate each stimulus as quickly and accurately as possible. They were also asked to use minimal mouth and facial movements while signing in order to avoid artifacts associated with facial muscle movements in the ERPs. In the event that a participant did not know what the picture represented or did not know the sign translation, they were instructed to respond with the sign DON'T-KNOW, thereby skipping the trial.

Each participant performed both tasks, which were blocked and counterbalanced[4]. Before each block, participants were familiarized with the upcoming task by practicing on a set of 15 stimuli that were not included in the experiment list (either 15 pictures or 15 English words, which represented the same concept). Participants were not familiarized with the pictures or English words prior to the experiment.

EEG recording and analysis. Participants wore an elastic cap (Electro-Cap) with 29 active electrodes (see Figure 2.2 for an illustration of the electrode montage). An electrode placed on their left mastoid served as a reference during the recording and for analyses. Recordings from electrodes located below the left eye and on the outer canthus of the right eye were used to identify and reject trials with blinks, horizontal eye movements, and other artifacts. Using saline gel (Electro-Gel), all mastoid, eye and scalp electrode impedances were maintained below 2.5 kΩ. EEG was amplified with SynAmpsRT amplifiers (Neuroscan-Compumedics) with a bandpass of DC to 100 Hz and was sampled continuously at 500 Hz.

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[4] Initially, we planned to always present the translation block before the picture-naming block to maintain consistency across all participants (see pre-registration document). However, the results of the Gimeno-Martinez and Baus (2022) study became available during the data collection period, and their study counterbalanced task order. To have the best possible comparison between the two studies, we therefore decided to counterbalance our task order as well.

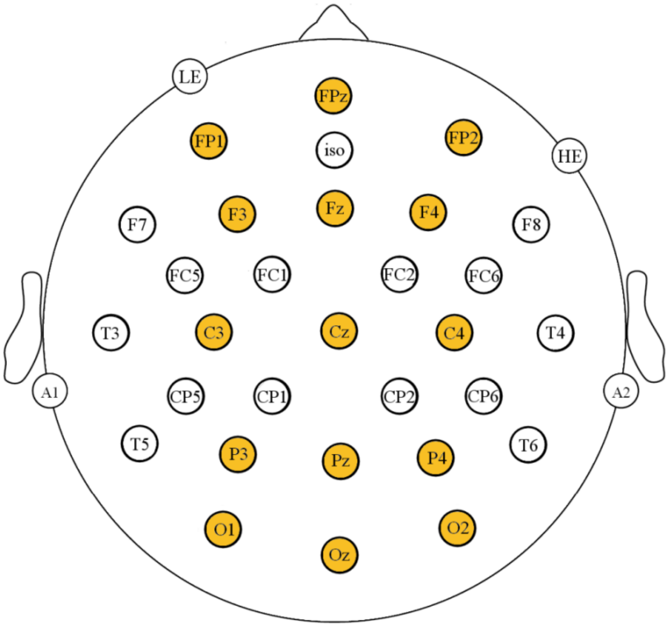

Figure 2.2. Electrode montage. Shaded sites indicate the electrodes included in the analyses.

ERPs were time-locked offline to the onset of the picture or the English word, with a 100ms pre-stimulus baseline. Trials contaminated with movement and blink artifacts were excluded from analysis, as were trials with reaction times shorter than 300ms or longer than 2.5 standard deviations above the individual participant's mean RT.

Mean amplitude was calculated for the N400 window (300-600ms after stimulus presentation). The selection of this window matched the N400 window from McGarry et al. (2020; Study One) and fit with a visual inspection of the grand means, which showed a negativity peaking around 400ms after stimulus presentation. An omnibus ANOVA was conducted on the mean N400 with two levels of Iconicity (Iconic, Non-Iconic), two levels of Task (Translation, Picture-naming), three levels of Laterality (Left, Midline, Right) and five levels of Anteriority (FP, F, C, P3, O). We also conducted follow-up analyses for each task separately. These ANOVAs included two levels of Iconicity, three of Laterality, and five of

Anteriority to assess the effect of iconicity on sign production during the N400 window for each task.

In addition, an exploratory analysis was conducted for an earlier epoch (140ms-210ms), which is the time window from Gimeno-Martínez & Baus (2022), using the same omnibus ANOVA as described above.[5]

Results

Behavioral analyses

To investigate whether the effect of iconicity on reaction times (RTs) and accuracy was different between the two tasks, we compared the 88 picture-naming trials with the 88 translation trials, paying particular attention to any interaction between iconicity and task. Unusually fast or slow trials were excluded from analysis through the criteria described above (5% of the data). Trials with incorrect responses (less than 3 trials or 3% of all data on average) were excluded from ERP and RT analyses. We used a linear mixed effects model with items and participants as random intercepts, and iconicity, task, sign frequency, picture prototypicality, and picture complexity as fixed effects. A significant interaction in the response latencies between task and iconicity was found, $t = 1.976$, $p = 0.03$, demonstrating that the model containing the interaction is better able to explain the RT data than the model without the interaction.

A significant interaction for accuracy between task and iconicity was also found, $t = -3.078$, $p = .004$, demonstrating that the model containing the interaction is better able to explain participants accuracy than the model without the interaction. To better understand these task interactions, we next conducted follow-up RT and accuracy analyses on each task separately.

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[5] We did not originally intend to analyze this time window, but we chose to include it after the publication of Gimeno-Martínez & Baus (2022).

Translation Task. To statistically compare translation latencies between iconic and non-iconic signs, the LME analysis included items and participants as random intercepts, and iconicity, sign frequency, picture prototypicality, and picture complexity as fixed effects. No effect of iconicity on RT was found, $t = 1.45$, $p = 0.69$, as iconic signs (*M* = 590ms, *SD* = 96ms) had similar translation times as non-iconic signs (*M* = 585ms, *SD* = 97ms). Similarly, we found no effect of iconicity on response accuracy, $t = -0.08$, $p = 0.47$.

Picture-naming task. To statistically compare naming latencies between iconic and non-iconic signs, the LME analysis included items and participants as random intercepts, and iconicity, sign frequency, picture prototypicality, and picture complexity as fixed effects. An effect of iconicity was found, $t= -1.958$, $p = 0.016$, such that pictures named with iconic signs (*M* = 798ms, *SD* = 165) had faster RTs than those named with non-iconic signs (*M* = 830ms, *SD* = 160). Similarly, we found that pictures in the iconic condition were named more accurately than those in the non-iconic condition, $t = 1.82$, $p = 0.04$.

Electrophysiological analyses

We conducted an ANOVA of the early time window (140ms-210ms) where Gimeno-Martínez and Baus (2022) found effects of iconicity. During this early time window, we found no effects of iconicity or interactions between task and iconicity, (all *p*s > = 0.11).

The ANOVA examining the N400 (mean amplitude between 300-600 ms) resulted in a significant interaction between task and iconicity, $F(1,25)$, $p = 0.005$, indicating that task and iconicity interacted in a way that significantly influenced ERP amplitude during the N400 window. In order to better understand this interaction, we conducted separate follow-up analyses on the data from the translation and the picture-naming tasks.

Translation task. There was no main effect of iconicity, *F*(1,25) = 1.69, *p* = .20, nor any interactions of iconicity with scalp distribution, indicating that translating iconic signs was not associated with a significantly more negative N400 amplitude than translating non-iconic signs (see Figure 2.3).

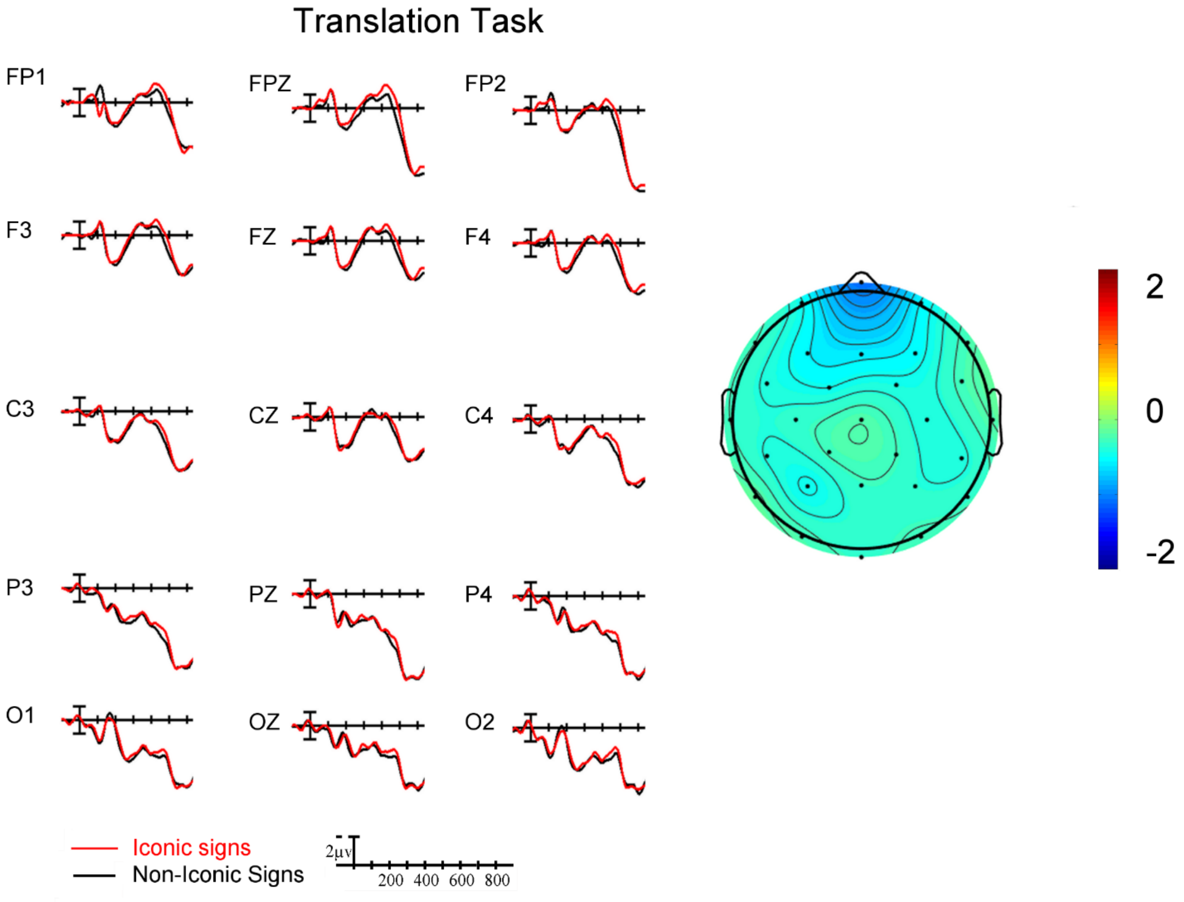

Figure 2.3. EEG recordings and voltage maps from the English-ASL translation task. Voltage maps are shown from 300 to 600ms after stimuli-presentation. The scale used for voltage maps is +/- 2 microvolts.

