Acquisition of a signed phonological system by hearing adults: the role of sign structure and iconicity

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I, Gerardo Ortega-Delgado, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

The studies reported in this dissertation received approval by the UCL Research Ethics Committee: 2209/001-002. All participants gave permission for their collaboration in these studies and their signed consent forms can be provided upon request.

This research was made possible through a scholarship funded by the National Mexican Council of Science and Technology (Consejo Nacional de Ciencia y Tecnología) CONACyT, grant 304770.

Acknowledgements

Writing this dissertation was a long, demanding process that required considerable motivation. This four-year journey has only been possible thanks to a number of people who have constantly reminded me of my target and given me support throughout. I have been incredibly lucky to carry out my research at the Deafness, Cognition and Language Research Centre (DCAL), one of the most prestigious centres in sign language research in the world. I would like to thank my supervisors, Prof. Gary Morgan and Prof. Bencie Woll, for all their guidance during the process. I would also like to thank my examiners, Prof. Anne Baker and Dr. Bronwen Evans, whose insightful comments helped improve the structure and content of the final version of this dissertation. A big thank you goes to Adam Schembri for his invaluable support and guidance in my understanding of sign linguistics. Not only do I respect him as a researcher, but I also value him as a dear friend. I would also like to thank David Vinson and Robin Thompson who shared their expertise in experimental psychology during the design of the priming studies. Andrea Davenport and Antonietta Esposito deserve a massive thank you their support in these four years. And thank you to everyone at DCAL for providing me with a stimulating environment to carry out my research.

I have to give special thanks to all the participants involved in the five studies of this dissertation and without whom this project would not have been possible. I would like to thank Amanda Smith, Ann Gregory, and the BSL students at York St. John's University for allowing me not only to collect data but also to share my findings with them. Signamic in London were incredibly helpful in the data collection of one of the priming studies: thanks for your support. I am also indebted to Alex Lau Zhu and Taffany Leung for their assistance in the coding of the sign repetition tasks. Hopefully they learnt as much from the project as I did from them. A million thanks go to my dear friends Simon Condon, Kelly Fagan, Jack Hardy, Deirdre Lyons and Jonathan Moore for helping me revise earlier versions of the final manuscript. I am also incredibly thankful to Rose Stamp with whom I shared the tears and joys of writing a dissertation. Her presence in the office and the pub made the process incredibly enjoyable. I want to thank my dear friends Rebecca Chamberlain, Jens Koed Mansen, Laura Speed, Chris Street, Sylvia Vitello and the entire PPG crowd for their invaluable friendship. I also want to thank the deaf community for being so welcoming and patient with me. Special thanks to my dear friends Robert Currington, Martin McLean, and in particular, Danny McManus for helping me to learn their language.

I must also thank the people who have been great support and inspiration during my Ph.D. Special acknowledgements go to Dr. Chris Hall and Dr. Amanda Holzrichter for making me discover the world of psycholinguistics and sign languages. Many thanks go to my dear friend Lorelei Howard. I was very lucky to meet the most amazing friend on my very first day at UCL. Marco Arabit, Gabriel Arredondo, Rodrigo Flores, Cedric Gianni and Cary Schneider: thanks for being my family in London. Very special 'gracias' go to Deirdre Lyons and Beccy Matthews who constantly remind me that friendship does not finish when one moves abroad. Jonathan Moore and Graham King: I will always be indebted for your support and friendship during my time in London.

Mamá y Papá: nunca voy a tener palabras suficientes para agradecerles todo lo que me han dado. Pero hoy quiero resaltar dos cosas que me han ayudado toda la vida: una gran educación y tenacidad para lograr mis objetivos. Esta tesis es para ustedes.

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Notation conventions

Throughout the dissertation, the English gloss of the BSL signs will be provided in capital letters (e.g., AEROPLANE). If more than one word is required to describe a single sign, the English gloss will consist of multiple words connected by hyphens (e.g., TO-DIVE). Appendix H provides illustrations of the most common handshapes in BSL along with their labels (e.g., B handshape).

Abstract

The phonological system of a sign language comprises meaningless sub-lexical units that define the structure of a sign. A number of studies have examined how learners of a sign language as a first language (L1) acquire these components. However, little is understood about the mechanism by which hearing adults develop visual phonological categories when learning a sign language as a second language (L2). Developmental studies have shown that sign complexity and iconicity, the clear mapping between the form of a sign and its referent, shape in different ways the order of emergence of a visual phonology. The aim of the present dissertation was to investigate how these two factors affect the development of a visual phonology in hearing adults learning a sign language as L2. The empirical data gathered in this dissertation confirms that sign structure and iconicity are important factors that determine L2 phonological development. Non-signers perform better at discriminating the contrastive features of phonologically simple signs than signs with multiple elements. Handshape was the parameter most difficult to learn, followed by movement, then orientation and finally location which is the same order of acquisition reported in L1 sign acquisition. In addition, the ability to access the iconic properties of signs had a detrimental effect in phonological development because iconic signs were consistently articulated less accurately than arbitrary signs. Participants tended to retain the iconic elements of signs but disregarded their exact phonetic structure. Further, non-signers appeared to process iconic signs as iconic gestures at least at the early stages of sign language acquisition. The empirical data presented in this dissertation suggest that non-signers exploit their gestural system as scaffolding of the new manual linguistic system and that sign L2 phonological development is strongly influenced by the structural complexity of a sign and its degree of iconicity.

1 Introduction: Acquiring the phonology of a signed language

After more than four decades of research there is little room to question the legitimacy of sign languages as languages in their own right. Despite their different channel of expression, it is now well known that speech and sign share most characteristics in terms of acquisition, cognitive architecture, and processing. It is now undeniable that apart from some inherent features associated with their linguistic modality, speech and sign are organised and processed in a very similar way. Sign languages have a sub-lexical structure (Battison, 1978; Stokoe, 1960), they are accessed by decomposition of their phonological parameters (Baus, Gutiérrez-Sigut, Quer, & Carreiras, 2008; Dye & Shih, 2006), and they are processed by almost overlapping brain regions (MacSweeney, Waters, Brammer, Woll, & Goswami, 2008; Petitto et al., 2000). Despite research having uncovered many of the linguistic aspects of sign languages, e.g., phonology, morphology, syntax, and pragmatics (Sandler & Lillo-Martin, 2006), the subject of sign language acquisition as a second language (L2) has been largely neglected. In the spoken modality, L2 research is a well consolidated field of study and includes in its research agenda topics as varied and specialised as bilingual learning (e.g., Genesee, 2001), L2 processing (e.g., VanPatten & Cadierno, 1993), L2 phonological acquisition (e.g., Iverson & Evans, 2009), and pedagogy (e.g., Krashen & Seliger, 1975). In contrast, our understanding on how users of a spoken language develop a second language in a second modality (visual) is minimal.

In-depth research in the area of sign L2 acquisition is needed given its important implications for the deaf community. Only 5-10% of deaf children learn a sign language from their deaf parents, which means that a small proportion of the deaf community develop the skill to communicate as native signers (Mitchell & Karchmer, 2004). The rest of the deaf population learns from their hearing parents who themselves have to acquire a sign language at the same time as their offspring. At best, the linguistic models for the majority of deaf children are hearing adults with an intermediate proficiency of a sign language, and, at worst, children's exposure to a first language is delayed until they attend a school with provisions in sign language.

Delayed and inconsistent exposure to a sign language cause deaf children to lag in the development of cognitive and linguistic skills with respect to native signers. Late signers are slower at developing some non-linguistic abilities like theory of mind (Mayberry, 1993; Mayberry, Chen, Witcher, & Klein, 2011; Mayberry, 2007) and they are less efficient at acquiring and processing a first sign language as well as successive spoken/written languages (Mayberry & Lock, 2003). Given that a setting to teach a sign language as a native signer is rare or difficult to reproduce, it is of upmost importance to understand the underlying mechanisms behind the acquisition of a sign language as L2 in order to produce good linguistic models for deaf children. Because sign languages are fully-fledged languages as their spoken counterparts, many of the findings in unimodal L2 acquisition should hold true for L2 acquisition across modalities (oral-aural vs manual-visual). That said, the nature of a visual language could also give rise to some modality-specific differences.

One specific aspect of sign L2 acquisition that has not been studied is the development of a visual phonological system by hearing adults. Signs, in the same way as words, can be decomposed into sub-lexical units (phonological parameters) which are the building blocks of a signed lexicon. A question that remains unanswered is how users of a spoken language learn these sub-lexical components in the visual modality. A factor that may influence this process is sign structure. During the acquisition of a sign language as a first language (L1), simple components are mastered before more complex ones suggesting that phonological structure is an important factor conditioning phonological development (Boyes-Braem, 1990). It remains to be investigated whether this holds in the context of L2 acquisition. Another determinant that may influence L2 phonological development is the presence of iconicity. The incorporation of physical and other features of a referent in the linguistic form is a less frequent phenomenon in speech but is prevalent in all studied signed languages (Klima & Bellugi, 1979; Taub, 2001). Given the saliency of this cross-modal difference, it would be expected that iconicity play a role during phonological development. Despite iconicity not being a recurrent feature of spoken languages, it is a relevant characteristic of many of the gestures produced in on-going speech. Because signs and gestures use the hands as vehicle of communication and both can incorporate features of a referent in their structure it is possible to speculate that experience producing and perceiving co-speech gestures may also influence sign L2 phonological acquisition.

1.1 Phonological structure of signs

Stokoe's work on sign languages was the first to suggest that American Sign Language (ASL) was not a random collection of gestures used by the deaf community but rather that signs consisted of meaningless parameters that together created meaningful signs. He proposed that there were three minimal parameters required to determine the structure of a sign: handshape, location, and movement (Stokoe, 1960). Orientation of the hand (Battison, 1978) and non-manual features (Brennan, 1992) were later added as relevant parameters that determine the structure of a sign.

Handshape is defined as the configuration of the hand during signing. This parameter exploits the hands' ability to flex and extend fingers together or individually in order to adopt a wide range of configurations. *Location* is the area in the signing space that the hand reaches during sign articulation. Hands can either move towards a body part or they reach the space immediately in front of the signer. This area is normally referred to as neutral or signing space and is the area right in front of the signer above the waist, below the head and between the shoulders (Brennan, 1992). *Movement* is any form of motion produced by the arms or the hands. These can, for instance, move across the space to reach a location on the body or in neutral space (path), they can have a more contained form by producing repetitive movements within the hands (internal) or they can include both types of movements. *Orientation* refers to the direction of the palm and fingers with respect to a plane (Battison, 1978). Despite debate over whether this parameter is independent from the rest or whether it is a by-product of hand configuration (Sandler & Lillo-Martin, 2006) it is widely recognised that orientation is a relevant parameter that defines a sign in full (e.g., Brentari, 1999; Sandler & Lillo-Martin, 2006; van der Kooij, 2002). Finally, the non-manual features of a sign include movements of the eyes, head and body, facial expressions, mouthing and mouth gestures (Brennan, 1992; Crasborn, Kooij, Waters, Woll, & Mesch, 2008; Lewin & Schembri, 2011). These occur in parallel to the manual component and are contrastive features in many signs (Sandler & Lillo-Martin, 2006).

Each of these phonological parameters includes a number of phonemes permissible in each sign language. For instance, the side and the area under the eye are permissible locations in Australian Sign Language (Auslan) but the eyebrows are not (Johnston & Schembri, 2007). In a similar way, Chinese Sign Language (CSL) includes a range of hand configurations not present in ASL (Klima & Bellugi, 1979). This shows that sign languages have a defined set of phonemes within each phonological parameter that may be shared across or be exclusive to a sign language. These phonemes have to be acquired during L1 and L2 phonological development.

In the spoken modality, L2 learners have to accurately perceive a new sound to create a transient phonological representation in working memory to then be capable of articulating it accurately (Snowling, Chiat, & Hulme, 1991). Rehearsals of these representations in the phonological loop are key for the creation of a robust representation in long-term memory (Baddeley, Papagno, & Vallar, 1988). Therefore, crucial for L2 phonological development is the capacity to segment and discriminate the sounds in the acoustic input. In the signed modality, success to discriminate accurately each sign component will greatly depend on each parameter and on the phonological complexity of the sign as a whole.

The term *markedess* has been adopted from speech phonology to describe phonological complexity of signs. According to markedness theory, there is a reduced number of underlying phonological representations from which all possible sounds stem (Kean, 1975). In sign linguistics the term has been used in a similar way despite the fact that the theory has been applied mainly to one parameter: handshape. It has been argued that there is a set of minimal handshapes (unmarked) from which more complex ones (marked) stem (Battison, 1978; Boyes-Braem, 1990). An important feature of unmarked handshapes is that they are the most salient because they have maximally distinct shapes, for example, a closed fist, a pointing index, or an open hand with abducted fingers (Brennan, 1992). Unmarked handshapes are the first to emerge in deaf children acquiring a sign language as L1 (Marentette & Mayberry, 2000), they are the most frequent (Johnston & Schembri, 2007) and they are present in all documented sign languages (Sutton-Spence & Woll, 1999). There is no general consensus as to which or how many unmarked handshapes there are because there are claims of unmarked handshapes being as few as four (Sutton-Spence & Woll, 1999) or as many as seven (Battison, 1978). Despite this inconsistency, sign linguists agree that there are a set of handshapes whose form is structurally simple, making them the first to be mastered during sign L1 language acquisition. The other three manual parameters have not been subject to a rigorous analysis to establish a set of minimal components from which more complex ones stem from.

The internal organisation of a sign has also been used as a measure of phonological complexity. Battison (1978) was the first to notice that sign structure was governed by a set of rules based on the role each hand takes during sign production. According to his description, the dominant hand (the right hand for right-handed people and the left for left-handed) is the most active and can have independent or dependent movement from the other hand. The non-dominant hand, in contrast, cannot execute independent movement and is restricted by the movement of the dominant hand. According to Battison, signs could be articulated with one or two hands and with symmetrical or asymmetrical movements and handshapes. The handshapes in a sign will be marked or unmarked depending on how the hands interact with each other. The rules that govern the permissible combinations of these elements are known as Dominance and Symmetry constraints (Battison, 1978) and will be described in detail in Section 3.1. As for now, it is important to note that according to this classification signs produced with one hand have fewer components and therefore may be easier to articulate than two-handed signs.

1.1.1 Iconicity

The traditional view of word-meaning links in language is that it is mainly a symbolic system relating arbitrary words to real life objects. The arbitrariness of language has been widely accepted from the onset of systematic linguistic research (De Saussure, 1916) and has dominated linguistic theories since then. This view has been further supported by recent experimental studies which propose that arbitrariness is fundamental for language learning and thus a key component of any linguistic system (e.g. Monaghan, Christiansen, & Fitneva, 2011). More recently, however, the dominance of arbitrariness has been challenged and the view that iconicity plays an equally important role in signed and spoken languages has gained popularity (Perniss, Thompson, & Vigliocco, 2010; Wilcox, 2004). Depending on the modality of the language and the nature of the referent, iconicity can take a wide range of forms.

Iconicity is present in a linguistic structure if its form is motivated by the perceptual properties of its referent. In the spoken modality, iconicity, also called sound symbolism, is a feature present in many spoken languages. Onomatopoeia is a common example in that the phonological form of a word is driven by the sound that its referent produces (Assaneo, Nichols, & Trevisan, 2011). Words like *'moo'* for cow and *'meow'* for cat are adaptations of the sounds these animals make. Sound symbolism is also observed at the sub-lexical level of words. Phonaestemes are word particles in which a phonemic cluster is associated with a semantic category, for instance, the nasal cluster *sn*- which is often associated with concepts related to the nose, (e.g., *sneeze, snot, sniff, snout*, and *snort*). The relationship between sounds and their referents appears not to be coincidence because these sound-referent associations occur above chance levels across different languages. Statistical analysis of the British English lexicon indicates that one third of all words including the *sn*- cluster denote the concept of nasality (Philps, 2011). The presence of phonaestemes is not exclusive of English. Recent evidence suggests that the prevalence of certain sounds being semantically associated with their phonetic articulators has been attested for a large number of languages. A cross-linguistic study investigating the prevalence of phonaestemes across 111 languages confirms that there is a tendency to associate certain sounds with meanings related to the articulators that produce them (Urban, 2011). Overall, languages contain a significantly higher number of nasal sounds for concepts related to nasality, and bilabial stops for terms related to lips.

Iconicity in the visual modality is more pervasive than sound symbolism because most concrete objects have an observable form but do not always produce a distinctive sound (Johnston & Schembri, 2007). Iconic signs are those whose form is motivated by the form of their referent. In contrast, arbitrary signs do not visually resemble the object or action they refer to (see Figure 1.1). Iconic signs employ a large number of mechanisms to depict a referent, like pointing at a present object (presentable objects), they can recreate the form of an object (substitutive depiction), pantomime an action (presentable actions), or describe a part of an object (virtual depiction) (Mandel, 1977). Signs can also represent more abstract concepts by making reference to an object associated with them (e.g., the sign HOLLAND depicts the traditional Dutch bonnet). In addition to the multiple ways in which iconicity is represented as a holistic sign unit, a number of sign linguists suggest that meaning can also be conveyed in the individual components handshape, location, movement and orientation. Cuxac (1999) proposed that signs in French Sign Language have a molecular nature because they consist of atomic constituents (i.e., phonological parameters) in which both the molecule and the atoms can encode some level of meaning (iconicity). Johnston and Schembri (2007) further support this claim by arguing that the handshape, location, movement and orientation of a sign provide information about the shape, motion, distribution and location of a referent. This assertion has been empirically attested for Italian Sign Language given that more than half of the handshapes and locations have an iconic motivation (Pietrandrea, 2002).