Picture-naming task. There was a significant main effect of Iconicity, *F*(1,25) = 9.36, *p* =.005, indicating that the production of iconic signs when naming pictures was associated with broadly reduced negativity during the N400 window compared to the production of non-iconic signs. Additionally, this iconicity effect was greater at right-hemisphere electrodes sites, as evidenced by an Iconicity x Laterality interaction, *F*(2,50) =3.83, *p* = .03 (see Figure 2.4).

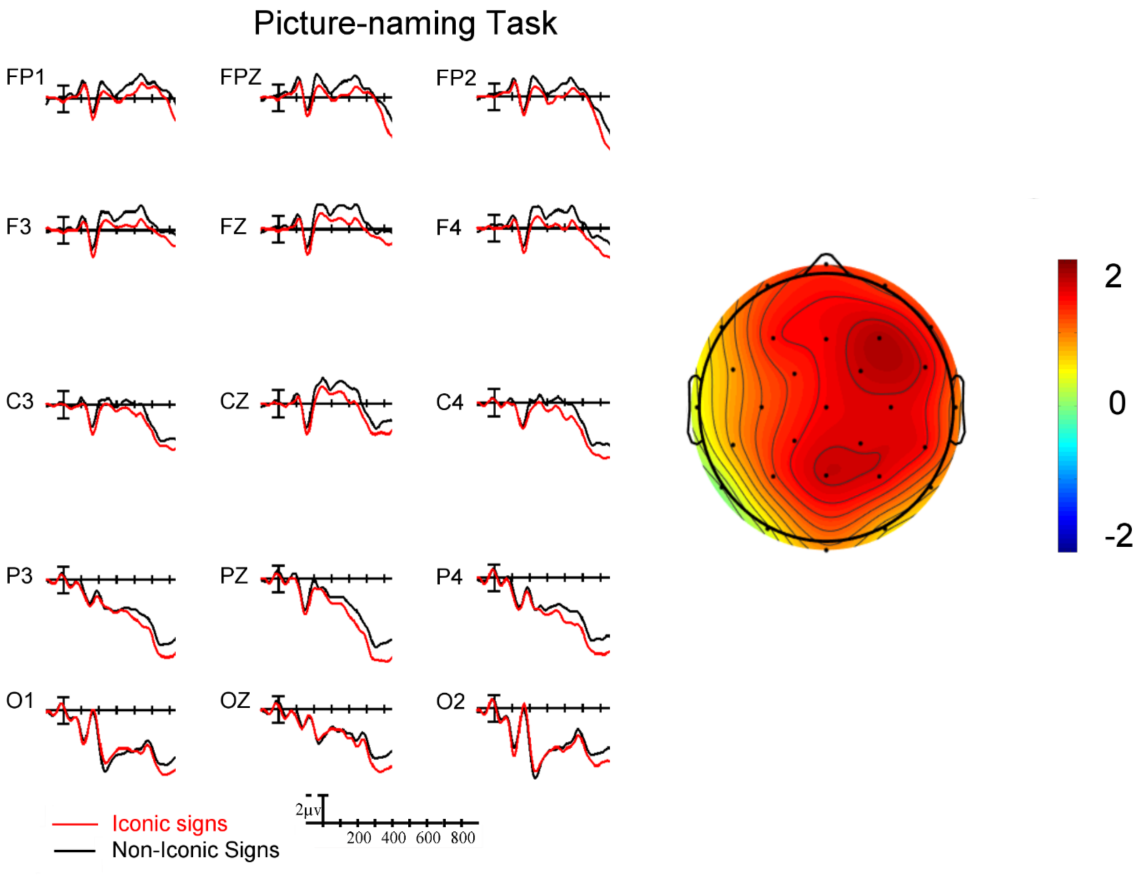

Figure 2.4. EEG recordings and voltage maps from the Picture-Naming task. Voltage maps are shown from 300 to 600ms after stimuli-presentation. The scale used for the voltage maps is +/- 2 microvolts.

Discussion

The primary goal of this study was to determine whether the faciliatory effect of iconicity found in prior research was due to a task-specific priming effect, or due to a more global increase in activation for iconic signs, due to more robust activation of sensory-motor semantic features. Previous studies across sign languages have found reduced response latencies for iconic signs compared to non-iconic signs in picture-naming studies (Vinson et al., 2015; Navarette et al., 2017; McGarry et al., 2020; Gimeno-Martínez & Baus 2022). In McGarry et al. (2020; Study One), we included ERPs to explore the stage of processing at which this facilitation onset and found evidence of an effect of iconicity on N400 amplitude. To determine which of the two hypotheses best explain this behavioral and electrophysiological facilitation for iconic signs, we compared participants response latencies and N400 amplitudes during a picture-naming task to those from an English-to-ASL translation task. If the task-specific hypothesis was true, and the effect of iconicity is driven by the visual alignment between the picture stimulus and the targeted sign, then iconicity effects should be observed only in the picture-naming task. If the faciliatory effects were instead due to a broad increase in semantic activation for iconic signs regardless of task, we expected that iconicity effects would occur in both the picture-naming and the translation task.

Consistent with the task-specific hypothesis and replicating Gimeno-Martinez and Baus (2022), we found that participants produced iconic signs more quickly and more accurately than non-iconic signs only in the picture-naming task, with no RT or accuracy differences in the translation condition. In McGarry et al. (2020; Study One), we found increased N400 amplitudes for iconic signs relative to non-iconic signs, which could be interpreted as evidence for increased semantic activation driven by the visual and sensory-motoric features encoded by iconic signs. However, we also found reduced (comparatively less negative) N400 amplitudes when the visual features of the picture overlapped strongly with the phonological features of the targeted sign. We interpreted this latter result as a priming effect when there is visual overlap between the picture and the form of sign, which is consistent with a task-specific benefit for iconicity.

In the present study, we included the most aligned pictures from McGarry et al. (2020; Study One), and so anticipated that we might find reduced N400 amplitudes for iconic signs compared to non-iconic signs in the picture-naming condition. Indeed, this is the pattern we observed. In contrast, there was no evidence of a difference in N400 amplitude between iconic and non-iconic signs in the English-ASL translation task. This pattern of results suggests that the faciliatory effect of iconicity is confined only to tasks that use stimuli that can map onto the sensory-motoric features encoded in iconic signs, such as pictures. Thus, rather than representing a task-general activation of signs with richer semantic encodings, effects of iconicity seem to arise when visual features of the stimuli used to elicit signs can be quickly matched with features of iconic sign forms in the lexicon. When there are no features of the stimuli that can map onto the sign forms, such as in printed words, this matching process cannot occur and no boost to lexical retrieval or production is conferred. Similarly, when extraneous features are portrayed in the stimuli, as in the non-aligned condition in McGarry et al. (2020; Study One), this matching process may not be completed as successfully.

In contrast to the present study, Gimeno-Martínez and Baus found increased early (140ms-210ms) negativities for iconic signs in the picture-naming task. This increase in negative amplitude is consistent with the polarity of the iconicity effects on the N400 in McGarry et al. (2020; Study One). To our knowledge, Gimeno-Martínez and Baus did not manipulate the amount of structured visual alignment between pictures and the targeted LSC signs, and so likely used pictures with variable degrees of alignment. We hypothesize that early onset of the iconicity effects in Gimeno-Martínez and Baus (2022) may have occurred because participants were familiarized with the pictures (and the Spanish words) prior to the experiment. The fact that participants had already viewed the entire set of stimuli before completing the task may have resulted in early onset for the iconicity effects, as participants had already seen the features of the pictures that mapped onto the iconic signs. Additionally, the finding of increased (early) negativities for iconic signs may suggest that the semantic-feature coding hypothesis is partially correct, and that the picture stimuli do result in more robust activation of the sensory-motoric sensory features of the iconic signs. It may be that the present study reflects that when all of the stimuli are strongly visually aligned with the targeted signs, the priming conferred by the pictures increases and overrides the more robust activation and overall reducing the amount of neural activity. In contrast, the non-aligned images in Study One and likely included in in Gimeno-Martínez and Baus (2022) may result in increased N400 amplitudes, as both the feature encoded in the iconic mapping and the feature present in the picture are strongly activated, resulting in greater overall semantic activation and larger amplitudes for these trials.

The majority of the targeted iconic signs in McGarry et al. (2020; Study One) and in Study Two were perceptually-iconic, meaning that the iconicity occurs through the mapping between phonological features of the sign and the visual features of the referent. Only a few of the iconic signs (5, or 23% of the stimuli) used a motoric or pantomimic mapping, where the form of the sign resembles the way one would handle or manipulate the referent (see Caselli & Pyers, 2020 and Ortega et al., 2017 for a discussion of perceptually-iconic and pantomimic/motorically-iconic signs). It is possible that one type of mapping between form and referent may be more faciliatory for sign production than the other, or that different regions of the brain are employed when accessing the sensory-motoric features encoded by iconic signs. Study Three explores potential behavioral and neural differences in lexical retrieval for these different types of signs.

The results of Study Two suggest that iconicity has a task-specific potential to facilitate sign production. In tasks with pictorial stimuli, such as picture-naming paradigms, the ability of iconic signs to map onto the features of the stimuli seems to prime those signs for production, resulting in behavioral facilitation. If all stimuli have strong visual alignment with the targeted iconic signs, this seems to result in an overall reduction of neural activity and N400 amplitudes, perhaps due to the overriding of an increased neural activity generated by the activation of the sensory-motoric features encoded in the signs. When this mapping cannot occur, as in translation tasks, no benefit of iconicity can occur. Taken together, these findings suggest that iconicity does not always facilitate sign production, but is able to do so when relevant to the task at hand.

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Chapter Three

Does the type of iconic mapping matter?: an ERP investigation of perceptually and motorically-iconic signs in American Sign Language

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Abstract

Iconicity is known to facilitate sign production in picture-naming paradigms. In these paradigms, different types of iconic mappings have not been systematically investigated. The present electrophysiological study compared the production of perceptually-iconic and motorically-iconic signs, which differ on whether they depict visual features of the referent or motoric experience with the referent. The results revealed that iconic signs were associated with reductions in N400 amplitude relative to non-iconic signs, but there is no difference in N400 amplitude between the two sub-types of iconic signs. Laplacian analyses were used to localize the ERP effects, and these analyses revealed different regions of neural activity during early stages of feature processing and lexical access as well as during the N400 window. These results suggest that while iconic signs regardless of mapping strategy result in priming during the N400 window perceptually-iconic signs may be processed through the ventral stream, and motorically-iconic signs through the dorsal stream.

Key words: Iconicity, ERPs, American Sign Language, N400, picture-naming,

Historically, languages were assumed to be arbitrary, with no meaningful relationship between form and meaning. This assumption stemmed from the lack of widespread iconicity in spoken languages, particularly those in the Indo-European language family. Since then, investigations have found that iconicity is in fact widely employed in spoken languages, though some language families and individual languages use iconicity much more than others (Dingemanse, 2017; Imai et al., 2015; Perniss et al., 2010; Perry et al., 2015). While the use of iconicity varies considerably amongst spoken languages, sign languages employ iconicity consistently and widely in everyday language (Novogrodsky & Meir, 2020; Oomen, 2021; Perlman et al., 2018; Trettenbrein et al., 2021). The difference in the degree of iconicity between spoken and sign languages likely stems from the fact that sign languages have visible articulators. As viewers can easily perceive the hands and fingers of the signer, sign languages can map linguistic structure onto 3D visual-spatial features of events and objects in the real world in ways that spoken languages cannot (Taub, 2001). This visual mapping allows for iconic signs to capture the way referents appear, as well as the ways that they move or are used.

In picture-naming tasks, iconic signs have been found to be produced more rapidly than non-iconic signs in a variety of signed languages (Gimeno-Martínez & Baus, 2022; McGarry et al., 2020, Study One; Navarrete et al., 2017; Vinson et al., 2015). Reduced response latencies have been attributed to iconic signs being activated more quickly and robustly than non-iconic signs due to semantic sensory and motoric features encoded in their iconic mappings (Navarrete et al., 2017). This speeded activation cascades into a faster ability to exclude non-targeted signs, and faster retrieval of the targeted signs. However, when similar investigations are conducted with experimental paradigms that do not use picture stimuli, such as word-to-sign translation tasks, there is no evidence of behavioral facilitation. Gimeno-Martínez and Baus (2022) found that when asked to translate written Spanish words into Catalan Sign Language (LSC), signers did not translate words with iconic sign translations more quickly than those with non-iconic translations, although a facilitatory effect of iconicity was found when the same items were presented in a picture-naming task. McGarry et al. (Study Two) replicated these results with American Sign Language (ASL) using an English-ASL translation task and a picture-naming task. It therefore seems that the faciliatory effect of iconicity may be limited to tasks where visual features of the stimuli (pictures) have the ability to map on to the iconic features of the targeted signs (see Figure 3.1 below).

The temporal resolution of Event-Related Potentials (ERPs) allows researchers to determine the stage of processing where effects of conditions arise. Specifically, ERPs allow us to explore whether the behavioral facilitation found for iconic signs in picture-naming or picture-sign matching tasks was due to facilitated lexical access, or due to strategic use of iconicity at a later stage of processing. We focus on the N400, a negative-going ERP component that indexes lexico-semantic processes (Luck et al., 2014, for review see Kutas & Federmeier, 2011). Increases in N400 amplitude (greater negativity) may suggest the activation of more robust networks, resulting in an increase of neural activity. For instance, concreteness is associated with behavioral facilitation, but also elicits larger frontal N400s than abstract items (see Barber et al., 2013; Holcomb et al., 1999; Kounios & Holcomb, 1994; van Elk et al., 2010). Rather than suggesting that concrete words are more difficult to process, which would be inconsistent with the behavioral facilitation, this increase in amplitude is likely a product of the stronger and denser network of semantic links caused by the activation of more sensory-motoric and visual information associated with concrete words.

In McGarry et al. (2020; Study One), participants were asked to name pictures while response latencies and ERP amplitudes were recorded. For signing participants, we found reduced response latencies and increased N400 amplitude (greater negativity) for iconic signs compared to non-iconic signs. This effect was strongest over frontal sites, providing a parallel with concreteness effects, and did not appear in non-signing controls who named pictures in English. These results suggest that iconicity provides a benefit similar to concreteness in picture-naming paradigms. Navarette et al. (2017) suggests that iconic signs are facilitated through an increase in the amount of semantic activation, which cascades into faster selection of the target signs. A second picture-naming study by McGarry et al. (Study Two) replicated the behavioral results (faster naming times for iconic than non-iconic signs), but found that iconic signs were associated *reduced* rather than increased N400 amplitudes. Regardless of direction, the N400 effects were stronger over frontal and central sites for both studies.

The difference in direction of the N400 effect between McGarry et al. (2020; Study One) and McGarry et al. (Study Two) could be explained by differences in the manipulation of picture-sign alignment by the two studies. In McGarry et al. (2020; Study One), the degree of structured visual overlap (alignment) between picture and targeted sign modulated the amplitude of the N400 component, as well as the degree of facilitation in the behavioral results. When the alignment was maximized, iconic signs were retrieved more quickly, and were associated with reduced N400 amplitudes. This combination of behavioral facilitation and reduced N400 amplitude is interpreted as evidence of priming (Kutas & Federmeier, 2011; Luck, 2014). Priming for visually-aligned trials has also been found in comprehension studies, such as picture-sign matching tasks (McGarry et al., 2021; Thompson et al., 2009; Vinson et al., 2015) (McGarry et al., 2021; Thompson et al., 2009; Vinson et al., 2015). When the pictures were intentionally aligned, maximizing the mapping between the visual features of the picture and the iconic features of the sign, neural activity and response latencies decrease. McGarry et al. (Study Two) included only visually-aligned images, capitalizing on the faciliatory effect of iconicity. Due to only including stimuli that could maximally align with the target sign, the resulting priming effect may overridden any increased neural activity that may have occurred due to the semantic features encoded in the iconic signs.

The behavioral and ERP effects for iconic signs compared to non-iconic signs do not occur when non-picture paradigms are used. When a written word-to-sign translation task is used, no behavioral or electrophysiological effects of iconicity are observed (Gimeno-Martínez & Baus 2022; McGarry et al., Study Two). The absence of facilitation in translation tasks indicates that the faciliatory effect of iconicity is not the result of a general increase in semantic activation for iconic signs compared to non-iconic signs. Instead, it seems that iconicity is facilitatory only when there is an ability for a structured mapping (alignment) between the visual features of a picture and the targeted sign, which results in the reduction of N400 amplitudes during sign retrieval.

Iconic signs do not all depict features of a referent in the same manner. Some signs depict visible features of the referent, and there is a motivated mapping between visual features of the referent and phonological features of the sign. Consider the iconic ASL signs CAT and BOOK (Figure 3.1a and 3.1b). Both cats and books have visibly salient features: the whiskers of a cat and the way the pages of a book appear when held open. There is a perceptual mapping between these visual features and form of the signs: the extended whisker shape of the fingers held to the signer's cheek, and the two hands unfolded as in the opening of a book. This type of iconicity has been described as 'perceptual iconicity', due to the mappings between the sign and signers' perceptual experience of the referent (Caselli & Pyers, 2020; Ortega, 2017; Padden et al., 2015; Padden et al., 2013; Perniss et al., 2010; Tolar et al., 2008). Perceptual iconicity contrasts with pantomimic or motoric iconicity, in which there is a mapping between the phonology of the sign and signers' motoric experience with the referent. Consider the motorically-iconic ASL sign HAMMER (Figure 3.1c). Though hammers have perceptual features (e.g., they are long and straight), the sign HAMMER depicts how a person grasps and swings a hammer.

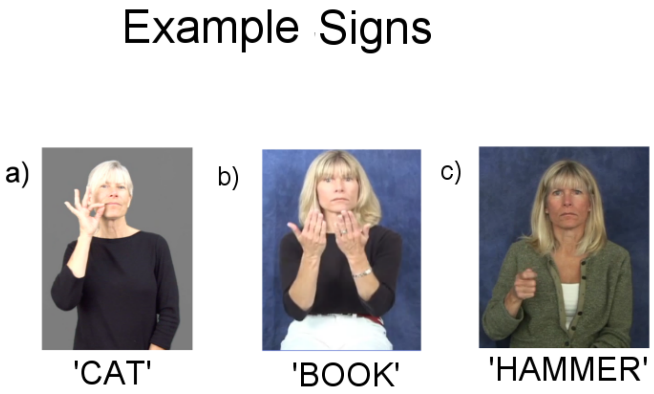

Figure 3.1. Examples of targeted signs. Perceptually-iconic signs are depicted in a) and b), while a motorically-iconic sign is depicted in c).