Figure 1.1 Examples of arbitrary and iconic signs. The BSL sign SISTER does not exhibit any similarity with its referent while the sign AEROPLANE depicts the wings and fuselage of a plane.

Iconic signs from many unrelated sign languages often have overlapping forms. For example, the sign TO-EAT mimics the action of bringing food to the mouth and is very similar in many sign languages (Emmorey, 2001). These overlapping similarities may be the reason behind the common misconception that there is one universal sign language. However, it is now well understood that despite these similarities, iconic signs conform to the phonological rules of their sign language and their structure is consistent across users. For example, despite the fact that the sign to represent a bicycle could exploit one of its many visual features (e.g., the handlebar, the tyres, or the pedals) the conventionalised sign in British Sign Language (BSL) BICYCLE depicts only the motion of the pedals. British signers consistently use this form and importantly, the sign is articulated with the permissible phonological constituents of BSL. In addition, even when different sign languages exploit the visual properties of a referent to describe a sign, they may differ in the features they choose to depict. Klima and Bellugi (1979) provide an example in which two sign languages exploit iconicity to describe the sign TREE: while ASL describes the form of the tree as a whole, CSL depicts the trunk (see Figure 1.2).

Figure 1.2 Examples of two different sign languages incorporating the visual properties of a tree in an iconic sign. Figures adapted from Klima and Bellugi (1979).

This shows that sign languages exploit a number of mechanisms to depict the physical properties of a concept and while some signs have a direct link between the sign and the referent (e.g., the sign TO-BRUSH is pantomime of brushing) some others require a certain level of abstraction to understand what the sign stands for (e.g., the sign depicting the traditional bonnet for HOLLAND). While *transparent signs* are the most evident and can be easily understood in isolation and without a context by signers and non-signers alike, *opaque signs* have a completely arbitrary form with no evident connection with their referent (Klima & Bellugi, 1979). This shows that iconicity is a graded property of signs and non-signers will have access to their meaning depending on how clearly signs depict their referent. Chapter 2 will explain that specific cultural knowledge is another factor that contributes towards comprehension of sign iconicity and will provide empirical data showing how different linguistic experiences contribute in different degrees towards the comprehension of sign iconicity.

1.1.2 Gesture

There are noticeable similarities in structure and meaning between some iconic signs and co-speech gestures. In spite of these apparent similarities, however, gestures have specific communicative functions, they have a less systematic structure than signs, and show a stronger dependency on speech (McNeill, 1992). Kendon (2004) defined gestures as hand movements associated with on-going speech. He suggested that depending on the context in which they occurred, hand articulations could be classified into gesticulation, mime, pointing, emblems, and sign languages. McNeill (1992) proposed that these different types of gestures have different degrees of expressive power and for this reason they vary in their level of dependency on speech. He proposed that gestures lie along a graded spectrum (also called Kendon's continuum) in which gesticulations are at one end, followed by mime, pointing, emblems and sign languages (McNeill, 1992).

Signs and gestures might be regarded as equivalent structures by non-signers for two reasons. First, both systems use manual communication; and second, some signs and gestures share similarities in structure and meaning. Indeed, sign languages make extensive use of mime, pointing and emblems. Therefore, in the same way that learners with a second spoken language are capable of recognising cognate words prior to experience in the target L2, non-signers are capable of recognising some signs despite their inexperience of a sign language. However, it has yet to be investigated how the similarities between signs and gestures affect L2 phonological acquisition.

1.2 Sign acquisition as an L1

The vast majority of studies on the acquisition of sign phonology have centred on how deaf children acquire a sign language from their signing parents. These studies have provided consistent cross-linguistic evidence that L1 phonological acquisition follows a common pattern of emergence. Sign structure and iconicity have been the main focus of attention with research suggesting that each play different roles during L1 acquisition.

Conlin, Mirus, Mauk, and Meier (2000) carried out a study that investigated how early sign articulation was influenced by manual dexterity. In the study, three deaf children brought up in households where ASL was the main language of communication were observed during naturalistic conversation with their parents. The errors produced by the three children showed a clear pattern of acquisition. Handshape presented the highest number of articulation errors and the greatest degree of variability. Movement was the second most accurately produced followed by location. Based on their results, the authors concluded that accurate sign articulation is hindered by children's limited physical capabilities and that articulation errors can be explained by their developing motor system. A case study describing the early signs of a child over a period of 12 months reported similar results (Marentette & Mayberry, 2000). Location showed the highest degree of accuracy, handshape the lowest and movement fell between these two parameters.

A significant contribution to our understanding on L1 phonological development is a case study of a deaf child learning BSL (Morgan, Barrett-Jones, & Stoneham, 2007). The relevance of this study is that the language of study was typologically different from ASL and that it presented an in-depth analysis on the acquisition of individual phonemes for each phonological parameter. The authors recorded a child's sign production in natural conversation with her signing parents and found the same pattern of errors in ASL: handshape was the parameter least accurately produced, closely followed by movement and location which was the most accurate. In addition to the overall accuracy rates for each of the major phonological parameters, this study also reports accuracy rates of individual phonemes. Two important findings stemming from this study are that, first, the errors produced by a child learning BSL follow the same pattern as those reported for children learning ASL; and second it gives quantitative information regarding the error distribution of specific phonemes. This suggests that within each phonological parameter some phonemes are mastered before others. For example, the study reports that four out of 13 handshapes attempted by the child were articulated significantly more accurate than the rest. Interestingly, these four handshapes are the closed fist (S), extended abducted fingers (5), pointing index (1), and extended adducted fingers (B) which have been argued to be the most unmarked (Sutton-Spence & Woll, 1999). The different types of movements also displayed gradual emergence. Controlled holds were the first to emerge before any other path movement and these were followed by forward-back, up-down, and finally circular movements (Morgan et al., 2007). This study suggests that maturity of the motor system and phonological complexity drive sign acquisition and explain the rate and type of errors found during L1 production. The question that arises is whether these factors have the same effect in adults learning a sign language as L2.

The role of iconicity during sign L1 acquisition has also been investigated. A number of studies provide evidence that deaf children do not favour iconic signs during sign language acquisition. Orlansky and Bonvillian (1984) examined longitudinal sign production of children from deaf parents during the initial stages of their linguistic development. The signs produced were classified into iconic (the sign clearly resembled its referent), metonymic (the sign represented a concept associated with its referent, e.g., a Dutch bonnet representing Holland), and arbitrary (there was no similarity between sign and referent). After comparing the proportion of signs produced across participants it was found that there were an equal number of signs in the three categories implying that all types of signs are learnt at the same rate. The researchers interpreted these results as evidence that the iconic elements in signs do not aid acquisition and that children are equally sensitive to iconic and arbitrary labels.

Newport and Meier (1985) proposed that children exposed to a sign language from birth lack the world knowledge to map signs onto their referents. For example, the BSL sign MILK, which re-enacts the action of milking a cow, can only be related to its meaning if the child knows what the action of milking looks like. The authors argue that mapping this relationship is cognitively taxing and thus favour the view that sign acquisition is governed by the phonological complexity of signs and not by the conceptual associations that children make with the real world.

Another study extends this argument by suggesting that acquisition of iconic signs does not exhibit at any point similarities with the early use of gestures. Meier, Mauk, Cheek, and Moreland (2008) analysed the signs produced by four deaf children to determine the degree of iconicity with which they were articulated. The iconic signs children produced were rated to determine whether iconicity was enhanced, reduced or whether iconicity remained neutral. Signs were predominantly produced neutrally with very weak hints of having a more iconic or gestural elements in them.

Recently these findings have been revisited and the role of iconicity during L1 acquisition has been challenged. Thompson, Vinson, Woll and Vigliocco (2013) analysed parental reports of the BSL version of the MacArthur Bates Communicative Development Inventory (CDI). The CDI is a word checklist in which parents assess whether their children are capable of producing and comprehending a set of common words. The analysis revealed that the 31 deaf children (age range 8 - 30 months) had a slight tendency to produce and perceive iconic signs before arbitrary signs. This trend persisted after factoring out phonological complexity. Not without debate, this study suggests that iconicity may be available to children from very early ages and that it may play a more important role during L1 acquisition than previously established.

This study aside, most empirical data provide considerable evidence that iconicity is irrelevant during L1 acquisition because children lack the world knowledge to make associations between iconic signs and their referent.

1.3 Sign acquisition as an L2

There have been few attempts to describe sign L2 phonological development in hearing adults. A study investigating L2 phonological acquisition in learners of ASL argues that the mature bodies of adults eliminate poor motor control as a source of articulation errors and that rather these stem from other sources (Rosen, 2004). The Cognitive Phonology Model (CPM) proposes that at the early stages of sign learning phonetic errors are explained by perceptual and dexterity constraints. According to the CPM, learners produce articulation errors because: a) they have problems perceiving the sign components, and/or b) they have not yet developed adequate signing skills. Despite lacking empirical data and not giving sufficient importance to the phonological complexity of signs, this model supports the idea that errors produced by L2 sign language learners may be partially motivated by perceptual factors.

Bochner, Christie, Hauser, and Searls (2011) investigated non-signers' ability to discriminate the phonological parameters of signs and in turn which parameters are more difficult to perceive. After testing beginner, intermediate hearing learners, and deaf native signers in a sign discrimination task, it was found that native signers were the most accurate, followed by intermediate signers and finally beginners, suggesting that experience and age of exposure significantly enhances phonological processing. The study also reports that the parameter most difficult to discriminate was movement, followed by orientation, then handshape, and finally location. This study provides evidence that some parameters are more easily perceived than others. This being the case, ease of discrimination between different parameters may impact the timing and sequence of acquisition of a visual phonological system in L2 learners.

Iconicity seems to play a more significant role during sign L2 acquisition. Hearing adults have more world experience than children and are capable of linking symbolic forms with a referent. The ability to make sign-referent associations has been shown to have a positive effect in the acquisition of iconic signs by hearing non-signers. Lieberth and Gamble (1991) compared the ability of non-signers to recall arbitrary and iconic signs after a short and long period of time. Over a short period non-signers were able to recall both arbitrary and iconic signs with comparable ease. However, over an extended period there was a significant drop in recall of arbitrary signs while the number of iconic items remained constant.

Campbell et al. (1992) replicated these findings by applying a forced choice recognition task to non-signers and hearing learners of BSL. Participants were shown a series of signs and asked to recall them as accurately as possible. During the testing phase a new list including previously seen and new signs was presented and participants were asked to identify old from novel signs. Adult learners with prior experience of BSL performed better than non-signers because learners had become sensitive to a visual phonology. Another finding was that iconic signs were easier to recognise than arbitrary signs by both participant groups. This demonstrates that even in the group with no prior exposure to a sign language, high iconicity correlates with better recall.

A more recent study found that iconicity has a facilitation effect in translation tasks in non-signers, but has a negative effect in proficient signers. Baus et al. (2012) tested how iconicity impacted on the translation skills in two groups with different levels of proficiency in ASL. In one experiment, non-signers were taught 28 ASL signs (14 iconic and 14 arbitrary) and were later tested with a group of fluent signers. In the task, an English word and an ASL sign were presented simultaneously and participants had to judge as quickly and accurately as possible whether sign-word pairs were matching translations of each other. Non-signers exhibited significantly faster reaction times and fewer errors for iconic signs while fluent signers were slower in making their judgments for iconic signs and made an equal number of errors for both types of signs. In a second experiment, participants had to produce forward and backwards translations (English-ASL and ASL-English) of the same items while their response times and accuracies were recorded. Again, non-signers exhibited significantly faster response times and fewer errors for iconic signs while fluent signers were slower for iconic signs and showed an equal number of errors for both sign types. These data adds to previous evidence suggesting that non-signers show a predisposition to recall iconic signs more easily because of the links they form with existing internal representations.

Together these studies show that adults have the ability to identify the link between symbol and referent and this helps them recall iconic signs at the early stages of sign language learning, even when they have never been exposed to a sign language. It remains to be explored how this influences L2 phonological development.

A note of caution is relevant here. One shortcoming on L1 and L2 acquisition research is that only the three major parameters (handshape, location and movement) have been investigated, so little is understood about the acquisition of individual phonemes. With few exceptions (Morgan et al., 2007), studies in L1 or L2 acquisition rarely provide a detailed description of the order of emergence of the phonemes within each parameter. Additionally, there is still minimal evidence to propose a hierarchy for phoneme complexity making it difficult to speculate about phonological emergence. That said, the use of the three major parameters has been consistently used with robust evidence arguing that the intrinsic phonological complexity of each parameter makes handshape the most difficult to acquire, followed by movement and then location. Until more information on individual phonemes becomes available, the major parameters are the only point of reference to make cross-linguistic contrasts to describe L1 and L2 phonological emergence. In addition, despite there being considerable work on how hearing infants interpret iconicity in gestures (Namy, 2004, 2008; Tolar, Lederberg, Gokhale, & Tomasello, 2008), it remains to be investigated how experience in processing gestures may impact acquisition of a manual language as a second language.

1.4 The present thesis

Empirical evidence to date suggests that the structure and iconicity of a sign are relevant factors during sign phonological development. In the L1 context, children's motor dexterity leads to articulation errors in particular for those parameters that are more structurally complex. Iconicity does not appear to be relevant during sign acquisition because children lack the world knowledge to make associations between iconic forms and real life referents. In the L2 context, adults have complete motor control and fully developed schemata, suggesting that adult phonological acquisition may follow a different pattern of emergence from that of deaf children. However, L2 phonological development has not yet been studied in a controlled empirical setting, so it remains unclear how sign structure impacts adult sign production. Iconicity seems to have a facilitation effect in the recall of iconic signs, but its impact on phonological development has not been studied. Furthermore, whether experience with co-speech gestures may influence the emergence of a visual phonological system has yet to be evaluated.

Based on these considerations, the present dissertation investigates the development of a visual phonological system by hearing adults. The three research questions addressed by the experiments carried out in this dissertation were:

1. How does sign structure influence the L2 acquisition of sign phonology?
2. What is the influence of iconicity on the L2 acquisition of sign phonology?
3. Are hearing adults biased towards perceiving iconic signs as co-speech gestures?

The structure of this dissertation is as follows. Chapter 2 investigates how the iconic elements of sign are perceived by two populations with different linguistic modalities (hearing non-signers and deaf signers). Because it was predicted that iconicity plays a role in the perception of phonological constituents of signs, it was important to determine what L2 learners regarded as iconic. This chapter presents a quantitative measure of perceived iconicity for different types of referents in order to develop a controlled set of signs that would be used as experimental stimuli throughout the rest of the dissertation. Chapter 3 describes the results of a sign repetition task investigating how sign structure affected articulation accuracy. It shows that the Dominance and Symmetry constraints (Battison, 1978) are a good measure to define phonological complexity in signs and that articulation accuracy is greater when signs have fewer phonological features to process. Chapter 4 set out to investigate how sign iconicity impacts the accuracy of sign production in hearing learners of BSL. This chapter reports the results of a sign repetition task that shows that non-signers articulated iconic signs less accurate than arbitrary signs, arguably because of their similarities with co-speech gestures. Building on the results from Chapter 4, Chapter 5 gathered empirical data to confirm the prediction that at the early stages of sign language acquisition, non-signers process iconic signs as gestures. Based on the finding that iconic gestures prime words (Yap, So, Yap, Tan, & Teoh, 2011), Chapter 5 reports the results of a cross-modal lexical decision task that show that iconic signs activate the L1 lexicon in the same way as gestures. In addition, it provides evidence that non-signers' pattern of activation changes after they gain some level of proficiency in BSL. Chapter 6 discusses in a comprehensive overview the conclusions that can be drawn from the experimental data and suggests lines for future research.

2 Perception of iconicity

2.1 Introduction

The prevalence of iconicity in the vocabularies of all documented sign languages makes it a key feature of the visual-spatial modality and an important focus of attention in psycholinguistic research. Evidence suggests that iconicity plays a distinctive role during sign processing (Ormel, Hermans, Knoors, & Verhoeven, 2009; Thompson, Vinson, & Vigliocco, 2009, 2010) and that it may have a prominent function during first (Thompson et al., 2013) and second language acquisition (Baus et al., 2008; Campbell et al., 1992; Lieberth & Gamble, 1991). Despite studies proposing that iconicity is a gradient property of signs (Klima & Bellugi, 1979) and that signs may depict different elements of a referent (Mandel, 1977), empirical studies have not yet investigated whether different types of iconicity are more accessible to specific populations. Often the blanket term iconicity has been used to encompass a wide range of signs depicting different referents but it is not yet clear how different types of iconicity impact on sign processing or acquisition, in particular to hearing people learning a sign language as L2.