The majority of the iconic signs included McGarry et al. (2022; Study One) and McGarry et al. (Study Two) were perceptually iconic, with relatively few motorically-iconic signs. Due to the different manner of mapping between perceptually-iconic and motorically-iconic signs, it is possible that different processes occur in the brain during lexical activation and selection. Because the type of encoded feature of the referent differs between these two categories of iconic signs, their ability to be facilitated by structurally-aligned pictures in a picture-naming study may differ significantly. Additionally, because perceptually-iconic signs focus more on visual experience, and motorically-iconic on motor experience, different areas of the brain may be involved during lexical retrieval. The distinction in mapping strategy between perceptually-iconic and motorically-iconic signs may reflect the distinction between the dorsal and ventral streams characterized by fMRI research on visual object recognition. The ventral stream in the visual pathways of the infero-temporal cortex is involved in the processing of the visual appearance of an object, while the dorsal stream in parietal cortex is involved in processing what an object does and how it is used (Cabeza & Nyberg, 2000; Chao & Martin, 2000; Milner & Goodale, 2006).

In picture-naming studies with spoken language, frontal N400s tend to be elicited when naming pictures of animals, and more parietal N400 effects tend to be elicited when naming pictures of tools (Hinojosa et al., 2001; Sitnikova et al., 2006). Though the two types of iconic signs do not match these categories, it is likely that both motorically-iconic signs and pictures of tools encode motoric experiences. Thus, it is possible that different regions of the brain are activated for the two types of iconic signs.

In order to investigate the effect of different types of iconic mappings on sign retrieval Study Three explored differences in behavioral facilitation and N400 amplitude modulation between perceptually-iconic and motorically-iconic signs. To do so, we designed a picture-naming study with an equal number of perceptually-iconic, motorically-iconic, and non-iconic target signs. The goal was to compare all iconic signs to the non-iconic signs (as in previous studies), as well as to directly compare the retrieval of perceptually-iconic and motorically-iconic signs. To our knowledge, no previous electrophysiological investigation of perceptually-iconic and motorically-iconic signs has been conducted, making this a novel line of inquiry.

If iconic signs, regardless of the nature of the iconic mapping, result in a faster ability to activate the correct target sign, we predict behavioral facilitation for both perceptually-iconic and motorically-iconic target signs, in comparison to the non-iconic signs. For the perceptually-iconic signs, the signs encoded features of the appearance of the referent, and we included picture stimuli with some overlap with these features. Pictures targeting motorically-iconic signs did not show the item in use to avoid the production of verbs (see Figure 3.2 for examples of stimuli). Instead, the picture showed the referent on a neutral white background, as though not in use. As children are known to be sensitive to motorically-iconic mappings and acquire these signs earliest, we predict that motorically-iconic signs may be retrieved more quickly than perceptually-iconic signs, resulting in reduced response latencies (Caselli and Pyers, 2018; Ortega et al. 2017).

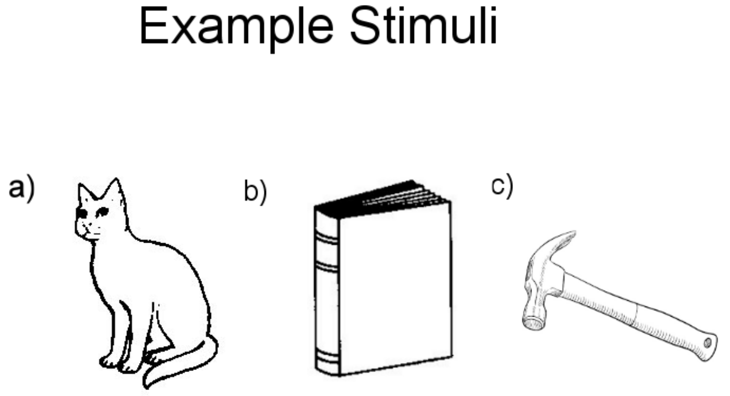

Figure 3.9. a-b) Stimuli examples targeting perceptually iconic signs CAT and BOOK. c) stimulus targeting motorically-iconic sign HAMMER

Though not all animal signs are perceptually iconic, and not all tool signs are motorically-iconic, animal and tool signs tend to pattern in this manner across a variety of sign languages (Hwang et al., 2017). Motorically-iconic animal/animate nouns are relatively uncommon, as a mapping onto the way an animal is held or handled is unlikely to be salient. In the present study, we included animal and non-animal signs in our perceptually-iconic condition, and both tool and non-tool signs in our motorically-iconic condition, in order to distinguish between semantic category and the manner of iconic mappings. This distinction allows us to investigate whether any effects are driven by the processing of perceptual vs. motoric features, independent of the distinction between tool and animal concepts. However, as there are relatively few animate motorically-iconic signs, the majority of iconic animate signs are perceptually-iconic. Hearing non-signers also named the same pictures in English to distinguish between effects of semantic class or animacy. If signing participants show differences between perceptually-iconic and motorically-iconic signs that do not appear for non-signing participants, this will demonstrate that there are differences between two types of iconic mappings.

We also investigated an early window (150-250ms after stimulus presentation) as well as the N400 window. This early window captures components sensitive to both early lexical access and early visual feature processing, which could potentially differ between predominately-animate and predominately-inanimate sets of pictures, and has been used to investigate these processes in other picture-naming paradigms (see Eddy & Holcomb, 2010; Strijkers et al., 2010). Additionally, this time window is similar to the 140-210ms time window where Gimeno-Martínez & Baus (2022) found early negativities for iconic signs. If the pictures that target perceptually-iconic signs differ in terms of how they are processed visually from those that target motorically-iconic signs, we would expect to see differences in both groups of participants during this epoch. However, we would not expect these effects to carry into the N400 window, which is sensitive to lexico-semantic processing (see Kutas and Federmeir 2011 for review).

Traditional monopolar EEG analyses have poor spatial resolution, and it is difficult to determine whether separate areas of the brain could be involved in different conditions. In order to improve on the spatial resolution, we used Laplacian transformation, which decreases spatial blurring through estimating the current source density (Riès et al., 2015). If different regions of the brain are involved in the activation and production of perceptually-iconic and motorically-iconic signs, we expect to see activity at different electrode sites after the Laplacian transformation. As our prior studies have predominantly included perceptually-iconic signs, and have found effects with frontal and central distributions, we expect to see differences between perceptually-iconic and motorically-iconic signs at fronto-central sites. We also expect to see differences between these two types of signs at parietal electrode sites, due to increased involvement in parietal regions of the brain for motorically-iconic signs.

Methods

Participants[6].

Fifteen deaf signers were included in the analyses (7 female; mean age = 37.4 years, *SD* = 8.6 years). Participants were born into deaf signing families (N = 9) or were exposed to ASL prior to the age of six (N = 6; mean age of exposure = 4.5 years). Control participants were 15 monolingual English speakers (9 female; mean age = 26.7 years, SD = 7.6 years). Control participants had no exposure to ASL beyond knowledge of the fingerspelled alphabet or a few signs. All participants had normal or corrected-to-normal vision, and had no history of any language, reading, or neurological disorders. One participant in each group was left-handed.

All participants received monetary compensation in return for participation. Informed consent was obtained from all participants in accordance with the Institutional Review Board at San Diego State University.

Materials. Stimuli consisted of digitized black on white line drawings. A total of 132 different drawings were presented to participants. One third of the pictures (44 total) were named with perceptually-iconic ASL signs, while another third (44 total) were named with motorically-

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[6] For the purposes of this dissertation, we present data from fifteen participants in each group, but we intend to run additional participants prior to publication.

iconic ASL signs. The remaining 44 pictures were named with non-iconic signs. Descriptive statistics for the targeted ASL signs are given in Table 3.1. Ratings of iconicity and subjective frequency were retrieved from the ASL-LEX database (Caselli et al., 2017; Sehyr et al., 2021), and the citation form of all targeted signs can be found there (http://asl-lex.org). Iconicity ratings were given by hearing non-signers, who judged ASL signs on a 7-point scale (1 = not iconic at all, and 7 = very iconic). Iconic signs received a rating of 3.7 or higher, while non-iconic signs were included if they received ratings of 2.9 or lower. Subjective frequency ratings were given by native signers, also using a 7-point scale (1 = very infrequent in everyday conversation, 7 = very frequent in everyday conversation). English frequency ratings were retrieved from the Corpus of Contemporary American English (COCA) (Davies 2008).

Iconic signs were classified as perceptually-iconic or motorically-iconic using similar criteria to those used by Caselli and Pyers (2018). Signs were classified as motorically-iconic ('pantomimic' in Caselli and Pyers, 2018) if the signer uses their own body to demonstrate the way the referent is held or handled, and were classified as perceptually-iconic if the signer uses their body to demonstrate visual-spatial features of the referent. We did not choose to include any signs expressing body parts (e.g., EYES), which Caselli and Pyers classified as pantomimic (Caselli & Pyers, 2018). The perceptually-iconic and motorically-iconic signs had similar iconicity ratings ($p = 0.131$) and frequency ratings in both ASL and English ($p = 0.337$, $p = 0.275$, respectively). Pictures in the two conditions had an equal percentage of anticipated responses (name agreement) in English ($p = .140$); name agreement was retrieved from past stimuli-norming surveys collected as part of past picture-naming studies (McGarry et al., 2020, Study One; McGarry et al. 2021). Participants in these norming studies were asked to view and name the pictures, and the percentage of expected responses was averaged across participants

(100% indicating all participants named the picture with the expected word, 0% indicating no participants named the picture with the expected word). The pictures in the two conditions additionally had equivalent image complexity (*p* = .952), which was assessed through Matlab's entropy function (see Table 3.2 for descriptive statistics for the picture stimuli).

The combined set of iconic signs did not differ significantly from the non-iconic signs in ASL frequency (*p* =.096), English translation frequency (*p* = 0.675), percentage of expected naming (*p* = 0.357) or image complexity (*p* = 0.360 and *p* = 0.079).

Table 3.1. Descriptive statistics for the ASL signs and English words.

	Iconicity (ASL) M(SD)	ASL Frequency M(SD)	English Frequency M(SD)
Perceptually-iconic signs	5.0 (1.5)	3.9 (1.2)	2219 (5042)
Motorically-iconic signs	5.4 (1.2)	3.7 (1.2)	3639.2 (6820.3)
Non-Iconic signs	2.0 (0.5)	4.0 (1.1)	3494 (9178.2)

Table 3.2. Descriptive statistics for the picture stimuli.

Pictures named with:	Naming agreement (% expected response) *M(SD)*	Image Complexity *M(SD)*
Perceptually-iconic signs	95.1% (6.1)	0.08 (0.06)
Motorically-iconic signs	92.6% (8.5)	0.08 (0.05)
Non-Iconic signs	94.6% (11.5)	0.09 (0.05)

The stimuli were put into two different lists containing all 132 pictures in pseudorandomized order. Each participant saw both lists, and the order of list presentation was counterbalanced across participants.

Procedure. For signers, each trial began with text advising them to press and hold down the spacebar of a keyboard placed in their lap. Upon doing so, a fixation cross appeared in the center of the screen for 800ms, followed by a 200ms blank screen, and then the picture stimulus. The picture remained on the screen for 300ms, followed by a blank screen. Participants released the spacebar and named the picture in ASL as quickly and accurately as possible. The spacebar release indicated the beginning of sign production, and response times were recorded as the time elapsed from when the stimulus appeared on screen to when the spacebar was released. After 500ms, the blank screen was replaced with text advising participants to hold down the spacebar when they were ready to proceed to the next trial. Participants could blink and move prior to pressing the space bar, as the next trial would not begin until they did so. Participants were also provided with three self-timed breaks, which allowed them to take a longer break as needed.

Hearing controls saw the fixation cross for 800ms, followed by a 200ms blank screen, and then the picture stimulus. The picture remained on screen for 300ms, followed by a blank screen for 500ms. Hearing participants were asked to name the pictures aloud as quickly and accurately as possible. After the 500ms blank screen, text appeared on the screen advising participants to press a button on the gamepad to move to the next trial when they were ready, giving them the opportunity to take breaks in-between trials. Hearing participants were also given three self-timed breaks.

If participants in either group did not know what the picture represented or could not recall the name, they were instructed to respond that they didn't know, thereby skipping the trial. Before beginning the study, participants were familiarized with the instructions by practicing on a set of 10 pictures not included in the experiment lists.

EEG recording and analysis. Participants wore an elastic cap (Electro-Cap) with 61 active electrodes (see Figure 3.3 for the electrode montage and the electrode sites selected for analyses). An electrode placed on the participant's left mastoid was used as a reference during the recording and analyses. Electrodes located on the cheek immediately below the left eye and on the outer canthus of the right eye were used for the identification of trials with blinks and horizontal eye movements. Using Electro-Gel saline gel, all electrode impedences were maintained below 2.5 kΩ. EEG signals were amplified with SynAmpsRT amplifiers (Neuroscan-Compumedics) with a bandpass of DC to 100 Hz and was sampled continuously at 500 Hz.

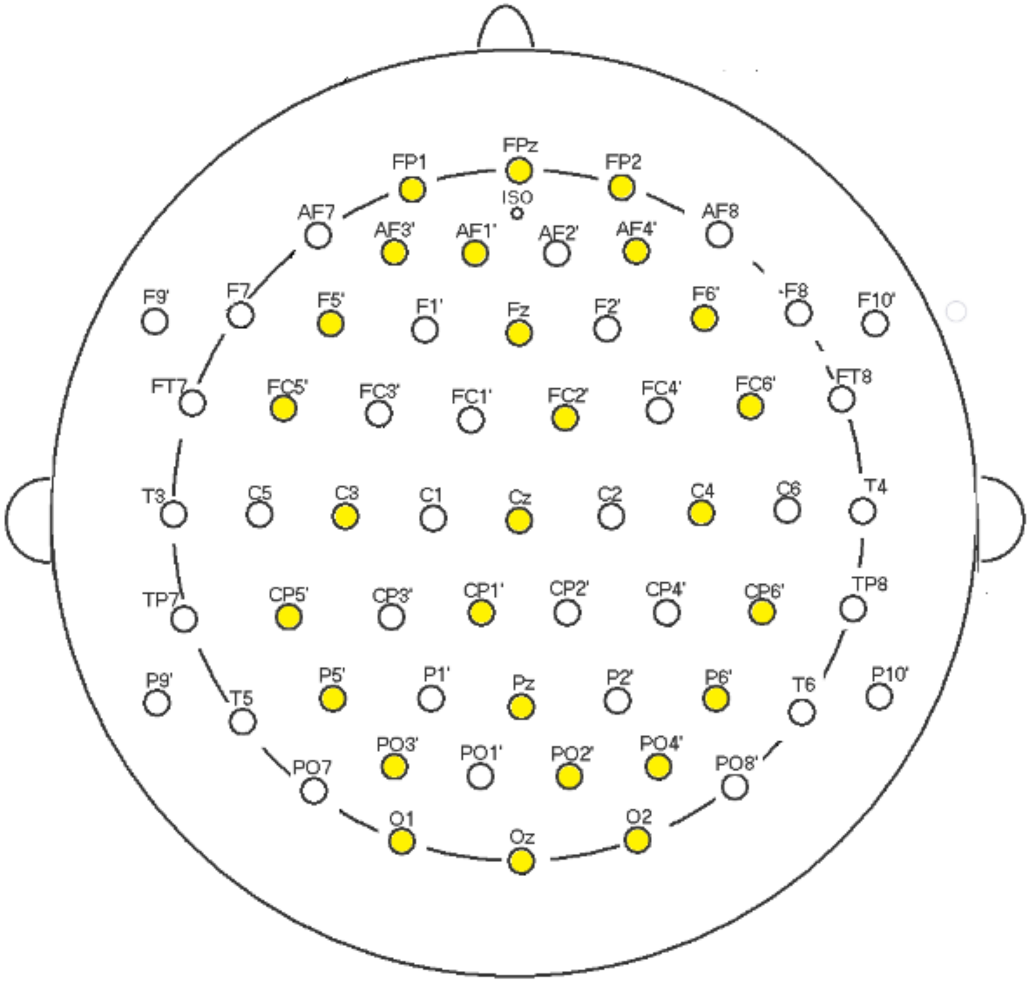

Figure 3.3. Electrode montage. Shaded sites indicate electrodes in the monopolar analyses.

Behavioral analyses

We compared response latencies and naming accuracy for the iconic and non-iconic conditions, as well as for the perceptually-iconic and motorically-iconic conditions. Trials with reaction times shorter than 300ms or longer than 2.5 standard deviations above the individual participant's mean RT and those with incorrect responses were excluded from naming latency analyses (13 trials or 5% of all data on average). We used a linear mixed effects model with items and participants as random intercepts, and iconicity, sign frequency, and image complexity as fixed effects. We used the same linear mixed effects model structure to compare accuracy between iconic and non-iconic conditions, as well as between perceptually-iconic and motorically iconic conditions.

ERP analyses

Monopolar analyses

ICA ocular correction was conducted through Matlab's EEGlab plugin (Delorme and Makeig, 2004). After correction, trials contaminated by eye and facial movements were rejected from analyses across all participants (less than 1% of all data on average). Mean amplitude was calculated for the N400 window (300-500ms after stimulus presentation) and the early visual feature processing window (150-250ms after stimulus presentation). The N400 time window was selected to capture lexico-semantic processing (see Kutas & Federmeir 2011 for review).

For each group of participants, two ANOVAs were conducted. The first ANOVA was conducted on all trials, with two levels of Iconicity (Iconic, Non-iconic), three of Laterality (Left, Midline, Right), and nine of Anteriority (FP, AF, F, FC, C, CP, P, PO, O). The second ANOVA was conducted only on the iconic trials, with two levels of Type (Perceptual, Motoric), three of Laterality, and nine of Anteriority.

Laplacian analysis

To improve on the spatial resolution of the EEG signal, we used Laplacian transformations to estimate the current source density, consistent with other studies (see Anderson et al., 2022; Riès et al., 2015). As Laplacian transformation is particularly sensitive to artifacts, we used Blind Source Separation based on Canonical Correlation Analysis (BSS-CCA) from the AAR toolbox for EEGLab (Gomez-Herrero, 2007). This procedure allowed us to reduce the impact of EMG artifacts from speech production or from facial movements while signing (see. Anderson et al., 2022; Riès et al., 2015; Vos et al., 2010,). Any remaining artifacts were hand-rejected after BSS-CCA.

After artifact rejection, we applied Laplacian transformations in BrainVision Analyzer 2.1 to each participant's individual average, and used these averages to create grand averages for each condition in each participant group (BrainVision Analyzer, Brain Products GmbH, Gilching, Germany). The Laplacian transformations increased the topographical localization of the EEG signals, allowing ERPs to be analyzed at individual electrodes. We present effects at sites F5 and P3. The F5 electrode is located on the frontal region of the left hemisphere, which is the general area we have found effects of iconicity in our previous picture-naming studies (McGarry et al., 2020, Study One; McGarry et al., Study Two). This site is also near the inferior temporal cortex, which is associated with the ventral stream of object recognition. Site P3, in contrast, is located over the parietal region of the left hemisphere, which is the location of the dorsal stream for object recognition.

Results

Behavioral results

Iconic vs. Non-iconic conditions

In contrast to previous studies, naming latencies between iconic and non-iconic signs were not significantly different (iconic = 713ms, non-iconic = 737ms, *p* = 0.25). Naming accuracy for iconic signs also did not differ significantly from non-iconic signs (iconic signs = 95% correct, non-iconic signs = 94% correct). As expected for English speakers, there was not a significant difference between the two conditions for response latency or accuracy (iconic = 594ms, non-iconic = 611ms, *p* =0.08 and iconic = 94% correct, non-iconic = 96% correct, *p* = .16).