Another aspect that needs further investigation is how linguistic experience affects the perception of iconicity. In empirical psycholinguistic studies, deaf and hearing participants are known to have a different perception of iconicity because each group is biased towards perceiving some iconic features but not others. What exactly these features are is yet to be explored. The aim of this study is to investigate how the type of iconicity and linguistic experience (speech vs. sign) affects the perception of iconicity.

2.1.1 Factors contributing towards the perception of iconicity

Section 1.1.1 explained that signs exploit multiple mechanisms to incorporate the properties of a referent into their structure. This suggests that non-signers will have access to the meaning of some iconic signs but not to others. This has been captured in the notion that iconicity is not categorical but rather a gradient property of signs (Klima & Bellugi, 1979). In addition, factors like age, cultural background, and linguistic experience are also important determinants in comprehension of sign iconicity (Griffith, Robinson, & Panagos, 1981; Pizzuto & Volterra, 2000).

Klima and Bellugi (1979) studied the extent to which hearing non-signers understood the meaning of iconic signs. In the study, hearing non-signers were shown iconic signs and were assessed on whether they were capable of guessing their meaning without external prompts. When viewed in isolation performance was low for most iconic signs. When participants were shown the signs with multiple options to choose from, participants significantly improved performance. The researchers concluded that iconicity lies within a continuum with some iconic signs showing clearer form-meaning links than others. Based on their results the authors concluded that depending on how easily accessible the meaning of the sign was to non-signers, iconic signs could be classified as transparent (e.g. CAMERA), translucent (e.g., TO-LIMP), obscure (e.g., HOLLAND) and opaque (e.g., WHAT, see Figure 2.1).

Figure 2.1 Examples of iconic signs with different degrees of meaning transparency. The BSL sign CAMERA (transparent), TO-LIMP (translucent), HOLLAND (opaque) and WHAT (obscure).

Apart from meaning transparency, shared cultural knowledge also comes into play in the perception of iconicity. Pizzuto and Volterra (2000) assessed how the cultural background and linguistic modality of deaf signers and hearing non-signers influenced perception of iconic signs. In a partial replication of the study by Klima and Bellugi (1979), deaf and hearing participants from six European countries were shown a set of iconic and arbitrary signs in Italian Sign Language and asked to guess their meaning. More than half of the iconic signs were correctly guessed by 50% of participants, suggesting that the mappings between sign and referent are evident to all participants regardless of their hearing status. A different picture emerged for arbitrary signs because none of them were correctly guessed by hearing participants. A more detailed analysis of the results showed that deaf participants were significantly better at guessing the meaning of arbitrary and iconic signs suggesting that their experience as users of a sign language allowed them to extract meaning from both types of signs. Finally, a set of signs which were regarded as typically associated with the Italian culture were guessed significantly less accurately by hearing non-Italian participants despite being rated as highly iconic by hearing Italian subjects.

Evidence suggests that iconicity may be equally accessible to all participants until individual experiences limit understanding of the concept depicted in a sign. When asked to rate a set of 100 signs for their degree of iconicity, deaf signers, hearing adults, and hearing children produced significantly similar ratings (Griffith et al., 1981). These results suggest that to certain degree participants from different ages and language modality base their perception of iconicity using the same parameters (e.g., physical similarity with the referent). Despite the strong correlation found between these three groups, however, the study indicates that comprehension of iconicity goes beyond sign-referent resemblance and that it is reliant on a number of factors grounded in human experience. For example, the sign DOCTOR (produced by touching the lower part of the wrist by the dominant hand as if checking someone's pulse) was easily recognised by deaf and hearing adults but children ranked it as highly arbitrary probably because they were unaware of this medical practice. What this study suggests is that, while some participants cannot identify the elements represented by some iconic signs, they can detect the iconic motivation of other iconic signs regardless of age or linguistic background.

Together, these studies show that hearing non-signers are capable of associating meaning to manual symbols regardless of the modality of their first language. This capacity, however, varies depending on the referent depicted and the degree of meaning transparency. In addition, the ability to produce correct sign-meaning associations is also constrained by cultural background, age, and world experience (Griffith et al., 1981; Pizzuto & Volterra, 2000). This suggests that multiple factors intervene in the comprehension of iconic signs with some factors relating closely to how signs encode iconicity and others relating to the world knowledge of the individual.

These studies provide compelling evidence that the presence of direct mappings between sign and referent facilitate the interpretation of iconic signs. This may only occur if the structure of a sign has a close correspondence to the concept depicted. This could be a visual property of an object or an action, accessible to all individuals regardless of modality of the first languages. Disparity between form and referent (less transparency) or the lack of sufficient world knowledge will translate in more difficulty in deducing the meaning of iconic signs (e.g., the sign HOLLAND). The common substrate between hearing and deaf and what types of iconicity are accessible to participants with specific linguistic experiences remain to be explored. Based on the prediction that iconicity will affect perception of the phonological components of a sign, it is important to understand what hearing adults regard as iconic.

To further investigate how iconicity in signs is perceived by two groups with different linguistic modalities, an analysis of iconicity ratings was carried out. In the current study, non-signing participants rated a set of BSL signs for their degree of iconicity. These signs had been previously recorded and rated by deaf participants in another norming study (Vinson, Cormier, Denmark, Schembri, & Vigliocco, 2008). The ratings produced by deaf participants in that study were compared to the ratings produced by hearing adults to investigate the degree of overlap between groups. Because signs exploit different mechanisms to depict different referents, iconic signs were classified into five categories (action, perceptual, metaphoric, facial, and emblematic) to assess whether the two groups associated the same iconicity values to signs depicting different referents. This classification was based on developmental studies of perception of iconicity by children of different ages (Tolar et al., 2008). This provided information about the elements that were regarded as iconic by both groups and for what types of referents linguistic experience would show significant differences. In addition, the videos and iconicity ratings in the present study were used as experimental stimuli in the subsequent chapters of this dissertation.

2.2 Methodology

2.2.1 Participants

Fifteen hearing university students (four male, mean age = 28.27 years) were recruited for this task. None had any prior knowledge of BSL or other sign language and all were monolingual native speakers of English.

2.2.2 Stimuli

The video clips of the signs were obtained from a norming study (Vinson et al., 2008) in which deaf adults rated on a 7-point scale 300 BSL signs for degree of iconicity, age of acquisition, and familiarity. The signs in each video clip were produced by four native signers of BSL. All signs were single tokens produced individually with their natural mouth patterns. The approximate duration of each sign was 3-4 seconds.

2.2.3 Procedure

Participants took part on a paper-based task in which they had to rate the degree of iconicity of the 300 signs on a 7-point scale. Specifically, they were asked to what degree the form of the sign corresponded to its closest English translation. In the scale, 1 represented signs with weak relationship with their referent (arbitrary) and 7 represented signs whose relationship was very clear (iconic). Signs were presented in randomised order on a computer screen along with their English translation. Each sign was immediately followed by the next to force participants to make quick and intuitive judgments. Participants had a list of the 300 signs in the order in which they were presented. Each item of the list had a 1-7 Likert scale for which they had to circle the number that represented their perceived iconicity rating. After the data were collected, the mean rating for each individual sign was calculated. One of the signs (SKIRT) had to be excluded from the analysis because of technical difficulties during the presentation of the video clip.

After all signs had been rated for their degree of iconicity, a 3.5 cut-off point was selected to divide iconic from arbitrary signs. Signs with ratings of 3.5 or higher were regarded as iconic and signs with ratings of 3.49 or lower were classed as arbitrary. This cut-off point has been used in other studies using the same stimuli (e.g. Thompson et al., 2009; Thompson, Vinson, & Vigliocco, 2010). The ratings obtained from non-signers were correlated with those produced by the deaf signers from the norming study from which the video clips were obtained. Following the correlation analysis, signs above the 3.5 cut-off point (iconic signs) were clustered into five categories depending on their iconicity type.

Action signs, also referred to as presentable actions (Mandel, 1977), represent pantomime of bodily movement. *Perceptual signs* were those in which the manual articulators depict an object, a part of it or its shape (e.g., the signs HELICOPTER, DEER and BOTTLE, respectively). *Metaphoric signs* included signs representing a concrete referent but the meaning of the signs derive from the image it produces. An example is the sign TO-DIVE in which extended adducted index and middle fingers moving in an arced downward trajectory representing a person diving into water. *Facial signs* were those in which the hand articulators did not have a formational relationship with the concept but rather the non-manual features of the sign (e.g., facial expression) encoded part of its meaning. The sign GUILTY, for instance, does not represent the referent but the facial expressions convey a negative meaning. *Emblematic signs* closely resemble conventionalised gestures used by hearing people during speech and are now part of the BSL lexicon (e.g. HOPE). They do not have structural similarity with a referent, and in the hearing community they have specific pragmatic uses (Kendon, 1995). See Figure 2.2 for examples.

Figure 2.2 BSL signs depicting different types of iconicity. CAMERA is pantomime of body motion. HELICOPTER depicts a referent as a whole. BOTTLE traces its shape. TO-DIVE is a metaphoric signs depicting a person jumping into water. GUILTY encodes negative connotation in the non-manual feature of the signs. HOPE is an emblem borrowed from conventionalised gestures.

A note on the classification used in this analysis is appropriate here. As was described in Section 1.1.1, sign linguists have produced different classifications of iconic signs based on how a sign depicts a referent (Mandel, 1977), how each phonological parameter contributes to the iconicity of a sign (Cuxac, 1999; Johnston & Schembri, 2007; Pietrandrea, 2002), and how accessible the sign meaning is to non-signers (Klima & Bellugi, 1979). However, these classifications are based on theoretical suppositions and are not grounded on psycholinguistic evidence. None of these classifications has been tested to support a distinct psycholinguistic origin nor tested to assess their relevance during sign acquisition or processing. While these categories have used different criteria for the classification of different forms of iconicity, they reveal little about how they impact cognitive processes. The classification used in the current analysis, in contrast, contains categories which have been used in developmental studies (Tolar et al., 2008). The results of this study show that these categories have validity and therefore were implemented in the present analysis.

2.3 Results

Participant ratings were averaged for each item producing a total of 299 iconicity ratings (the sign SKIRT having been excluded from the analysis). These scores and those reported for the group of deaf signers (Vinson et al., 2008) were rank ordered and compared using a Pearson correlation. There was a statistically significant correlation between the ratings given by both groups ($\rho = 0.799$, $p < 0.001$). After the correlation was established, the number of signs above the 3.5 cut-off point was calculated. There were a total of 118 and 138 BSL signs for the hearing and deaf groups, respectively. The deaf group included 20 signs more than the hearing group in the iconic sign cohort. See Appendix A for a complete list of signs and their iconicity ratings.

Based on the iconicity ratings from hearing and deaf participants, signs above the 3.5 threshold were classified into one of five categories: action, perceptual, metaphoric, facial, and emblems. This classification was cross-checked by an independent researcher. There was 88.14% and 91.00% intercoder reliability in the sign classification for the hearing and deaf lists, respectively. Disagreements were discussed until full agreement was reached.

Figure 2.3 shows the proportion of iconic signs clustered by iconicity type and plotted against ratings by hearing and deaf participants. The balloon size represents the proportion of signs in each cluster compared to the total number of iconic signs for each group of participants. The proportion of signs in each category for hearing non-signers (grey circles) was as follows: action 0.39 (46 signs), perceptual 0.31 (37 signs), metaphoric 0.22 (26 signs), facial 0.05 (6 signs), and emblems 0.03 (3 signs). The mean iconicity rating for each cluster was: action 5.84, perceptual 5.10, metaphoric 4.70, facial 4.14, and emblem 6.63. This analysis shows that there was a linear trend in which relative cluster size was directly proportional to its iconicity rating: the bigger the cluster the higher its iconicity rating. This linear correspondence applied to all sign groups except emblematic signs.

A similar pattern was observed in the ratings given by deaf participants (this analysis was not carried about by the authors of the original norming study). The proportion of signs for each cluster was: action 0.41 (57 signs), perceptual 0.38 (53 signs), metaphoric 0.15 (21 signs), facial 0.03 (4 signs), and emblems 0.02 (3 signs). The iconicity ratings of each cluster were: action 5.54, perceptual 5.13, metaphoric 4.31, facial 4.83, and emblems 4.43. There was again a direct relationship between cluster size and iconicity ratings. Contrary to the trend observed in the hearing data, in the deaf group emblematic signs had significantly lower iconicity ratings which were proportional to their cluster size.

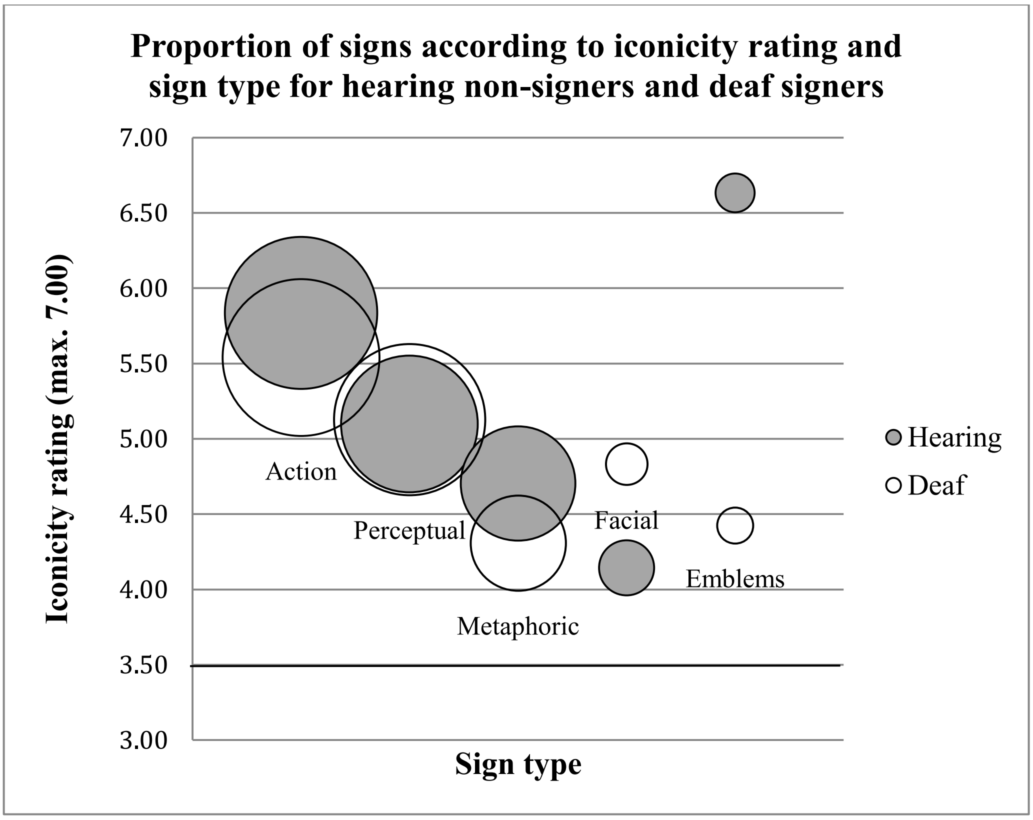


Figure 2.3 Comparative figure of different sign clusters and iconicity ratings given by hearing non-signers and deaf signers. The bold horizontal line represents the cut-off point (>3.5) between arbitrary and iconic signs.

2.4 Discussion and conclusion

The aim of this study was to investigate how different types of iconicity were perceived by participants with differing linguistic backgrounds (hearing non-signers vs. deaf signers). The analysis revealed that hearing non-signers and deaf signers presented a significant correlation in their iconicity ratings confirming the prediction that the iconic elements encoded in most signs can be perceived by all participants regardless of their sign language experience. Despite the strong correlation, a detailed analysis revealed that there were differences in iconicity ratings for specific sign types that could be attributed to the linguistic modality of participants.

The data suggest that high iconicity values are assigned when sign-referent mappings are clear. This is the case of signs depicting pantomimes (action signs) and objects (perceptual signs) which were given the highest iconicity ratings by both groups. It is possible that high ratings are the consequence of action and perceptual signs having strong resemblance to events and objects grounded in physical reality. That is, signs depicting actions and objects have close correspondences with their referent making the concept they represent clearer to the observer. Because hearing non-signers and deaf signers gave similar iconicity ratings to these types of signs it is possible to argue that access to their meaning does not recruit expertise in a sign language because the visual relationship between sign and referent are sufficient to make a conceptual link. It must be noted, however, that both groups assigned higher iconic ratings to actions than to perceptual signs suggesting that the former are more easily mapped to a referent than the latter. Deducing the meaning of signs representing objects may be more cognitively taxing which may be the reason why hearing and deaf participant assigned lower ratings to items in the perceptual condition. This follows previous research that found that young children can map signs depicting actions to their real referents more easily that objects (Tolar et al., 2008).

Metaphoric signs also received similar iconicity ratings from both groups of participants but these were lower than for action and perceptual signs. The ratings for this category may reflect the fact that both groups are equally capable of extracting meaning from the image produced by the sign perhaps because they can link a phonological component of a sign with a referent. For instance, the handshape and the movement in the sign TO-DIVE (Figure 2.2) may have been accurately mapped onto an image of a person diving. This is evidence that non-signers are capable of detecting iconicity in the phonological parameters in signs despite their lack of understanding of BSL. The slightly lower iconicity ratings by deaf participants suggest that, while hearing people may view these types of signs as an array of iconic gestures (and may be processed as such), for deaf participants they are frozen lexicalised signs where the iconic element is not as salient. This implies different processing mechanisms which need to be further investigated.