Type of Iconicity: perceptual vs. motoric

Within the iconic condition, response latencies between the two types of iconic signs were not significantly different (perceptually-iconic = 719ms, motorically-iconic = 706ms, *p* = 0.44). There was also no significant difference in accuracy between the two types of signs (perceptually-iconic = 94.6%, motorically-iconic = 95.1%, *p* = 0.39). For hearing participants, there also were no significant differences in response latency or accuracy (perceptually-iconic = 595ms, motorically-iconic = 626ms, *p* = 0.92 and perceptually-iconic = (96%, motorically-iconic = 93%, *p* = 0.16).

Monopolar EEG results

Iconic vs. non-iconic conditions

During the early epoch (150ms-250ms), there was no omnibus effect of iconicity for the signing participants (*F*[1,15] = 0.17, *p* = 0.69). However, there was a significant interaction between iconicity, anteriority, and laterality for the this group (*F*[16,224] = 1.87, *p* = 0.024). The production of iconic signs was associated with increased negativity over occipital sites, and reduced negativity over frontal and central sites, particularly over the left hemisphere (see Figure 3.4). For the non-signing controls, there was no effect of iconicity or interactions with iconicity during the early epoch (all *p*'s greater than *p* = .10)

During the N400 epoch (300-500ms), the three-way interaction between iconicity, anteriority and laterality persisted for signing participants (*F*[16,224] = 1.88, *p* = 0.024). The production of iconic signs continued to be associated with increased negativity at the occipital sites and reduced negativity over central sites, with a bias towards the left hemisphere (see Figure 3.4). For the non-signing controls, there continued to be no effect of iconicity or interactions with iconicity during this epoch (all *p*'s greater than *p* = .11).

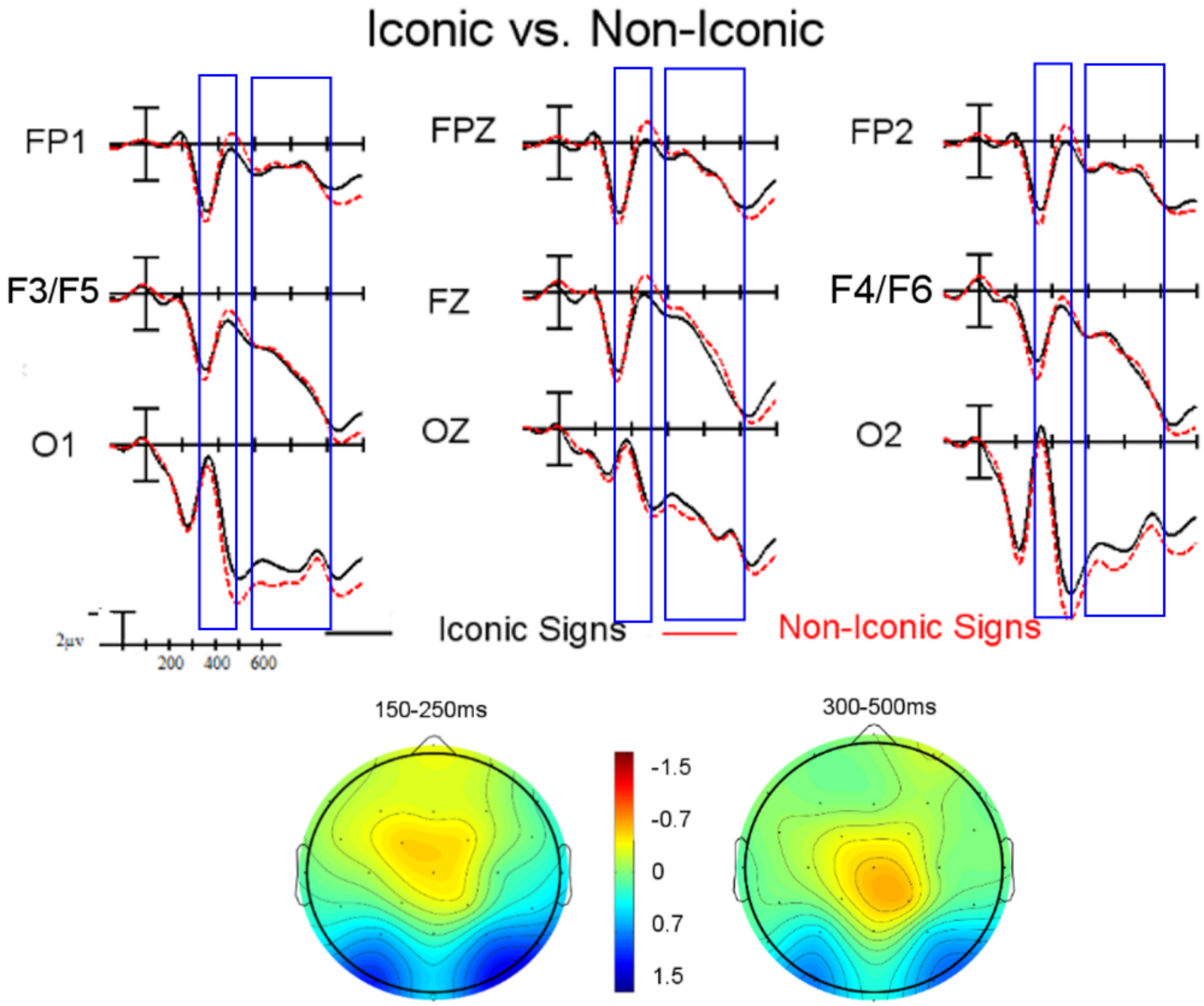

Figure 3.4. ERP results from nine selected electrode sites. The voltage map illustrates the reduced frontal and central negativities, and increased occipital negativities, for iconic signs in both windows

Type of Iconicity[7]

Early time window: 150ms-250ms

For signers during the early epoch, there was a marginal main effect of iconicity type ($F[1,15] = 3.17$, $p = 0.097$). Perceptually-iconic signs were associated with more negative

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[7] I plan to collect additional data prior to publication, some of the marginal effects may become significant with increased power.

amplitudes during this epoch (see Figure 3.5). In non-signing participants, the interaction between type of iconicity and posteriority just missed significance (*F*[8,112] = 4.3, *p* = 0.057). This trend suggests that for non-signers, naming pictures targeting perceptually-iconic signs was associated with more negative amplitudes at occipital sites, and less negative amplitudes at frontal sites (see Figure 3.6).

N400 time window

For signers during the N400 epoch, there continued to be a marginal main effect of iconicity type (*F*[1,14] = 3.24, *p* = 0.093). Perceptually-iconic signs continued to be associated with more negative amplitudes (see Figure 3.5). In non-signing participants, there was no effect of iconicity type during this window (all greater than *p* = .4).

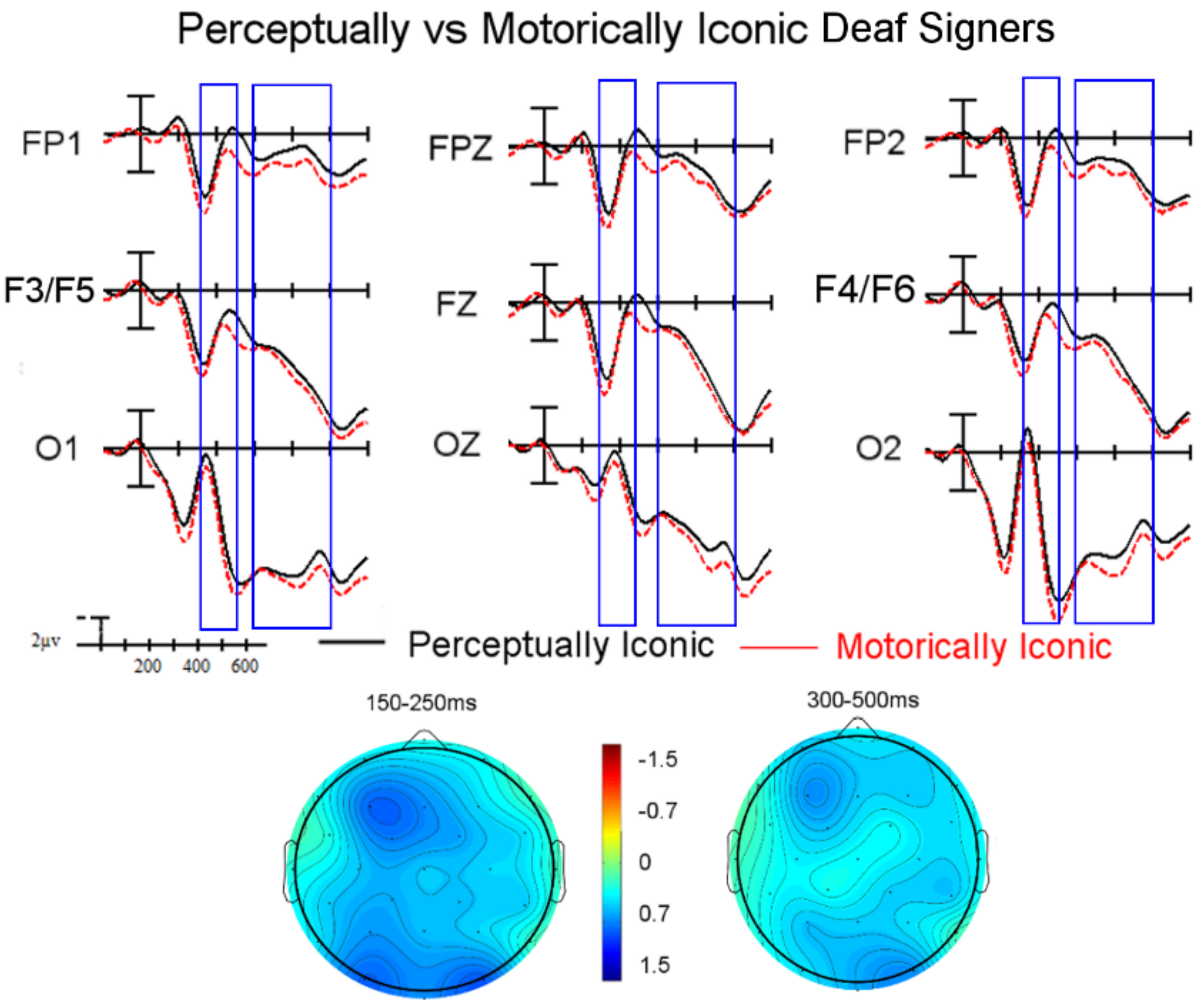

Figure 3.5. ERP results from nine selected electrode sites. The voltage map illustrates the increased negativities for perceptually-iconic compared to motorically-iconic signs in both time windows.