Facial signs were another category displaying some difference in iconicity ratings. Despite participants being asked to rate the resemblance between the manual components of signs to their referents, the data suggests that both groups also exploited the non-manual features of the sign to make their judgments. Non-signers were clearly capable of associating this information with the meaning of a sign in the same way as deaf signers. The slightly higher ratings by deaf signers suggest that they are more aware of this parameter possibly because non-manual features are fundamental constituents of a sign which convey important phonological and prosodic information (e.g., sentence and clause boundaries, interrogative marking) (Sandler & Lillo-Martin, 2006). Experience in the visual modality may be the cause of the higher iconicity ratings for facial signs in deaf participants.

One of the significant differences in the iconicity ratings by hearing and deaf participants is observed in the category of emblematic signs. Both groups included the same proportion of signs in each category but while the hearing group gave this category the highest rating (6.63) the deaf group gave it the lowest (4.43). Despite the hand configurations in emblems not having physical or metaphoric resemblance with its referent, hearing adults gave these signs a higher rating than any other category. This could be attributed to the presence of emblems in the hearing community during communication. Hearing participants are aware of the meaning of emblems thus they may have based their ratings on the overlapping meaning with the sign. This was not the case for the deaf group who gave significantly lower ratings to signs in this category. Experience in a manual language may explain these results. Deaf participants use the visual-manual channel as primary means of communication with emblematic signs being just a small set of a large number of manual structures. The absence of visual mappings between emblems and their concrete referent may reflect the low ratings compared to those of non-signers. However, the fact that deaf signers assigned emblems a mean iconicity rating of 4.43 (above the 3.5 threshold) suggests that they still considered them somewhat iconic.

The ratings of the facial and emblematic categories suggest that signers and non-signers alike process visual input from various channels (facial expressions, conventionalised gestures) to make sense of a multi-modal utterance. The fact that participants gave high ratings to signs encoding iconicity in facial expressions and in gestures with no evident form-referent mapping clearly indicate that iconicity is not restricted to the physical resemblance of the manual component of a sign and a referent.

Despite hearing and deaf participants giving iconicity ratings for the same set of signs, the analysis revealed that the deaf group regarded as iconic more signs than the hearing group. This difference could be attributed to the different linguistic experiences of each group. It is possible that deaf signers rely not only on the physical resemblance between a sign and its referent, but that they also have access to additional etymological information about the historical changes in signs. That is, experience in the usage of a sign language provides them with metalinguistic information which allows them to be more aware of the visual motivation of a sign. For instance, Johnston and Schembri (2007) report that in Australian Sign Language one variant of the sign LIBRARY represents a hairclip. This sign came into use because the sign name of a librarian at a school for the deaf was HAIRCLIP because she always wore one. In this example there is no visual resemblance between the sign (i.e., HAIRCLIP) and the referent (i.e., a library) but there is a connection between the referent and an object associated with it. This link is only evident to those with metalinguistic information about the origin of the sign. A similar situation may be present in some signs used in the study and could be the reason why deaf participants rated a larger number of signs as iconic. This may be the case, for instance, for the sign MSN (see Figure 2.4) which was rated as iconic by deaf but not by hearing participants. There is anecdotal evidence that this sign was originally produced with two hands facing each other, representing two faces engaged in communication. The sign variant shown to participants has lost some of its iconic features to conform to the phonotactics of BSL. In the current sign, even when the iconic element is partially absent (and inaccessible to non-signers), deaf signers may still be aware of the visual motivation of the sign and rate it as iconic.

Figure 2.4 Example of a sign which has lost its iconic elements; BSL sign MSN.

In summary, the comparison of iconicity ratings of a set of signs suggests that deaf and hearing participants have equal access to the iconic elements of some signs regardless of the modality of their native language. The data presented here suggests that judgement of iconicity will be more similar between groups when signs depict clear visual properties of a referent. As iconic signs move away from depicting physical properties of a referent and gradually move towards a more abstract depiction, ratings between non-signers and deaf signers become more disparate, with linguistic modality playing a more relevant role in shaping iconicity judgments. That is, as the direct mapping with a referent becomes less evident, it is harder for non-signers to perceive the motivation of the sign.

The importance of this analysis is two-fold: first, it shows that to a large extent iconicity is perceived in similar ways by hearing and deaf participants, in particular in signs depicting physical features of a referent. Secondly, it gives a better understanding of how different types of iconicity are perceived by hearing adults. This helps to shed light on how different types of iconicity affect the perception of the phonological components of signs during L2 acquisition.

3 Sign repetition: the effect of sign structure

3.1 Introduction

As explained in Section 1.1, signs have systematic internal organisation with hand configuration, place of articulation, movement (Stokoe, 1960), and orientation (Battison, 1978) being the phonological parameters required to establish their structure [1]. The psychological reality of these parameters has been confirmed in that they are acquired at different stages during L1 phonological development (Conlin et al., 2000; Marentette & Mayberry, 2000) and they play distinct roles during lexical access (Baus et al., 2008; Carreiras, Gutiérrez-Sigut, Baquero, & Corina, 2008; Dye & Shih, 2006; Gutiérrez, Müller, Baus, & Carreiras, 2012). Hearing adults acquiring a signed phonology have to develop an internal representation for these parameters so as to allow recognition during communication. Proficient L2 signers are known to exploit the phonological structure of a sign for lexical access (Shook & Marian, 2012) but how these visual representations emerge in hearing learners is not yet well-established. It is possible that, as it happens in spoken languages, they develop through learners' ability to perceive the distinctive phonological constituents of an L2 lexical item (Escudero, 2005). The aim of the present study was to determine ease of articulation for each individual parameter in beginner sign L2 learners and to quantify their articulation as a function of signs' phonological complexity. In order to do so, this study looked at the articulation errors by hearing non-signers in a sign repetition task.

Section 1.3 explained that some sign parameters are easier to discriminate by non-signers than others (Bochner et al., 2011). This would suggest that establishing an internal representation for each parameter will occur gradually and at different points in time depending on ease of perception for each parameter. In addition, learners' success in

[1] Non-manual features like eye movements, facial expressions, mouthing and mouth gestures are also part of the sign structure (Brennan, 1992; Crasborn et al., 2008) but they will not be investigated in this study and thus not discussed in more detail.

distinguishing distinctive manual features will greatly depend on the phonological complexity of a sign. Complex signs have a larger number of features so it may be more cognitively taxing to discriminate and retain all of them in working memory, deterring the process of phonological emergence. There is still no general consensus about the exact phonological properties of signs, therefore establishing a definition of phonological complexity is not easy. However, a good approximation is to attend to the number of phonemes permissible in a sign depending on its internal structure.

Battison (1978) noted that signs have systematic organisation and that only certain combinations of handshape, location and movement are possible depending on whether a sign involves one or two hands. Importantly, Battison discovered that the specific phonemes signs may adopt depend on how the main articulators (i.e., the hands) interact with each other. Based on his observations, he proposed the Dominance and Symmetry constraints (Battison, 1978) in which he establishes four types of signs:

1. Type 0 signs are one-handed signs.
2. Type 1 signs are two-handed signs with the same handshape and producing a symmetrical (synchronised or alternating) movement.
3. Type 2 signs are also two-handed signs both with the same handshape but the dominant hand acting on the non-dominant (i.e., both hands move independently from each other).
4. Type 4 signs are two-handed signs with the dominant hand acting on the non-dominant hand and both presenting different handshapes.

Battison stipulated that, from an articulatory perspective, two-handed signs are more complex than one-handed signs and that signs in which the hands act independently require greater articulatory dexterity than signs with symmetrical movement. The validity of this structural organisation holds not only at the lexical level but extends to the morpho-syntactic level (classifiers) because these organisational constraints have been documented across different unrelated signs languages (Eccarius & Brentari, 2007).

The prevalence of this systematic organisation across different sign languages has been attributed to the pressure posed by signers' perceptual system to be capable to process efficiently a manual signal (Johnston & Schembri, 2007). Peripheral vision has limited acuity compared to central vision hence it is better at processing two-handed signs. This claim is supported by the distribution of signs in Australian Sign Language in which almost 70% of two-handed signs occur in neutral signing space (Johnston & Schembri, 2007). Together this research suggests that one-handed signs are easier to perceive and articulate than two-handed signs because the latter have more components to process (a handshape, location, movement and orientation for each hand). To date, no study on L1 or L2 acquisition has incorporated the Dominance and Symmetry constraints as determinant in phonological emergence. Instead, all studies have mainly focused on the order of emergence of each phonological parameter.

Section 1.2 reported cross-linguistic research on L1 acquisition showing that infants acquiring a sign language from their signing parents display a systematic pattern of errors in sign articulation. Handshape is the parameter least accurately produced, followed by movement, and then location (Conlin et al., 2000; Marentette & Mayberry, 2000; Morgan, 2006). There is a less clear picture of the features that characterise sign L2 phonological development. As described in Section 1.3, the only study investigating error production by hearing learners suggests that L2 acquisition is different from L1 and that articulation errors are driven by perceptual limitations (Rosen, 2004). Bochner et al. (2011) investigated the ability to discriminate the phonological parameters of signs in hearing signers and found that movement was the most difficult to discriminate, followed by orientation, then handshape, and finally location. What these studies show is that sign structure does not influence L1 and L2 acquisition in the same way. Children learning a visual language from their parents exhibit a canonical order of errors with some parameters being consistently mastered before others (Conlin et al., 2000). In contrast, the limited evidence available from adults suggests that their pattern of phonological development is different from L1 acquisition (Rosen, 2004).

In the present study a sign repetition task was used to investigate how sign structure influences articulation accuracy in sign L2 learners. In the spoken modality, the word repetition task is a sensitive technique that requires phonological decoding of the acoustic input, assembly of the phonemes into a lexical entry, and articulation of the word (Coady & Evans, 2008). The adaptation of this technique to the visual modality has been implemented to determine signers' ability to discriminate, assemble, and articulate the components of signs in both typical (Mann, Marshall, Mason, & Morgan, 2010) and atypical populations (Mason et al., 2010). By controlling for sign structure it will be possible to evaluate how this factor affects sign articulation by L2 learners.

Following Rosen (2004), the first prediction of this study was that the pattern of errors produced by hearing non-signers would be different from those reported in deaf children. If indeed the errors produced by hearing learners are driven by perceptual constraints it would be expected that movement would be the parameter least accurately produced, followed by orientation, then handshape, and finally location (Bochner et al., 2011). Alternatively, if adult articulation errors are the product of the interaction between perceptual and motoric constraints, articulation errors will follow a different pattern. Based on the Dominance and Symmetry constraints (Battison, 1978), the second prediction was that two-handed signs are more complex than one-handed signs thus presenting a higher perceptual/production burden during articulation by hearing non-signers. That is, as the number of components of a sign increase, the articulation accuracy will decrease accordingly.

3.2 Methodology

3.2.1 Participants

Fifteen hearing adults (7 females, mean age = 23.93 years) were recruited to take part in this experiment. All participants were monolingual native speakers of English and none had prior knowledge of any sign language. Three participants were left-handed.

3.2.2 Stimuli

The stimuli was selected from a set of 300 video clips of individual BSL signs from a norming study in which deaf BSL signers were asked to produce ratings for age of acquisition, familiarity, and degree of iconicity (Vinson et al., 2008). These signs were fully described in Section 2.2. From these signs, a total of 96 signs were selected. Participants had no prior knowledge of a sign language so to them the stimuli were meaningless non-signs. Based on the Dominance and Symmetry constraints (Battison, 1978), Battison's sign Types were adapted to create six subcategories of increasing articulatory complexity. In addition to his four sign Types, two more sign Types were added to be able to make a distinction between signs articulated in signing space or those located on the body. Signs articulated in neutral signing space were regarded as lacking a specification location (Van der Kooij, 2002). Therefore, it was predicted that signs with body contact would pose a higher cognitive burden than signs in neutral space. This reasoning, along with Battison's sign types resulted in a total of six subcategories. Type 1 signs were one-handed signs produced in neutral signing space (e.g., EUROPE) and type 2 signs consisted of one-handed signs making contact with the body (e.g., SISTER). The commonality between these two sign Types is that both include movement of the dominant hand only but differ in their place of articulation (signing space and the body, respectively). The next two Types of signs involve both hands with the non-dominant hand being a mirror image of the dominant hand. Both hands execute the same movement and use the same handshape. The difference being the place of articulation: Type 3 signs were symmetrical two-handed signs with no body contact (e.g., HOSPITAL) and Type 4 signs were symmetrical two-handed signs with body contact (e.g., RELAX). Type 5 and 6 signs were also two-handed signs where the dominant hand acted independently from the non-dominant hand. In both cases the dominant hand acts upon the non-dominant hand but while in Type 5 signs both articulators used the same handshape (e.g., CORKSCREW), Type 6 signs present different handshapes (e.g., THEATRE). Importantly, in Type 6 signs the non-dominant hand always has an unmarked hand configuration and the dominant hand can have any hand configuration (see Figure 3.1 for examples).

The final stimuli consisted of 16 one-handed signs articulated in neutral space (Type 1), 16 one-handed signs with contact with the body (Type 2), 16 two-handed signs with symmetrical movement in neutral space (Type 3), 16 two-handed signs with symmetrical movement with body contact (Type 4), 16 two-handed signs with symmetrical handshapes and the dominant hand acting on the non-dominant (Type 5), and 16 two-handed signs with asymmetrical handshapes and the dominant hand acting on the non-dominant (type 6). The most simple signs were Type 1 signs because they present only four parameters and location is articulated in neutral signing space, the default location of all signs (Van der Kooij, 2002). The most complex signs were Type 6 signs because they involved two hands moving independently from each other and with two different handshapes in each hand (see Appendix B for a full list of the signed stimuli).

Figure 3.1 BSL signs exemplifying the Dominance and Symmetry constraints (Battison, 1978). (1) EUROPE, one-handed sign with no contact with the body; (2) SISTER, one-handed sign with contact with the body; (3) HOSPITAL, two-handed sign with symmetrical movement in neutral space; 4) RELAX, two-handed sign with contact with the body and symmetrical movement; (5) CORKSCREW, two-handed signs with asymmetrical movement and non-dominant hand as place of articulation; (6) THEATRE, two-handed sign with asymmetrical movement and handshape, and dominant hand acting on the non-dominant.

3.2.3 Procedure

Participants were tested individually in a quiet room on a portable computer. A video camera was located 1.5 m from participants at a 45 degree angle to record all sign repetitions. The task consisted of three phases. At the beginning of each trial, a fixation point appeared in the middle of the screen for 1000 ms. During the priming phase, an English word presented in lower case black letters was displayed for 2000 ms. In the perception phase, a video clip of the BSL sign was presented. When the video clip stopped and disappeared from the screen, participants started the production phase in which they had up to 5000 ms to imitate the sign as accurately as possible. Participants were explicitly told that they were only allowed to imitate the stimuli after the video had disappeared from the screen. This forced them to produce the sign from memory and not whilst they could self-correct their articulation. Participants had to complete a practice trial with ten word-sign pairs before taking part in the actual experiment. None of the practice trials were included in the experiment.

3.2.4 Analysis

After the data were collected, the videos of the articulation of each participant were glossed using the linguistic annotator programme ELAN (Lausberg & Sloetjes, 2009) and each rendition was glossed with its English translation. Articulation accuracy for all signs was measured for each of its formational parameters (handshape, location, movement, and orientation) using the following guidelines.

Most phonological models coincide that the structure of a handshape is defined by a set of selected fingers with a determined aperture (Brentari, 1999; van der Kooij, 2002). In the present study, a participant's handshape was regarded as accurate when it had the same selected fingers as the model and with the exact type of aperture. With regards to movement, typical errors by hearing adults with no knowledge of a sign language include deletions, substitutions (Rosen, 2004) and proximalisations (the production of movements from joints proximal to the torso instead of distal ones) (Mirus, Rathmann, & Meier, 2001). In the present study, accuracy of movement articulation was measured by evaluating if participants avoided these tendencies. With regards to place of articulation, a sign's location could be either neutral signing space or a body part. As mentioned in Section 3.2.1, signing space is regarded by some phoneticians as signs' default location with no contrastive features if they are articulated to the left, right or centre (Van der Kooij, 2002). Therefore, target signs in neutral space were considered accurate unless they were articulated outside this signing area (see Section 1.1 for a definition of signing or neutral space). Signs whose locations were a body part were subject to a stringent coding and if participants deviated in the slightest from the model they were scored as errors. Orientation is the most understudied parameter in terms of phonological characteristics. For this reason, it was established that an orientation error would be when participants' rendition deviated 90 degrees or more from the model's production.