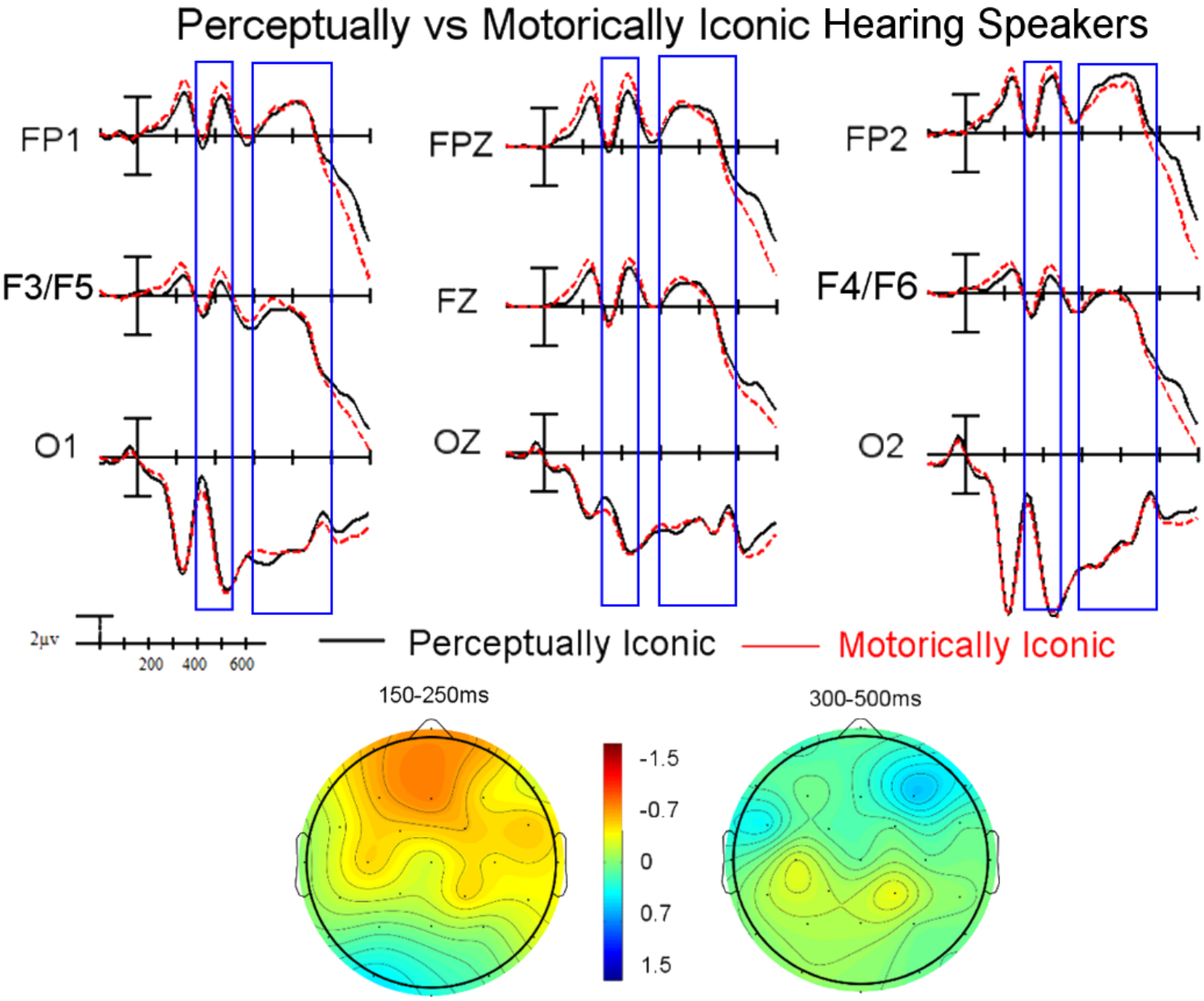

Figure 3.6. ERP results from the nine selected electrode sites. The voltage map illustrates the reduced frontal negativities for pictures targeting perceptually-iconic signs over frontal sites in the early time window.

Laplacian results

Voltage maps in the 150-250ms and 300-500ms time windows, as well as waveforms, are presented in Figures 3.7 and 3.8.

Overall iconicity: Iconic vs. Non-Iconic

At electrode site F5, effects emerged during the N400 window, where the production of iconic signs elicited reduced negativities (t[15] = -2.02, *p* = 0.05, see Figure 3.7). This effect was not present during the early 150-250ms time window (t[15] = 0.02, p = 0.98), and was constrained to the left hemisphere (no effects at the contralateral site F6).

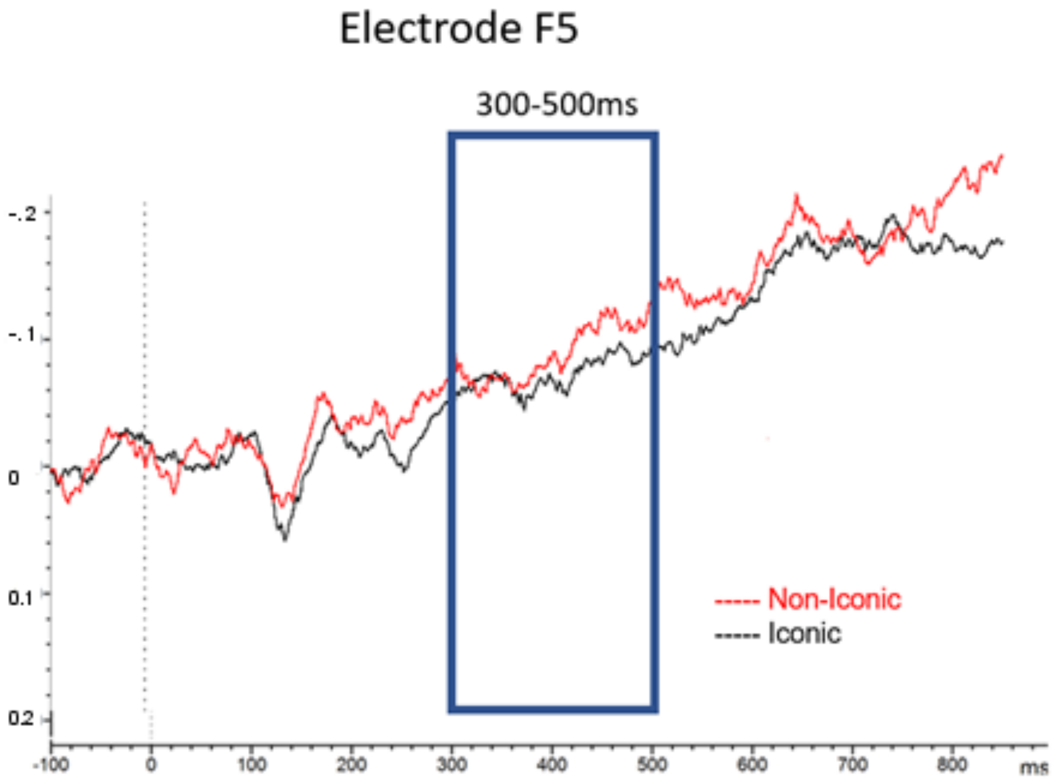

Figure 3.7. Effects of overall iconicity in deaf signers at electrode F5, showing reduced negativities for iconic signs.

Type of iconicity: perceptual vs. motoric

At electrode P3, there was a marginal difference between the two types of iconic signs in the opposite direction (t[15] = 1.84, *p* = 0.08), such that motorically-iconic signs were associated with greater negativity than perceptually-iconic signs (see Figure 3.8). The effect of iconicity type at P3 persisted during the N400 window and just missed significance (t[15] = -2.44, *p* = 0.06).

There were no effects on the contralateral sites (P4). None of these effects were present for non-signing control participants (all *p*-values greater than .3).

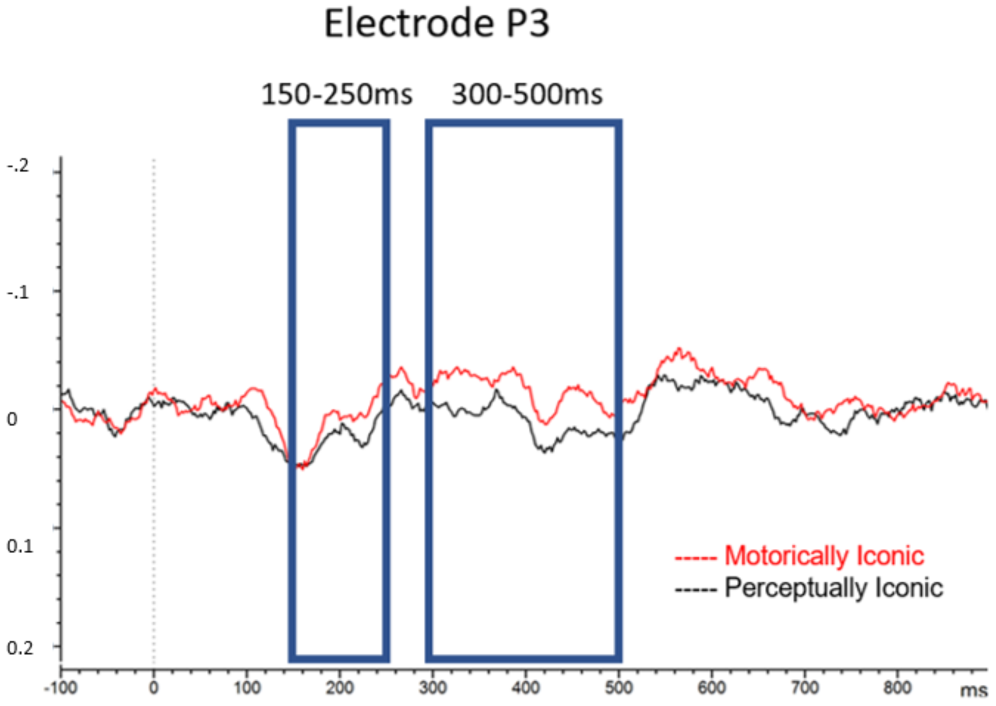

Figure 3.10. Effects of type of iconicity for deaf signers at electrode P3, showing increased negativities for motorically-iconic signs.