It is well documented that during natural signing, interlocutors modify the phonological structure of a sign's citation form for ease of articulation. Such processes include hold reduction, movement deletions, preservation and anticipation (Liddell & Johnson, 1989). In some instances, participants' renditions adopted phonetic forms that could occur during natural signing. However, participants were instructed to articulate the signed stimuli as accurately as possible in order to assess their ability to discriminate and articulate the phonological parameters of a sign. For this reason, if participants' imitations were not exactly the same as the model, they would be regarded as errors even if the signs could be possible phonetic forms during naturalistic interaction. If a phonological parameter was correct, it was assigned a value of one and zero if it was an articulation error. The degree of articulatory accuracy for each sign was calculated by adding the scores of all four phonological parameters, with 4 being the highest achievable score and 0 the lowest. For example, if a participant produced the orientation and location of a sign correctly, but not the movement and handshape, this rendition would yield an overall accuracy of 2 (1+1+0+0). Two researchers coded all participants' articulations independently and reached 85% agreement. Disagreements were discussed and resolved until 100% agreement was reached.

3.3 Results

The phonological parameters were articulated with significantly different accuracies as shown by a one-way ANOVA [$F(1,89) = 1119.01$, $p < 0.000$, $\eta^2 = 0.926$]. Paired-samples t-tests after Bonferroni corrections revealed that the proportion of articulation accuracy for handshape (mean = 0.576, SD = 0.01), location (mean = 0.922, SD = 0.01), movement (mean

= 0.765, SD = 0.01) and orientation (mean = 0.889, SD = 0.01) were significantly different from each other. Namely, handshape was articulated significantly less accurately than location [$t(89) = 19.636$, $p < 0.000$], movement [$t(89) = 10.956$, $p < 0.000$] and orientation [$t(89) = 17.735$, $p < 0.000$]. Movement was articulated significantly less accurately than location [$t(89) = 8.673$, $p < 0.000$] and orientation [$t(89) = 6.759$, $p < 0.000$]. Finally, orientation was articulated significantly less accurately than location [$t(89) = 6.759$, $p < 0.000$]. According to these data location was the parameter most accurately produced, followed by orientation, then movement and finally handshape.

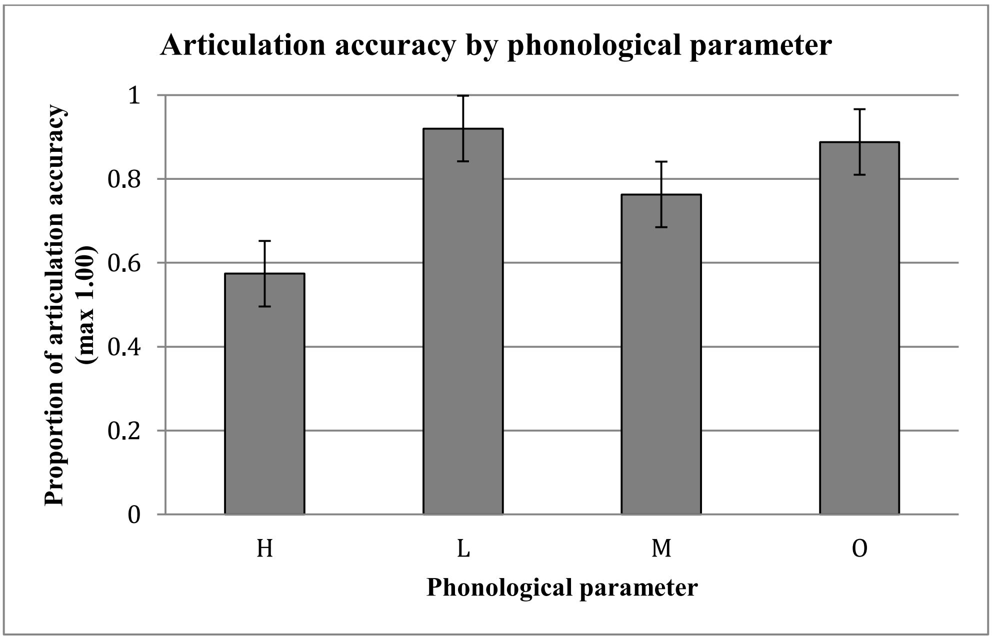


Figure 3.2 Proportion of correct articulations per phonological parameter (bars represent standard error).

A one-way ANOVA with sign Type as dependent variable showed that articulation accuracy varied as a function of sign Type [$F(1,14) = 1968.20$, $p < 0.000$, $\eta 2 = 0.993$]. Mean articulation accuracy for each sign type was: Type 1 = 0.809 (SD = 0.01), Type 2 = 0.804 (SD = 0.03), Type 3 = 0.767 (SD = 0.02), Type 4 = 0.797 (SD = 0.02), Type 5 = 0.783 (SD = 0.02) and Type 6 = 0.760 (SD = 0.03). Paired sample t-tests after Bonferroni corrections were carried out to determine significant differences amongst sign Types. The analysis revealed that sign Type 1 and 3 [t(14) = 3.400, p = 0.004] and sign Type 1 and 6 [t(14) = 2.806, p = 0.014] were articulated significantly different from each other. The rest of the comparisons were not significant[2]. The corresponding trendline of the data shows that as the number of phonological parameters in a sign increases (higher sign Type) the articulation accuracy gradually decreases (slope = - 0.008, $R^2 = 0.54$). The data did not confirm the assumption that signs articulated in the body would pose a higher cognitive burden to participants because sign Types which only differed in body as place of articulation (sign Types 1 and 2, and Types 3 and 4) did not reach significance [t(14) = 0.205, p = 0.806; t(14) = 0743, p = 0.470, respectively].

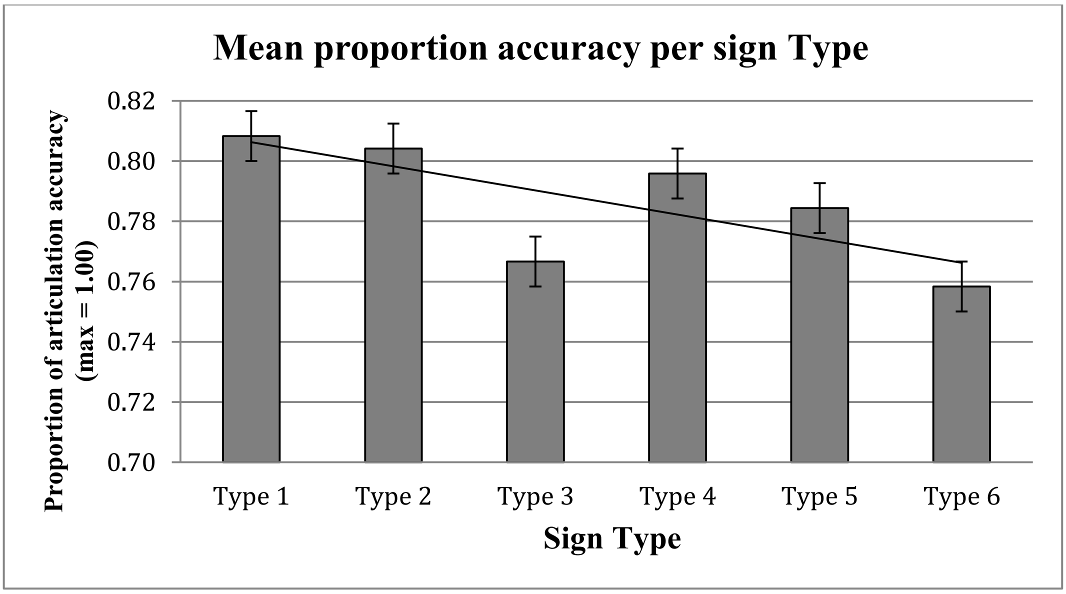


Figure 3.3 Proportion of correct articulations according to each sign Type (bars represent standard error). The line above the dataset represents the corresponding trendline (slope = - 0.008, $R^2 = 0.54$).

3.4 Discussion and conclusions

The aim of this experiment was to quantify and describe the phonetic errors produced by hearing non-signers during a sign repetition task. Sign structure was manipulated as an

[2] For purpose of readability, only the significant differences are reported here. See Appendix C for a table displaying *t* and *p* values for all paired comparisons.

independent variable because it has been shown to influence L1 (Boyes-Braem, 1990; Morgan, 2006) and L2 sign language acquisition (Bochner et al., 2011; Rosen, 2004). The analysis revealed that articulation accuracy was dependent on the phonological parameter and sign Type. Location was the parameter most accurately articulated followed by orientation, then movement, and finally handshape. The analyses also revealed that articulation accuracy decreased as the number of components of a sign increased (i.e., lower accuracy at the higher sign Types).

Adults learning BSL as an L2 exhibited the same pattern of errors as those reported in L1 phonological development. This is surprising given that the errors produced by infants have been explained by their immature motor system, their inability to articulate fine movements (Meier et al., 2008) and because they have not yet developed schemata of their bodies (Marentette & Mayberry, 2000). Adults with full control of their sensory-motor system should therefore display a different order of phonological development. In addition, adults errors have been attributed to perceptual constraints (Rosen, 2004). Based on this claim, it was predicted that the parameters more difficult to perceive would also be the most difficult to articulate. Research on phonological discrimination by sign L2 learners found that movement was the parameter most difficult to perceive, followed by handshape and then location (Bochner et al., 2011). A similar pattern of errors would be expected in sign production by L2 learners if perception were the sole factor in determining articulation accuracy. Because adult errors followed a different pattern than that predicted by perceptual difficulty, it is unlikely that perception of the phonological parameters alone can explain articulation accuracy at the early stages of sign language learning.

Articulation accuracy would seem to be better predicted by the interaction between perception and articulatory complexity of the parameters of signs. In spoken languages, research in phonological development has gathered abundant evidence that accurate perception does not predict accurate production. Despite some studies finding mild correlations between perception and production of novel sounds (Flege, MacKay, & Meador, 1999), most studies propose that there is no one-to-one correlation and that perception of a phoneme does not equate to accurate production (Peperkamp & Bouchon, 2011). In the current experiment, some parameters may have been accurately perceived but their intrinsic articulatory complexity may have led to articulatory inaccuracies. A complementary explanation comes from L2 research in the spoken modality. Children (Brown, 1973) and adults (Bailey, Madden, & Krashen, 1974) learning English as an L2 exhibit the same order of emergence of structures as in L1 development (Dulay & Burt, 1974). The findings of these studies suggest that complexity and frequency of the target structures are the explanation behind these developmental similarities i.e., simple and more frequent structures are mastered before complex and less frequent ones in both the L1 and L2 (Larsen-Freeman, 1976). If this explanation extends across modalities, it is possible that the similar pattern of errors by children and adults is the result of the interaction between the structural complexity of signs and their frequency of occurrence.

An alternative explanation for these results is that learners' inexperience in using their hands as linguistic articulators made them produce child-like errors. This phenomenon has been reported in the literature previously. When asked to imitate signs from a foreign sign language, adults with no prior expertise with the spatial-visual modality tended to produce the proximalised movements that characterise L1 phonological development (Mirus et al., 2001). Deaf signers, in contrast, were less likely to proximalise movement because of their experience with their own sign language. It is possible that the pattern of errors observed in the present sign repetition task may be driven by learners' developing their skills to use parts of their body as linguistic articulators.

The design of this experiment does not allow us to tease apart whether inaccuracies were the product of perceptual mismatch, articulatory complexity or evidence of participants' developing signing skills (see Chapter 6, section 6.2 for a proposed study that could resolve this issue). However, given that adult errors exhibited the same pattern as those of children, what these data do suggest is that neither motor dexterity nor perception alone can explain the errors produced by hearing adults at the early stages of sign learning. The similarities between L1 and L2 articulation errors could be a reflection of the fact that each phonological parameter has varying degrees of complexity and that it is due to these intrinsic differences that they are mastered by children and adults in the same order.

The results also indicate that articulation accuracy varied inversely with the number of elements of a sign; i.e., articulation in Type 1 signs exhibited the highest accuracy and then gradually declined as the number of parameters in the sign as a whole increased. Two important conclusions can be drawn from these data. First, the negative value of the trendline coefficient suggests that articulation accuracy decreases as a function of sign Type (i.e., signs with more components were articulated less accurately). These findings provide empirical evidence for Battison's proposal that sign Types vary in articulation complexity. Participants in this study may not have been capable of discriminating all the phonological components of signs in the more complex sign types and this translated into more articulation errors. At the lower levels of complexity, signs had fewer components to discriminate; therefore participants’ perceptual system was capable of processing all the phonological components, storing them in working memory, and imitating them accurately. In contrast, the larger number of components in more complex sign Types may have overloaded the perceptual capacities of participants. Participants may have overlooked some of the constituents of the signs, or perhaps they created an inaccurate representation in working memory, thus causing a larger proportion of errors.

The present data also give evidence about the articulation complexity of each sign type. The data show that one-handed signs (type 1 and 2) were articulated significantly more accurate than two-handed signs with symmetrical handshapes (type 3 and 4). This suggests that the distinction between signs being produced in contact with a body part or in neutral space is not relevant for predicting articulation accuracy. This can be concluded given that no significant difference was found between sign Types that only differed in place of articulation (sign types 1 and 2, and 3 and 4). These results are in line with research in sign L1 and L2 acquisition which reports that location is the most accurately produced parameter because of its perceptual saliency (Bochner et al., 2011; Marentette & Mayberry, 2000; Morgan et al., 2007). Hearing adults also seem to perceive and produce signs in the correct location from the onset of sign language learning, possibly because of the visual saliency of this parameter.

One-handed signs were articulated significantly more accurate than two-handed signs with symmetrical (Type 3) and asymmetrical handshapes and movements (Type 6). In regards to Type 3 signs, it seems that a significant level of complexity derives from signs having one or two manual components. Despite two-handed signs in Type 3 and 4 having the same features in both hands, the participants of this study seem to have experienced more difficulties than with one-handed signs possibly due to the extra set of phonological parameters that they have to process. With the lowest accuracies, Type 6 signs seem to display the highest degree of articulation complexity to hearing signers. Type 6 signs have two distinct handshapes, movements, locations and orientations thus posing additional cognitive pressure to participants to perceive and produce with precision their phonological parameters. These results strongly support the prediction that signs with more features translate into more articulation errors.

In conclusion, the findings of this study suggest that sign structure drives articulation errors. The pattern of errors produced by sign L2 learners mirrors those produced during L1 acquisition reflecting that both groups may experience the same level of difficulty to perceive / produce the parameters that constitute signs. The data also support the prediction that signs with more features are articulated less accurately than signs with fewer features. Specifically, the data suggests that one-handed signs are articulated more accurately than two-handed signs with symmetric features, and that two-handed signs with asymmetric features (i.e., different handshape, movement, location and orientation) are the least accurately articulated from all signs.

4 Sign repetition: the effect of iconicity

4.1 Introduction

In spoken languages, L2 learners are often influenced by their L1 because they tend to replace target L2 sounds with phonemes from their native language, causing what is commonly known as 'foreign accent' (Piske, MacKay, & Flege, 2001). Because signing occurs in a different modality, it would be expected that phonological development of a sign language would not be subject to any form of interference from learners' spoken L1. Hearing adults, however, have experience using their hands during natural conversation through the production of gestures. Signs and gestures have fundamental structural and functional differences but a shared similarity is their capacity to represent features of a referent (iconicity). Often natural signs and some types of gestures exhibit striking similarities making them indiscernible to the untrained eye. How these similarities may influence the acquisition of a conventionalised sign language has not yet been subject to thorough examination. The aim of this study is to explore whether experience in perceiving iconicity in gestures influences sign L2 phonological development.

Research in the spoken modality has recognised the importance of the L1 during L2 phonological acquisition. The Speech Learning Model (Flege, 1995, 2007) proposes that successful acquisition of a novel L2 sound is a two-step process which requires: 1) accurate perception of the target sound; and 2) the creation of a novel phonemic category. The model predicts that, if an L2 sound is sufficiently different from sounds in the existing L1 phonology, learners will perceive them as distinct and will set up a new phonological category. If, in contrast, L1 and L2 sounds are similar but present slight phonetic differences, L2 phonemic acquisition will be blocked because the perceptual system will perceive both sounds as equal and will not establish a new category. It is evident that this phenomenon arises because the native and target languages are both within the aural-oral modality. The distinct communicative channels between speech and signs make it a physical impossibility for spoken phonemes to interfere with L2 sign production. However, the perceptual system may block the creation of new visual phonological categories given the structural similarities between iconic signs and gestures.

Section 1.1.1 explained that while many signs do not exhibit any formational similarity with the concept they depict (arbitrary signs), the form of a large number of signs is motivated by the visual characteristics of their referent (iconic signs) (Mandel, 1977; Taub, 2001). Section 1.1.2 established that the capacity to incorporate features of a physical referent is not exclusive to signs because the speaking community also makes use of the same resources during gestural production. Gestures have a variety of forms and functions and they may involve re-enactment of an action (mimes), refer to an object present (pointing), or have a more conventionalised structure within a culture (emblems) (McNeill, 1992). It is clear from the findings in Chapter 2 that non-signers can recognise many iconic signs, arguably due to the shared similarities in form and meaning with their own co-speech gestures. Some iconic signs are recognisable manual forms to non-signers despite their lack of knowledge of a sign language. This may occur because signing communities have integrated gestures from the speaking community into their manual lexicon. BSL, for example, makes extensive use of mime, pointing, and emblems as part of its lexical repertoire (see Figure 4.1). Additionally, all sign languages have evolved from the gestures used in the surrounding speaking community and this connection is still apparent in modern sign languages (Janzen & Schaffer, 2002). A crucial distinctive characteristic, however, is that signs have undergone lexicalisation processes and their structures comply with the phonotactic rules of a sign language (Corina & Sandler, 2009). Despite iconic signs showing resemblance with their referents, they consist of the building blocks permissible in a sign language. In contrast, gestures are holistic units incapable of sub-lexical decomposition (McNeill, 1992). Iconic signs may show resemblance with some gestures, but the key difference is that sign constituents are highly conventionalised within a signing community. How the structural similarities between both types of manual forms may affect sign L2 acquisition remains unexplored.

Figure 4.1 Conventionalised BSL signs sharing structural similarities with co-speech gestures. The sign TO-BRUSH is pantomime of brushing, TIME is produced by pointing at an imaginary watch and HOPE is an emblem used in many Western cultures.

Section 1.2 explained that children acquiring a sign language as L1 do not seem to exhibit any preference in learning iconic over arbitrary signs (Orlansky & Bonvillian, 1984) and they do not exaggerate the iconic features of a sign (i.e., more gesture-like) at any stage of their learning (Meier et al., 2008). The explanation is that the ability to link iconic signs with their referent is cognitively taxing (Newport & Meier, 1985). Children have limited world knowledge, thus they are unable to make symbolic mappings with a referent (Namy, 2008). In contrast, studies on sign L2 acquisition have consistently reported the facilitation effect of iconicity in different perceptual tasks. Section 1.3 described a series of studies showing that signers and non-signers alike have a better performance on iconic than arbitrary signs in forced choice and translation tasks (Baus et al., 2012; Campbell et al., 1992; Lieberth & Gamble, 1991). This facilitation occurs because the links between a sign and the conceptual system are reinforced by the iconic elements featured in the sign (Baus et al., 2012). This argument has been further supported by behavioural and neurological data showing that iconicity activates imagistic information, facilitating L2 learning (Kelly, McDevitt, & Esch, 2009). What these studies have shown is that the ability to make those links makes iconic signs more memorable and easier to recall. An unanswered empirical question is if the facilitation effect of iconicity is also present during the articulation of the phonological components of signs.

The present study implemented a sign repetition task to investigate to what extent hearing adults were capable of articulating the phonological constituents of iconic and arbitrary signs. Following previous evidence that iconic signs are easier and more accurately recalled (Campbell et al., 1992; Lieberth & Gamble, 1991), this study investigates whether articulation accuracy varies as a function of iconicity. Iconic signs have been shown to have a facilitation effect in perceptual tasks, thus it was predicted that it would also show an effect during production tasks. Namely, it was hypothesised that there would be a significant difference in articulation accuracy between arbitrary and iconic signs.

4.2 Methodology

4.2.1 Participants

Fifteen hearing learners of BSL were recruited for this experiment. Participants were monolingual native speakers of English and all except one had resided in the UK from birth (one participant was an American exchange student). None had knowledge of any sign language but five reported basic knowledge of the BSL manual alphabet. All participants had good or corrected vision and two participants reported being left-handed. Participants were required to take part in a sign repetition task twice: before they started the first module of BSL Level 1 and once more after they completed the 11-week course (22 hours of instruction). Six participants failed to return to the second testing session so their data was excluded from the analysis. The final cohort of participants consisted of nine BSL students (8 female, mean age = 20.22 years).

4.2.2 Stimuli

Based on the iconicity ratings for 300 signs reported in Chapter 2, a cohort of 96 signs were selected (48 iconic and 48 arbitrary). Signs with ratings above 3.5 were regarded as iconic and signs with lower values were regarded as arbitrary. Following the guidelines of the described in Chapter 3 (see Section 3.2.1) the stimuli were classified in six subcategories. In the arbitrary condition there were: 8 one-handed signs articulated in neutral space (Type 1); 8 one-handed signs with contact with the body (type 2); 8 two-handed signs with symmetrical movement in neutral space (Type 3); 8 two-handed signs with symmetrical movement with contact with the body (Type 4); 8 two-handed signs with symmetrical handshapes and the dominant hand acting on the non-dominant (Type 5); and 8 two-handed signs with asymmetrical handshapes and the dominant hand acting on the non-dominant (Type 6). The same criteria was used for the iconic condition making a total of 96 signs (6 sign Types x 8 signs in each type x 2 conditions = 96 signs). This distribution ensured that each condition contained overall the same number of phonological parameters.

The stimuli were selected so that all signs' phonological parameters in both conditions were balanced for phonological complexity. In order to achieve this, signs were selected so that there were a balanced number of movement, handshape, and location types (see Section 1.1 for a full description of sign phonology and the concept of markedness). For movement, the stimuli were selected so that signs in both conditions had a balanced number of path, hand internal movements, or both (path and internal). With regard to handshape, stimuli were selected so that arbitrary and iconic signs included approximately the same number of marked and unmarked handshapes (Sutton-Spence & Woll, 1999). Given that there are some signs that involve transition from one handshape to another, the stimuli was also selected so that both conditions had a balanced number of signs including handshape change. The place of articulations of all signs was also balanced so that the signs were articulated in approximately the same locations. Because of the limited literature on orientation and its marked features, this parameter could not be balanced. See Appendix D and Appendix E for a complete list of stimuli and their phonological features.

4.2.3 Procedure

Participants were tested under the same conditions and in the same lab as participants in Chapter 3. Similarly, this study followed the same procedure except that in the present study the English translation of the BSL sign did not precede the signed stimuli (see Section 3.2.2). At the beginning of each trial, a fixation point appeared in the middle of the screen for 1000 ms. Then the video clip of a BSL sign was shown for its entire duration (approximately 4000 ms). When the video clip had stopped and disappeared from the screen, participants had 5000 ms to imitate the sign as accurately as possible. These participants also had to run a practice trial with ten signs before taking part in the actual experiment. Unlike participants in Chapter 3, these participants were tested before they started their BSL course and once again after 22 hours (11 weeks) of instruction. The signed stimuli were the same items in both testing sessions and were presented in different randomised orders.

4.2.4 Analysis

Following data collection, the videos of each participant's articulations were glossed using the linguistic annotator programme ELAN (Lausberg & Sloetjes, 2009). In order to determine articulation accuracy, each sign was rated for each sign parameters (handshape, location, movement, and orientation). The coding and validity schemes in this study followed the same guidelines described in Chapter 3 (see Section 3.2.3) and were applied to both testing sessions.

4.3 Results

In order to investigate how sign structure and iconicity impact sign articulation, a 2 (iconic vs. arbitrary) x 6 (sign Type) repeated measures ANOVA with testing session as a between-subjects factor was carried out. There was a main effect of iconicity [$F(1,16) = 11.919$; $p = 0.003$, $\eta^2 = 0.427$] with iconic signs (mean = 0.807, SD = 0.011) being articulated less accurately than arbitrary signs (mean = 0.836, SD = 0.01; $t(107) = -1.679$, $p = 0.048$). The analysis revealed that there was a main effect of sign Type [$F(5,80) = 9.780$; $p = 0.000$, $\eta^2 = 0.379$] with overall articulation accuracy decreasing as the sign Type increased: Type 1 (mean = 0.840; SD = 0.011), Type 2 (mean = 0.864; SD = 0.009), Type 3 (mean 0.789; SD = 0.018), Type 4 (mean = 0.830; SD = 0.012), Type 5 (mean = 0.815; SD = 0.013), and Type 6 (mean = 0.792; SD = 0.015). There was no significant interaction between sign Type and testing session [$F(5,80) = 0.886$; $p = 0.494$, $\eta^2 = 0.052$] or between iconicity and testing session [$F(1,16) = 0.265$; $p =0.265$, $\eta^2 = 0.016$]. There was no significant interaction between sign Type, iconicity, and testing session [$F(5,80) = 0.488$; $p = 0.784$, $\eta^2 = 0.030$]. However, the interaction between sign Type and iconicity was significant [$F(5,80) = 7.377$; $p = 0.000$; $\eta^2 = 0.316$].

Post-hoc comparisons between iconic and arbitrary signs for each sign Type were carried out. The analysis revealed that iconic signs in the Type 1 group ($mean_{iconic} = 0.868$, SD = 0.060) were articulated more accurately than arbitrary signs ($mean_{arbitrary} = 0.8111$; SD = 0.084; $t(17) = 2.202$; $p = 0.042$). There was no significant difference in articulation between iconic ($mean_{iconic} = 0.873$; SD = 0.053) and arbitrary signs ($mean_{arbitrary} = 0.855$; SD = 0.048; $t(17) = 1.262$; $p =0.224$) in signs Type 2. Similarly, there was no significant difference in articulation accuracy between iconic ($mean_{iconic} = 0.778$; SD = 0.113) and arbitrary signs ($mean_{arbitrary} = 0.798$; SD = 0.071; $t(17) = -0.946$; $p = 0.357$) in Type 3 signs. Type 4 signs showed a significant difference with iconic signs ($mean_{iconic} = 0.802$; SD =

0.082) being articulated less accurately that arbitrary signs (mean $_{arbitrary}$ = 0.857; SD = 0.072; $t(17) = -2.229$; $p = 0.040$). Type 5 signs also displayed significant differences, with iconic signs (mean $_{iconic}$ = 0.773; SD = 0.079) being articulated less accurately than arbitrary signs (mean $_{arbitrary}$ = 0.855; SD = 0.060; $t(17) = -4.507$; $p = 0.000$). Type 6 signs revealed a similar pattern given that iconic signs (mean $_{iconic}$ = 0.745; SD = 0.087) were also articulated less accurately than arbitrary signs (mean $_{arbitrary}$ = 0.839; SD = 0.839; $t(17) = -4.540$, $p = 0.000$). Figure 4.2 displays the interaction between sign type and iconicity.

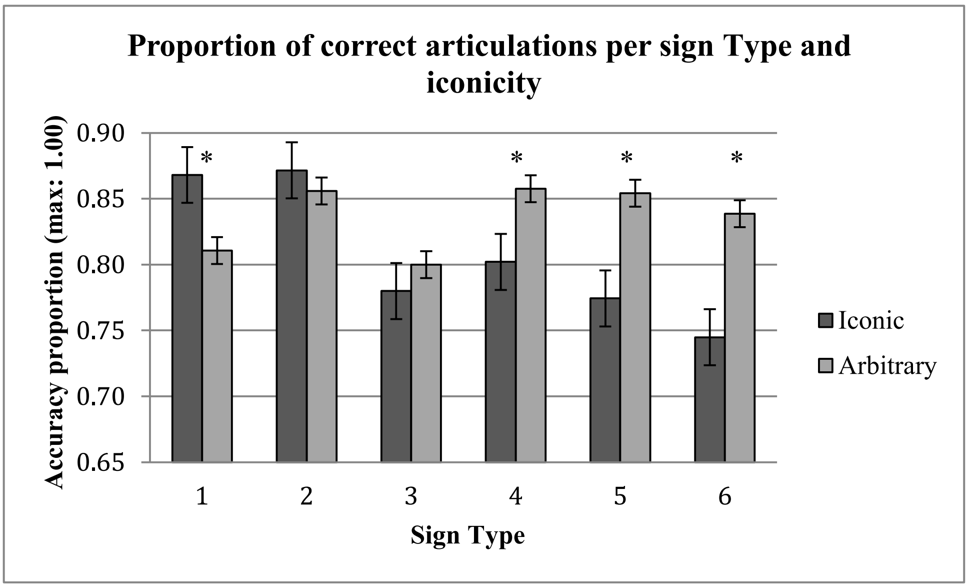


Figure 4.2 Proportion of correct articulations for iconic and arbitrary signs according to each sign Type (bars represent standard error).

Articulation accuracy for each phonological parameter in the iconic and arbitrary conditions in both testing session are presented in Table 4.1. A 2 (iconic vs. arbitrary) x 4 (phonological parameter) ANOVA with testing session as between-subjects factor was used to detect differences in sign articulation. The analysis revealed that there was no main effect of iconicity [$F(1,16) = 0.539$; $p = 0.474$; $\eta^2 = 0.033$], but there was a tendency to articulate the parameters in iconic signs (mean = 0.793, SD = 0.02) less accurately than in arbitrary signs (mean = 0.812, SD = 0.01). There was no significant interaction between iconicity and testing session [$F(1,16) = 0.058$, $p = 0.813$, $\eta^2 = 0.004$]. There was, however, a main effect of phonological parameter [$F(3,48) = 188.135$; $p = 0.000$; $\eta^2 = 0.922$]. Location was the most accurately articulated (mean = 0.931; SD = 0.086), followed by orientation (mean = 0.884; SD = 0.086), then movement (mean = 0.766; SD = 0.114), and finally handshape (mean = 0.626; SD = 0.115). Post-hoc comparisons revealed that all parameters where articulated significantly differently from each other. The parameter handshape was articulated significantly differently from location [$t(35) = -19.712$; $p < 0.000$], movement [$t(35) = 8.454$; $p < 0.000$], and orientation [$t(35) = -16.089$; $p < 0.000$]. Location was significantly different from movement [$t(35) = 13.135$; $p < 0.000$] and orientation [$t(35) = 5.603$; $p = 0.000$]. Movement was articulated significantly differently from orientation [$t(35) = -11.259$; $p < 0.000$]. There was no significant interaction between phonological parameter and testing session [$F(3,48) = 0.848$, $p = 0.474$, $\eta^2 = 0.050$], or between parameter and iconicity [$F(3,48) = 2.070$, $p = 0.117$, $\eta^2 = 0.115$]. There was no significant interaction between phonological parameter, iconicity, and testing session [$F(3,48) = 0.272$, $p = 0.845$, $\eta^2 = 0.017$]. To further investigate whether iconicity hindered sign articulation in each phonological parameter, degree of accuracy and iconicity ratings were rank-ordered and compared with each other. A Pearson product-moment correlation coefficient revealed that there was a statistically significant negative correlation between these two measures ($\rho = -0.190$, n = 96, $p = 0.032$) suggesting that as iconicity ratings increase, articulation accuracy decreased accordingly.

Table 4.1 Proportion of correct articulations per phonological parameter (SD in parenthesis) in iconic and arbitrary signs in both testing sessions.

	Time 1		Time 2	
	Iconic	Arbitrary	Iconic	Arbitrary
H	0.57 (0.14)	0.56 (0.10)	0.67 (0.08)	0.68 (0.10)
M	0.69 (0.15)	0.74 (0.14)	0.78 (0.04)	0.83 (0.05)
O	0.83 (0.12)	0.86 (0.09)	0.90 (0.03)	0.92 (0.05)
L	0.90 (0.12)	0.87 (0.09)	0.96 (0.04)	0.97 (0.03)

4.4 Discussion and conclusions

The objective of the present study was to examine the effect of iconicity on sign articulation by hearing learners of BSL. The results show that iconicity has a negative effect because iconic signs were articulated consistently less accurate than arbitrary signs. There was an interaction between degree of iconicity and sign structure because signs with more phonological features were less accurate in the iconic than in the arbitrary condition. The data show that, while accuracy in arbitrary signs remains relatively stable across the different sign Types, in iconic signs it gradually decreases until it reaches its lowest point in Type 6 signs. Lower articulation accuracies in iconic signs were evident also at the sub-lexical level. Accuracy in each phonological parameter followed the same pattern as the reported in Chapter 3 because handshape was the least accurate, followed by movement, then orientation and finally location. There was a tendency of these parameters to be less accurate in iconic than in arbitrary signs.

These results support the prediction that iconic signs would be articulated as significantly different from arbitrary signs. It is possible that when viewing arbitrary signs, participants were unable to map them onto a referent and consequently had to pay close attention to their components in order to imitate them accurately. In contrast, participants did not have to pay attention to the phonological structure of iconic signs because they recognised their meaning due to their clear mappings with their referent. Participants may have processed iconic signs at a superficial level, thereby overlooking some of the exact phonological sign components causing significantly more articulation errors. In other words, participants were able to associate iconic signs with their referent, and during articulation they retained their iconic elements but dismissed some of their phonological constituents.

A plausible explanation behind these findings is the similarities between iconic signs and co-speech gestures. In BSL, as in many sign languages, iconic signs share structural overlap with the gestures used by hearing people during speech. However, in spite of their apparent similarities, signs depicting physical features of a referent consist of systematic meaningless constituents (Stokoe, 1960). Gestures do not consist of meaningless components but rather are holistic manual units that cannot be decomposed into sub-lexical elements (McNeill, 1992), which makes them more structurally variable within and across speakers. Given that participants are used to processing meaningful hand movements that resemble conventionalised iconic signs, they may be biased towards processing iconic signs as iconic gestures.

Arguably, phonological complexity may be partially responsible for the pattern of errors produced by participants. Indeed, the articulation errors of the current experiments follow the same pattern as those reported in Chapter 3 and those observed in deaf children acquiring a sign language from birth (Conlin et al., 2000; Marentette & Mayberry, 2000; Morgan et al., 2007): handshape being the least accurately produced, followed by movement, then orientation and finally location. However, the analysis of articulation accuracy for iconic and arbitrary signs clearly shows that this pattern holds regardless of sign Type, but with accuracy being lower in iconic signs. In other words, some parameters are clearly more difficult to produce than others, but in iconic signs they are articulated consistently less accurately. This suggests that signs that resemble iconic gestures are produced with sufficient structural similarity to display the physical features of a referent but without the exact conventionalised elements of BSL (i.e., without phonology).