Discussion

During object recognition in picture-naming paradigms, participants activate both what an object is and the manner in which that object may be used. These two types of information are processed independently through the ventral and dorsal pathways in the brain. Perceptually-iconic and motorically-iconic signs are two distinct classes of iconic signs, which encode features of the referent in unique ways. Because perceptually-iconic signs map onto how an object and its features are perceived, and motorically iconic signs map onto how an object is used or handled, these classes of iconic signs encode types of information that are likely to be processed through the ventral and dorsal streams, respectively. The present study aimed to investigate whether the known faciliatory effect of iconicity differed between these two types of iconic signs, and whether different regions of the brain are recruited during lexical activation.

Somewhat unexpectedly, we did not find significantly reduced response latencies or increased accuracy for pictures named with iconic signs compared to non-iconic signs. We also did not find significant differences in RTs or accuracy between the perceptually-iconic and motorically-iconic signs. The absence of an overall effect of iconicity on response latencies is surprising, considering that several prior picture-naming studies found that iconic signs are retrieved more quickly than non-iconic signs (Gimeno-Martinez and Baus 2022; McGarry et al., 2020, Study One; McGarry et al., Study Two; Vinson et al., 2015). However, the failure to find significant effects may be due to small sample size of the current study, as there were only fifteen participants in each group. Previous studies included more than 20 deaf signers. It is therefore possible that the lack of significant behavioral findings is due to inadequate power.

For ERPs, in the early time window (150-250ms) in the monopolar analyses, we found an effect of iconicity for signers only: reduced amplitude for pictures named with iconic signs over the frontal sites. This early effect is interesting, as it suggests that a faciliatory effect of iconicity in picture-naming might be starting during very early stages of lexical access. The retrieval of iconic signs was also associated with increased negativity over the occipital sites in this same early time window. Increased negativity at occipital sites could reflect an early mapping between visual features of the picture onto sensory-motoric semantic features depicted by iconic signs. This pattern of reduced amplitudes over frontal sites and increased amplitudes over occipital sites persisted into the N400 window. This finding may suggest that iconicity continues to facilitate semantic processing during the N400 window, while at the same time increased processing of visual and sensory-motoric features occurs over the occipital sites. These effects were not found for the non-signing controls, indicating they are not a result of systematic differences between picture stimuli in the two conditions, and are instead a result of the mapping between the visual features of the picture and the phonological features of the iconic signs.

When comparing the two types of iconic signs, we found some evidence that perceptually-iconic signs may be associated with more negative amplitudes than motorically-iconic signs, though this effect was marginal. This finding could suggest that perceptually-iconic signs result in increased semantic feature processing. If so, the increased processing of semantic features may be due to the fact that the iconicity of these signs hinges on a visually-salient feature of the referent, and this feature is often apparent within the picture stimulus. When this feature is processed, it may in turn result in increased activation of the feature encoded in the iconic sign. In McGarry et al. (2020; Study One), which predominately included perceptually-iconic signs, we found that all iconic signs were associated with greater negativities. If perceptually-iconic signs do in fact result in greater negative amplitudes than other types of iconic signs, this may have driven the increased N400 amplitudes for the iconic condition in

McGarry et al. (2020; Study One), as the majority of the iconic signs in this condition would have increased activation of the perceptual semantic features.

In non-signing participants, there was a marginal effect of type of iconicity at the occipital sites, where pictures targeting perceptually-iconic signs seemed to elicit more negative amplitudes. As this effect did not continue into the N400 window, it is unlikely that it is a result of increased semantic processing, but rather may indicate a difference between the stimuli in the two conditions. For example, pictures eliciting perceptually-iconic signs tended to depict animate items, in contrast to pictures targeting motorically-iconic signs which mostly depicted inanimate objects. Such differences might be driving additional activity in the visual pathways of the brain during the early epoch, resulting in increased negativities over the occipital sites.

Our Laplacian analyses were consistent with the effects found in the monopolar data. For the iconic condition, we found reduced amplitudes for iconic signs compared to non-iconic signs at a frontal site during the N400 time window. In both our prior picture-naming studies, we found that the N400 component for sign production tended to be fronto-central in distribution, which is consistent with the marginal effect visible at electrodes F5. As in McGarry et al. (Study Two), iconic signs resulted in reduced amplitudes compared to non-iconic signs. While we did not find behavioral evidence of priming in the current study, we interpret both the monopolar and Laplacian effects to indicate facilitated retrieval of iconic signs during the N400 epoch due to a priming effect.

For the within-iconicity condition comparing perceptually-iconic and motorically-iconic signs, we found some evidence suggesting that the production of motorically-iconic signs may be associated with increased negativity over parietal sites during the early time window and the N400 epoch. If this pattern is strengthened when data from more participants is included, it would suggest increased activation of the dorsal stream for motorically-iconic signs, which may be due to increased processing of features having to do with how the referent is handled or manipulated. This potential distinction in distribution between the two different types of iconic signs would be a novel finding, mapping neatly onto the differences in the types of features encoded in the iconic mappings for these two types of signs. The early onset of these effects could suggest that the dorsal stream of object recognition is able to quickly begin processing these sensory-motoric features, which continues throughout the N400 window as the motorically-iconic sign is retrieved.

Taken together, the electrophysiological evidence supports our past findings that iconicity, regardless of the manner of the iconic mapping, results in priming through the reduction (less negativity) in ERP amplitudes, particularly over frontal and central sites. The combination of reduced amplitudes, both during the early window and the N400 window suggest that when iconic signs are able to map onto features of the referent depicted by the stimuli, they may be activated more efficiently.

To our knowledge, there are no past studies using electrophysiological measures to evaluate differences between perceptually-iconic and motorically-iconic signs. In this study, we found some evidence suggesting that different types of mappings between conceptual representation and sign form may result in different signatures of neural activity, and found that these potential differences occur during both the early window and during the N400 window. These differences in amplitude suggests that perceptually-iconic and motorically-iconic signs may be processed differently, perhaps due to the features they encode. On average, however, they still result in an overall priming effect for iconicity. However, these effects were marginal, which may be due to low statistical power, as there were only fifteen participants in each group.

Previous ERP studies that found significant iconicity effects included a larger number of participants (e.g., Gimeno-Martinez & Baus, 2022; Study One, Two).

Iconicity is known to facilitate sign production in picture-naming tasks through the ability to map onto the visual/sensory-motoric features depicted in picture stimuli. While iconic signs may be initially processed in separate regions of the brain, they ultimately result in the same priming effect in frontal regions of the brain, regardless of the nature of their iconic mappings. This finding suggests that the faciliatory nature of iconicity in picture-naming paradigms comes not just from the ability to perceive a feature in a picture that maps onto a visual feature of the targeted sign, but that the facilitation stems from a picture visually representing some element of the signer's experience with the referent, be it the visual features (such as the beak of a bird) or the motoric experience of interacting with the referent (such as the swing of a hammer).

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Conclusion

The three studies included in this thesis investigated the effect of iconicity during sign-production paradigms, and generally found that iconicity facilitates sign production both behaviorally and electrophysiologically when certain conditions are met. In **Study One**, I demonstrated that iconic signs were produced more quickly than non-iconic signs, and that when the picture-stimuli and the form of the targeted iconic sign visually overlapped, the amplitude of the N400 component was reduced over frontal and central sites, indicative of priming. These results were consistent with two potential hypotheses: either iconicity is broadly faciliatory regardless of the task at hand, or picture-naming represents a particular opportunity for priming. In **Study Two** I tested these two hypotheses by repeating the picture-naming study from Study One and comparing it with an English-to-ASL translation condition. While I continued to find behavioral and electrophysiological evidence of priming in the picture-naming condition (especially over the frontal and central sites), I found that there was no effect of iconicity on response latency, accuracy, or N400 amplitude in the English-to-ASL translation task.

The presence of a faciliatory effect of iconicity in the picture-naming tasks and not in the translation task indicates that the effect of iconicity is not broad. Instead, the benefit of iconicity is contingent on the ability of the stimulus to represent some aspect of the referent. When this feature of the stimulus is present, the picture can be aligned with the form of the targeted ASL sign, and the sign can be retrieved more quickly, more accurately, and with less neural activity. There is, however, more than one type of iconic sign, and both Study One and Study Two predominantly included signs that depicted perceptual features of referent. In contrast, there are signs that are motorically-iconic, which depict the motor experience of handling or otherwise using the referent. In **Study Three**, I investigated whether the faciliatory effect of iconicity held in picture-naming paradigms, regardless of the nature of the iconic mapping. While I did not find behavioral differences between perceptually-iconic and motorically-iconic signs, I did find that there may be some differences in ERP amplitudes during a time window associated with visual feature processing and early lexical access, as well as during the N400 window.

The finding that amplitudes tended to be higher for perceptually-iconic signs over frontal sites, and higher for motorically-iconic signs over parietal sites suggests that there may be different regions of the brain involved in the processing of these types of signs. If this difference in distribution holds with more participants, then it would suggest that perceptually-iconic signs are processed through the ventral stream, while motorically-iconic signs are processed through the dorsal stream. Both the dorsal and ventral streams may process the features encoded by iconic signs, and this information ultimately leads to an overall priming effect for iconicity. Taken all together, iconicity facilitates sign retrieval, but only when there is a mapping between the picture stimulus and the sign, and this facilitation is able to occur through both pathways of object recognition.