In sum, the explanation for the current results is that at the early stages of sign L2 acquisition, learners' experience processing gestures interfere in the processing of the exact phonological features of iconic signs. Arbitrary signs cannot be matched with a meaningful representation hence participants have to be more careful in decoding their exact components. Because it is possible to access the meaning of iconic signs by processing them as holistic units, attention to their specific phonetic components is less relevant. It appears that sign L2 learners substitute real iconic signs with their own co-speech gestures, and this leads to lower articulation accuracies. Only after gaining experience with a sign language, will participants learn to selectively look for the relevant components of a sign to produce them accurately.

Interference from existing internal representations has been reported in the spoken modality. In non-word repetition tasks, for instance, when target non-words include phonemes not present in participants' phonological inventory, they will tend to be substituted with their closest available equivalent (Flege, 1992, 1995). In the context of L2 acquisition, when a novel phoneme has overlapping similarities, but lacks the exact phonological specifications of an existing L1 sound (e.g., /i/ vs. /ɪ/), learners will perceive them as equivalent and will fail to create a new category for them. The same underlying principle appears to govern sign repetition tasks: If existing acoustic representations block the accurate perception of similar novel sounds, it is likely that visual-manual representations will interfere in the perception of a visual-spatial language. It is possible that such a source of interference is co-speech gesture.

The data from these sign repetition tasks suggest that iconicity hinders sign articulation. This does not imply that phonological complexity can be disregarded as an important factor during sign perception. Natural sign production is quick and naïve signers may only be capable of perceiving the most salient phonological elements, making them overlook more subtle or ephemeral parameters (e.g., hand internal movements). What this study shows, however, is that in addition to the structural complexity of a sign, iconicity is another factor that negatively impacts on the articulation of iconic signs, arguably because of their resemblance with co-speech gestures. In order to further investigate this claim, the following chapter explores whether iconic signs produce the same behavioural effects in the mental lexicon of non-signers as iconic gestures.

5 Cross-modal priming

5.1 Introduction

Gestures are a fundamental aspect of human communication and are observed in speakers of all ages and cultures. Overwhelming empirical evidence has shown that speech and gestures are not independent but rather form complex, highly integrated systems that convey important semantic and pragmatic information of a multi-modal utterance (Kelly, Kravitz, & Hopkins, 2004; Kendon, 1995). The influence that gestures exert in speech has been found at many levels including syllabic articulation (Gentilucci & Dalla Volta, 2008), sentence processing (Taylor & Zwaan, 2008) and neural activation (Buccino, et al., 2004). Relevant to this study is the claim that gestures aid lexical retrieval because speech and gesture are interconnected to the same conceptual representations (Krauss, 1998). Support to this claim comes from recent empirical data demonstrating that iconic gestures prime words in speakers' native language (Yap et al., 2011). The behavioural response that iconic gestures produce in the lexicon of non-signers could be exploited to determine whether non-signers process iconic signs as gestures at the early stages of sign language learning.

Cross-modal activation between sign and speech has been documented in recent years. Morford, Wilkinson, Villwock, Piñar, and Kroll (2011) asked deaf ASL-English bilinguals to determine whether English word pairs were semantically related (e.g., *heart-brain*) or unrelated (e.g., *body-lion*). Semantically related words whose underlying ASL translations shared phonological features, i.e., they shared handshape, location, movement or orientation (see Figure 5.1) were detected faster because their overlapping structures facilitated access to the semantics of the target word. In contrast, semantically unrelated word pairs whose ASL translations had phonological overlap produced slower response times because the additional activation produced by the signs had to be suppressed in order to produce a negative response.

Figure 5.1 Phonologically related sign pairs in ASL, MOVIE (left) and PAPER (right). Figure adapted from (Morford et al., 2011).

The same cross-modal effect has been documented in a typologically unrelated sign language. Using a word-picture verification task, Ormel, Hermans, Knoors, and Verhoeven (2011) asked deaf children who were users of Dutch and Sign Language of the Netherlands (NGT) to make judgments about the semantic relatedness of picture-word pairs. In one condition, the underlying sign translations of the word and the picture had phonological overlap. In another condition, the underlying NGT translations were highly iconic (e.g., the NGT sign HOUSE depicts the pointed roof of a house). The results showed that for mismatching pairs in both conditions, response times were slower than controls because phonological overlap and high iconicity activated two signs simultaneously, causing lexical competition and slowing response times.

This cross-modal activation effect is not limited to deaf signers who have acquired a sign language as L1. Using a visual world paradigm, Shook and Marian (2012) investigated whether hearing ASL-English bilinguals co-activated lexical items in the spoken and visual modality. Participants were instructed, in English, to select one object from a display of pictures while their eye-movements were recorded. Participants looked more at competitors when they shared underlying ASL phonological overlap, showing that selection of a spoken word leads to activation of lexical items across modalities.

These findings show that deaf and hearing bilinguals co-activate their two languages despite the different modalities of their phonological systems. Importantly, they demonstrate that iconicity has a facilitation effect during lexical access (Ormel et al., 2011). These studies, however, give evidence of cross-linguistic cross-modal interaction in groups with high proficiency in a sign and spoken/written language. An important question is whether iconic signs activate the mental lexicon of hearing non-signers and whether this effect is the result of their experience with processing iconic gestures.

The study of manual communication has undergone extensive scrutiny over the last years, with research producing convincing evidence that gesture and speech have a strong bidirectional relationship. Both are highly synchronised systems in which the lexical items of a spoken utterance have temporal and semantic overlap with the gestures with which they co-occur (Kita & Özyürek, 2003). Speakers simultaneously integrate information from the verbal and manual signal to decode the meaning of a multi-modal utterance (Kelly, Creigh, & Bartolotti, 2010; Ozyürek, Willems, Kita, & Hagoort, 2007). Iconic gestures, in particular, play a prominent role during speech comprehension. During naturalistic communication, interlocutors increase the production of iconic signs to clarify lexical ambiguity (Holler & Beattie, 2003) and to facilitate the exchange of complex information (Campisi & Özyürek, 2013). The prominent role of iconic gestures during speech comprehension may relate to the claim that they aid lexical retrieval (Krauss, 1998).

Gesture research has generated a number of proposals supporting the idea that iconic gestures facilitate lexical access. The Image Activation Hypothesis proposes that iconic gestures help to maintain the visual characteristics of a referent while the linguistic system performs a search of a lexical item (De Ruiter, 1998). The Lexical Retrieval Hypothesis argues that iconic gestures activate conceptual information which in turn leads to activation of semantically related words through cross-modal priming (Krauss, Chen, & Chawla, 1996; Krauss, 1998). These hypotheses coincide that iconic gestures ground in physical reality the spatial features of an object while the linguistic system searches for the label of a referent. Despite some differences in their theoretical grounding, both hypotheses support the notion that iconic gestures activate conceptual features of a referent to facilitate lexical retrieval.

Yap et al. (2011) have generated empirical evidence to further support the close interaction between iconic gestures and speech at the lexical level. By implementing a cross-modal lexical decision task, the study showed that iconic gestures prime semantically related words. Participants were shown iconic signs followed by target words, after which they had to decide whether the word was real (e.g., *bird*) or a pseudowrd (e.g., *flirp*). Target words (e.g., *bird*) could be preceded by an iconic gesture to which they were semantically related (e.g., flapping hands) or unrelated (e.g., tracing a square with the fingers). The results show that words were identified significantly faster when they were preceded by semantically related gestures, supporting the notion that processing iconic gestures facilitate lexical retrieval. If, as Section 4.1 explained, iconicity lies at the intersection between signs and gestures, iconic signs would be expected to produce the same behavioural responses as gestures in the mental lexicon of non-signers.

Chapter 4 showed that non-signers articulated iconic signs less accurately than arbitrary signs, arguably because during the processing of their structure, the iconic features were retained but the exact phonological structure was overlooked. These results were interpreted as non-signers being biased towards processing iconic signs as gestures given their apparent structural similarities. Non-signers are unlikely to be sensitive to the phonological features of iconic signs because access to their meaning (as well as of iconic gestures) does not require phonological mediation. The aim of the present study is to seek further support to the claim that iconic signs are processed as iconic gestures (i.e., without paying attention to the sub-lexical units of signs).

Chapter 2 explained that iconic signs are not a homogenous group because the features of their referent can be incorporated in a number of ways (Cuxac, 1999; Johnston & Schembri, 2007; Klima & Bellugi, 1979; Mandel, 1977; Pietrandrea, 2002; Taub, 2001). It was also explained that iconicity is not a categorical property but rather lies in a continuum which allows non-signers different levels of access to the meaning of signs. Developmental studies clearly show that the ability to perceive iconicity of different types of iconic signs develops gradually (Tolar et al., 2008). This was further attested by the findings from Chapter 2 which showed that iconicity ratings by non-signing adults varied as a function of the referent depicted, with signs depicting actions being regarded as the most iconic of all. Based on these premises, the second aim of this study was to determine whether rate of activation in the mental lexicon varied as a function of meaning transparency.

The present study implemented a cross-modal lexical decision task to investigate whether iconic signs prime semantically related words in participants with no prior knowledge of a sign language. If hearing non-signers interpret iconic signs as meaningful gestures, presentation of iconic signs is likely to activate semantically related words in their spoken L1 in the same way as iconic gestures do (Yap et al., 2011). If hearing non-signers do not exploit their gestural knowledge to access the meaning of iconic signs, semantically related and unrelated words will be recognised at the same rate. In addition, if opaque signs (lower iconicity ratings) are more difficult to understand, it would be expected that their priming effect would be lower, arguably because interpretation of these signs is more cognitively taxing. In contrast, iconic signs with more direct mappings (i.e., higher iconicity ratings) will be easier to understand and thus will produce faster priming effects.

5.2 Methodology

5.2.1 Participants

Two groups of participants took part in this experiment: non-signers and proficient signers. The non-signer group consisted of 20 right-handed monolingual native speakers of English (9 female, mean age = 29.38 years). The group of proficient signers consisted of 20 hearing native speakers of English (14 female, mean age = 35.45 years). These were carefully screened so that they all had achieved the British National BSL level 2 certification and had the same length of exposure to BSL.

5.2.2 Stimuli

The stimuli used for this study were individual BSL signs from the set of 300 signs described in Chapter 2. Iconic signs were defined as those whose iconicity ratings were above 3.5 (see Section 2.2). For the purposes of the study, iconic signs depicting actions or objects were selected (see Figure 5.2). The experimental stimuli consisted of a total of 28 action and 28 perceptual signs with mean iconicity ratings of 6.32 (SD = 0.35) and 5.17 (SD = 0.96), respectively. A paired sample t-test revealed that there was a significant difference in iconicity ratings between both sign groups [$t(27) = 9.765$, $p < 0.000$].

Figure 5.2 The BSL sign CAMERA (left) is an action sign because it is the pantomime of the manipulation of an object. The sign AEROPLANE (right) is a perceptual sign because it depicts the shape of an object.

Each sign in the action and perceptual condition was matched with a semantically related word from the Edinburgh Associative Thesaurus (Kiss, Armstrong, Milroy, & Piper, 1973). To date there is no empirical data on semantic associations across modalities (word-gesture/sign). It was therefore assumed that the BSL sign would have the same effect on semantically related words as its English translation. In other words, it was assumed that the BSL sign CAMERA would activate the semantically related word 'photo' in the same way as in the spoken modality the word 'camera' activates the word 'photo'. The semantically related words in each condition were controlled for length and frequency. The mean length of words in the action condition was 4.68 (SD = 0.81) and 4.18 (SD = 1.21) for perceptual signs. A paired sample t-test showed that there was no significant difference in word length between both conditions [$t(27) = 1.537$, $p = 0.136$]. The word frequency values were collected from the MRC Psycholinguistic Database (Wilson, 1988). The mean frequency values for the words in the action and perceptual condition were 81.00 (SD = 105.95) and 82.93 (SD = 77.15), respectively. A paired sample t-test showed that there was no significant difference between the frequencies of both word groups [$t(53) = 0.0043$, $p = 0.039$]. Action and perceptual signs were also paired with a semantically unrelated word. These were the semantically related words used in the other sign condition (i.e., the semantically related words in the action condition were the semantically unrelated words for the perceptual condition and vice versa). Lastly, signs were matched with non-words to allow participants to make the lexical decision. These words were drawn from ARC non-word database (Rastle, Harrington, & Coltheart, 2002). See Appendix F and Appendix G for a full list of experimental items.

In sum, each sign in the action and perceptual conditions was shown four times: with a semantically related word, with a semantically unrelated word, and with two different non-words making a total of 224 sign-word pairs. The experiment was divided into two blocks with a break in-between. Each block consisted of 56 sign-pairs from the action condition and 56 pairs from the perceptual condition making a total of 112 sign-word pairs in each block. Ten participants saw block 1 first and block 2 second and the rest of participants saw the blocks in reversed order.

5.2.3 Procedure

Participants were tested individually on a portable computer in a quiet room. The programme E-prime v. 2.0.8.90 (Schneider, Eschman, & Zuccolotto, 2002) was used to display trials and measure reaction times. The procedure was as follows: first, a fixation point appeared in the centre of the screen for 500 ms. This was followed by the video clip of the iconic signs which lasted 2000 ms. Immediately after the video stopped playing, a lower case target word in black letters over white background appeared on the screen for 1500 ms. Participants were instructed to pay close attention to the sign and decide whether the word that followed was real or not. If they considered that the word was real they had to press as quickly and accurately as possible the key 'J' with their right (dominant) hand. If they believed the target word was a non-word they had to press the 'F' key with their left (non-dominant) hand.

Reaction times were recorded in milliseconds from the onset of the target word. Responses 2.5 standard deviations away from the mean (4.9% and 0.95% for non-signers and proficient signers, respectively) were classed as outliers and removed from the analysis. Inaccurate responses (7.3% and 1.09% for non-signers and proficient signers, respectively) were also excluded and replaced with the condition mean.

5.3 Results

As for non-signers, a 2 (word relatedness) x 2 (iconicity type) ANOVA per participants (F_1) and items (F_2) revealed that there was a main effect of word relatedness [$F_1(1, 19) = 20.862$, $p = 0.000$, $\eta^2 = 0.523$; $F_2(1, 27) = 7.175$, $p = 0.012$, $\eta^2 = 0.210$]. Real words were recognised faster when they were preceded by semantically related signs (mean = 567.573 ms, SD = 9.72) than when they were paired with unrelated signs (mean = 583.93 ms, SD = 11.05). The analysis further revealed there was no main effect of iconicity type [$F_1(1, 19) = 0.859$, $p = 0.366$, $\eta^2 = 0.043$; $F_2(1, 27) = 0.014$, $p = 0.907$, $\eta^2 = 0.001$]. Participants were equally fast at identifying semantically related words paired with action signs (mean = 573.375 ms, SD = 11.21) as semantically related words paired with perceptual signs (mean = 578.132 ms, SD = 9.89). The interaction between iconicity type and word relatedness was significant in the analysis per participant [$F_1(1, 19) = 4.763$, $p = 0.042$, $\eta^2 = 0.200$] but not in the analysis per item [$F_2(1, 27) = 2.260$, $p = 0.144$, $\eta^2 = 0.077$]. Planned pairwise t-tests after Bonferroni corrections showed that within the action condition, real words were identified faster when they were preceded by a semantically related sign (mean = 568.138 ms, SD = 49.09) than when they were preceded by an unrelated sign (mean = 578.613 ms, SD = 52.795, $t(19) = 2.545$, $p = 0.020$). Similar results were observed in the perceptual condition: words preceded by semantically related signs were recognised faster (mean = 567.008 ms, SD = 41.71) than words paired with semantically unrelated signs (mean = 589.257 ms, SD = 49.05, $t(19) = 0.4.611$, $p = 0.000$). Pairwise t-tests after Bonferroni corrections between the semantically related pairs in the action condition (mean = 568.13 ms, SD = 49.09) and the semantically related pairs in the perceptual condition (mean = 567.00, SD = 41.71) revealed no significant differences [$t(19) = 0.187$, $p = 0.854$]. No main effects or interactions were found in the error analysis (see Figure 5.3).

These results confirm the hypothesis that iconic signs activate semantically related words across modalities in the same way as gestures do (Krauss, 1998). This supports the results reported in Chapter 3 and 4 that iconic signs are interpreted as co-speech gestures by hearing non-signers. However, contrary to the initial prediction, signs depicting action do not facilitate recognition because both action and perceptual signs yielded the same reaction times. This suggests that the more direct iconic mappings in action signs do not accelerate identification.

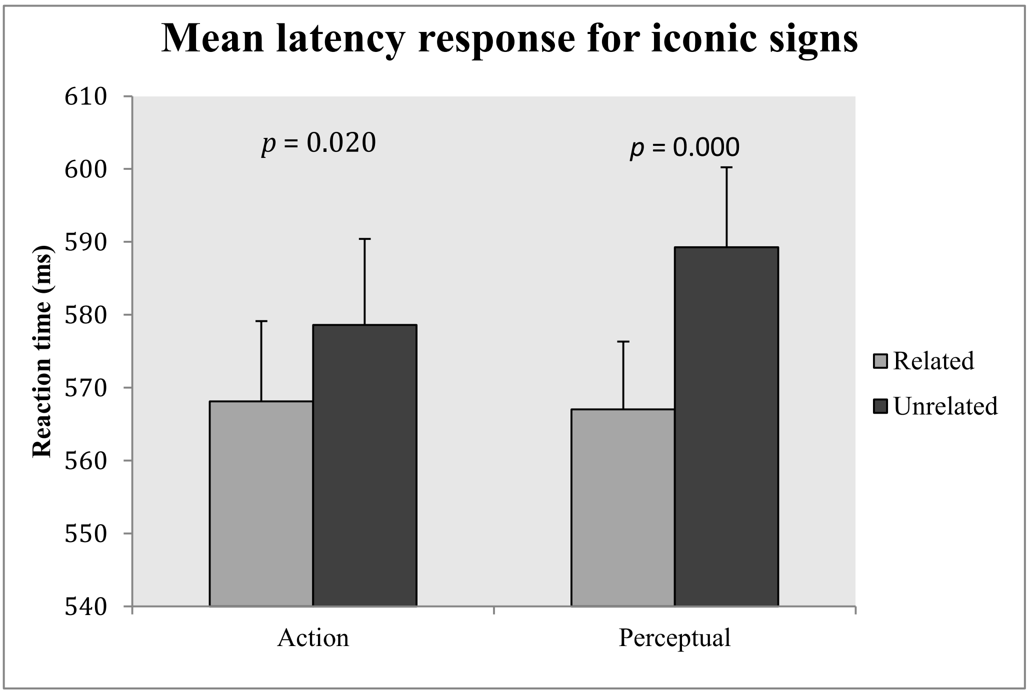


Figure 5.3 Mean reaction times in ms for target words preceded by semantically related and unrelated BSL signs for non-signers. Bars represent standard error.

As for proficient signers, a 2 (word relatedness) x 2 (iconicity type) ANOVA per participants (F_1) and items (F_2) revealed that there was no significant main effect on word relatedness [$F_1(1, 19) = 1.895$, $p = 0.188$, $\eta^2 = 0.089$; $F_2(1, 27) = 3.381$, $p = 0.077$, $\eta^2 = 0.111$] suggesting that words preceded by semantically related signs (mean = 571.969 ms, SD = 14.77) are not recognised faster than words preceded by semantically unrelated sign (579.02 ms, SD = 14.336). There was a significant main effect of iconicity type [$F_1(1, 19) = 21.429$, $p = 0.000$, $\eta^2 = 0.530$; $F_2(1, 27) = 7.633$, $p = 0.010$, $\eta^2 = 0.220$] with words paired with action signs yielding faster response times (mean = 565.734, SD = 13.47) than words paired with perceptual signs (mean = 585.256, SD = 15.41). The analysis per participant [$F_1(1, 19) = 7.757$, $p = 0.012$, $\eta^2 = 0.290$] but not per item [$F_2(1, 27) = 1.934$, $p = 0.176$, $\eta^2 =$

0.067] revealed a significant interaction between word relatedness and iconicity type. Pairwise t-tests after Bonferroni corrections revealed that in the action condition, semantically related pairs yielded faster response times (mean = 557.244, SD = 13.10) than semantically unrelated pairs (mean = 574.223, SD = 14.33, $t(19) = -3.744$, $p = 0.001$). In contrast, in the perceptual condition semantically related pairs were slightly faster (mean = 586.694, SD = 16.81) than unrelated pairs (mean = 583.816, SD = 14.88), but these differences did not reach significance [$t(19) = 0.377$, $p = 0.710$]. The analysis also revealed that words associated with a semantically related action sign were detected significantly faster than words preceded by semantically related perceptual signs [$t(19) = -4.920$, $p = 0.000$]. Semantically unrelated words preceded by action or perceptual signs were identified at the same rate [$t(19) = -1.013$, $p = 0.071$]. The error analysis revealed no significant main effects or interaction (see Figure 5.4).

The different pattern of results exhibited by non-signers and signers is interpreted as evidence that proficiency in a sign language affects the mechanisms for processing iconic signs. Importantly, while the distinction between different types of iconicity did not affect lexical access in hearing non-signers, it had an effect on signers who had developed a visual phonological system.

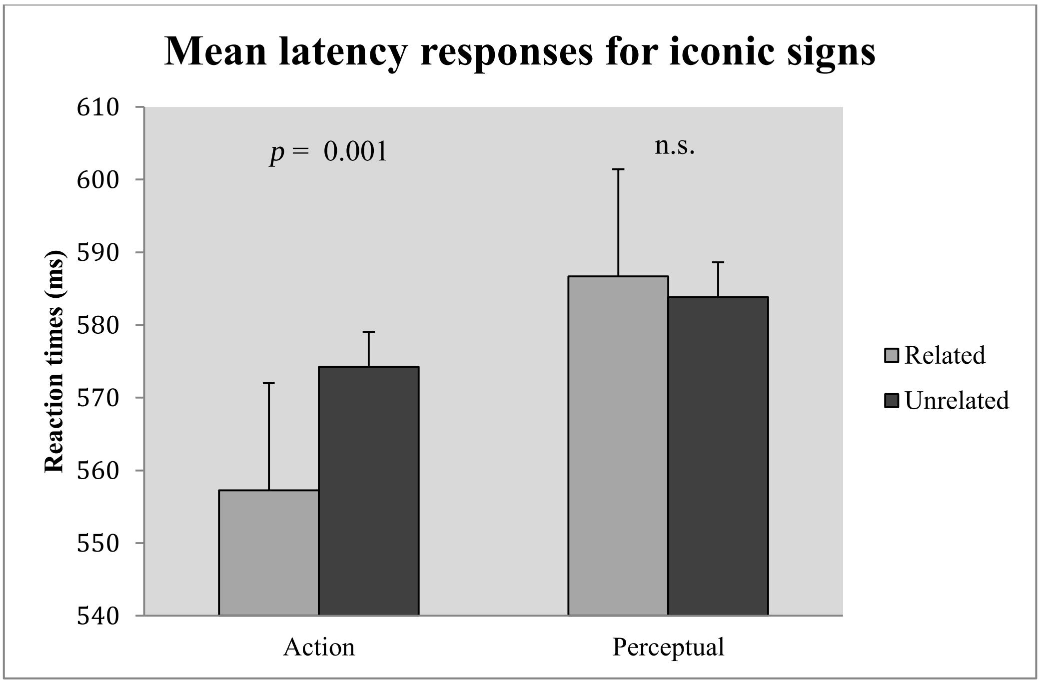


Figure 5.4 Mean reaction times in ms for target words preceded by semantically related and unrelated BSL signs for proficient signers. Bars represent standard error.

5.4 Discussion and conclusions

The data from non-signers shows that iconic signs activated semantically related words in hearing non-signers regardless of their unfamiliarity with BSL. However, the distinction between signs depicting actions and those depicting perceptual features of an object was not significant because semantically related words were activated at the same rate by both types of signs types. It was also predicted that the pattern of activation of proficient signers would be different from non-signers because they have developed the visual phonological categories. Contrary to predictions, iconic signs did not affect the lexicon of proficient signers in the same way as hearing non-signers because only action signs activated semantically related words in the proficient group.

Cross-modal sign-word activation in deaf signers has been reported before (Morford et al., 2011; Ormel et al., 2009; Shook & Marian, 2012). Participants of the present study, however, had no knowledge of BSL, thus the mechanism by which iconic signs activated their lexicon must follow an alternative route. The explanation put forward is that experience in understanding and producing iconic gestures caused lexical activation. Research has shown that gesture and speech have temporal and semantic alignment and that speakers are sensitive to the iconic gestures produced during natural communication to facilitate speech perception and production (Campisi & Özyürek, 2013; Holler & Beattie, 2003; Kita, 2000). Relevant to this study is the claim that gestures facilitate lexical retrieval in typical (Krauss, 1998) and atypical populations (Marangolo et al., 2010). The data from non-signers suggest that the capacity to activate semantically related words is not restricted to gestures because iconic signs generated the same effect. Non-signers are unaware of the subtle structural differences between signs and gestures, so they may rely on the image produced by iconic signs. It appears that non-signers evoke visual imagery to deduce the meaning of any manual representation (i.e., signs or gestures) and this leads to lexical activation. Given that both iconic signs and gestures depict characteristics of a referent, both can activate non-signers' lexicon in a similar way. This suggests that cross-modal lexical activation in the absence of a visual phonology is caused by non-signers interpreting iconic signs as iconic gestures.

How different types of iconicity activate the lexicon of non-signers was also investigated. Iconicity is a property that extends on a continuum, with some sign being easier to understand by non-signers than others (Klima & Bellugi, 1979). This assertion was confirmed for BSL given the variation in ratings for different types of iconic signs (Chapter 2). In the present study, it was expected that comprehension of action signs would be favoured in the adult population because of the direct mappings with their referent. This prediction was supported by the significant differences in iconicity ratings between action and perceptual signs in the experimental stimuli. In addition, previous studies have found that children match action signs with their referent more accurately than signs featuring properties of objects (Tolar et al., 2008). Therefore, the prediction was that the clear mappings between action signs and their referents would lead to faster activation of semantically related words than in the perceptual condition. However, the data did not support this prediction. Contrary to expectations, semantically related words preceded by action signs yielded the same response times as words preceded by perceptual signs. This result could be explained by the accessibility of mental images during communication. Some studies propose that concrete words, like actions and objects, are processed by both the verbal and the image-based systems (Paivio, 1986). If comprehension of iconic signs is mediated by mental imagery, it may be possible that visual representations of actions and objects are equally accessible with neither being accessed more easily. Action and perceptual signs may display the same level of transparency and as a result both may be understood with the same ease. If all mental images (actions and objects alike) are equally accessible when attempting to extract meaning from iconic signs, they will also lead to the same rate of lexical activation.

The results from proficient signers indicate that the relationship between sign prime and target word did not facilitate lexical recognition. Words preceded by semantically related signs did not lead to faster lexical retrieval. This is interpreted as evidence that these L2 learners have developed independence between their spoken (English) and signed (BSL) languages and that lexical retrieval in one does not have cross-modal effect in the other. Previous research has reported similar findings. A study investigating the simultaneous production of sign and speech by hearing proficient signers (code-blending) argues that simultaneous retrieval of a sign and a word is not a serial process but rather is a mechanism that occurs in parallel (Emmorey, Petrich, & Gollan, 2012). The data presented here suggests that proficient signers do not need to match the form of the sign with a mental image but rather that the phonological parameters of a sign mediate lexical access.

An important finding is that the type of iconicity had a different effect in lexical activation in proficient signers. The significant interaction between the type of iconicity and semantic relatedness clearly shows that perceptual signs did not have the same effect in word activation as action signs. While semantically related words paired with action signs were identified significantly faster than unrelated words, semantically related words paired with perceptual signs remained unaffected. The similar pattern of word activation in the action condition by non-signers and signers is interpreted as evidence that they follow the same mechanism in the processing of signs depicting pantomime. It appears that despite their established signed phonological repertoire, proficient signers also process action signs as gestures.

It is evident, however, that proficiency in BSL affects the relationship between perceptual signs and words. Proficient signers recognised words in the semantically related and unrelated conditions at the same rate suggesting that perceptual signs do not spread activation across modalities. Perceptual signs do not have the same direct links with words in the L1 as those observed for action signs. A possible explanation for these results is that awareness of the phonological components of signs impact on the processing of perceptual signs. Psycholinguistic research has shown that lexical access in the signed modality involves encoding and decomposition of the phonological components of signs (Baus et al., 2008; Dye & Shih, 2006). Proficient signers have developed a signed phonological system and thus are aware of the sub-lexical structure of signs. Indeed there is evidence that, when hearing adults gain a certain level of sign language proficiency, they exploit the phonological structure of a sign for lexical processing (Shook & Marian, 2012). It is possible that the proficient signers of the present study have developed the skill to look selectively for the sub-lexical components of signs and exploit them for lexical access. Perhaps slower reaction times in semantically related words in the perceptual condition are the result of perceptual signs being accessed by phonological decomposition and not by evoking a mental image as is the case for action signs.

An alternative explanation relates to perceptual signs having multiple meanings. Research suggests that some iconic signs are not fully specified but rather have partial meanings that become fully specified within a context (Johnston & Schembri, 1999). In addition, some of the phonological parameters of iconic signs may be semantically loaded (Demey & Van der Kooij, 2008; van der Kooij, 2002; Wilcox, 2004). For instance, an index finger on the dominant hand placed on a B-handshape of the non-dominant hand has the unspecified meaning of 'an elongated vertical entity lying on a flat surface'. In the right context this sign could mean 'pencil on a table' or 'person in bed'. Perhaps experience with a sign language has given proficient signers understanding of the multiple meanings associated with some signs and as a consequence processing is slower. Indeed, previous research has shown that iconic signs are accessed more slowly by proficient signers. A study investigating how iconicity affected performance in translation tasks found that the multiple meanings associated with iconic signs slowed lexical access in proficient signers (Baus et al., 2012). A similar effect was observed in the present data. When signers viewed a perceptual sign, multiple meanings may have been activated thus delaying lexical identification. Signs were shown in isolation with no mouthing patterns so there were no syntactic or pragmatic cues to disambiguate their meaning. The perceptual sign BUTTERFLY, for instance, was paired with the semantically related word 'net'. BUTTERFLY has the same form as the sign ANGEL so it is possible that during the task, the two entries competed for selection causing delay in detecting the target word 'net'. With multiple meanings to choose from, participants did not have enough time to compute all possible options before they had to make their lexical decision. The lack of contextual information to disambiguate these signs from the multiple potential candidates could have delayed access to the intended meaning, thus delaying identification of the English words. The different pattern of responses observed from non-signers may be the consequence of multiple meanings competing for selection in perceptual signs.

The distinction between different types of iconic signs did not result in a significant effect in non-signers but it clearly affected the way proficient signers accessed iconic signs. Importantly, the results indicate that experience with a sign language does not affect how action signs are processed. Instead of exploiting their sub-lexical components, it seems that hearing signers process action signs via non-linguistic (visual) representations in the same way as non-signers. That is, both process action signs as gestures. In regards to perceptual signs it is likely that the slower response times are caused by signs having multiple meanings or being accessed by phonological decomposition. These two reasons are not mutually exclusive. Only further research can shed light on the exact mechanisms that govern lexical access of iconic signs in bilingual bimodals.

Taken together, these results suggest that iconicity is an important factor in facilitating sign comprehension. Experience with co-speech gesture allows non-signers to access the meaning of iconic signs even when they have never been exposed to a sign language. This can be concluded given that iconic signs activated semantically related words in the same way as gestures. Possibly the capacity of signs and gestures to incorporate physical attributes of a referent may be responsible for the same behavioural response in non-signers' lexicon. Given that iconic signs and gestures exhibit the same effect in the L1 lexicon, and so, it can be argued that they act as 'cognates' within the manual modality. The present findings also suggest that proficiency in a sign language diminishes the relevance of gestures or visual imagery during access of iconic signs whilst linguistic factors (e.g., processing mechanisms and neighbourhood density) gain relevance during lexical access.

This study strengthens the argument that gestures act as precursor of a conventionalised sign language in early sign L2 learners.

6 General discussion and conclusions

Based on the notion that sign acquisition is shaped by sign structure and its degree of iconicity, this dissertation integrated these two variables to investigate how users of a spoken language develop visual phonological categories. After performing a quantitative analysis of perception of iconicity, followed by two sign repetition tasks and two cross-modal priming experiments it was possible to confirm that sign structure and iconicity are fundamental factors that determine order of emergence of the phonological components of signs. The present dissertation set out to address three research questions:

Question 1: How does sign structure influence the L2 acquisition of sign phonology?

The empirical data from this dissertation have demonstrated that L2 learners of a sign language do not acquire the phonological parameters of signs at the same rate. Also, the order of acquisition of these parameters is the same as those reported for L1 suggesting that both children and adults face the same difficulty in discriminating the components of signs. In addition, it can be concluded that phonological acquisition is more difficult for signs with multiple components (more phonological complexity) than signs with fewer defining features.

Question 2: What is the influence of iconicity on the L2 acquisition of sign phonology?

The data suggest that despite iconicity helping recall the meaning of iconic signs (Baus et al., 2012; Campbell et al., 1992; Lieberth & Gamble, 1991) it does not assist during phonological acquisition given that learners systematically produced the phonological parameters of iconic signs less accurately than arbitrary signs. The similarities between iconic signs and iconic gestures may be driving this effect. Both manual forms can encode the physical features of a referent but only signs have conventionalised internal structure. It appears that learners substitute iconic signs with their own gestures, which have less conventionalised forms.

Question 3: Are hearing adults biased towards perceiving iconic signs as co-speech gestures?

Iconic signs activated semantically related words in the same way as gestures. This demonstrates that non-signers process iconic signs without phonological mediation. The reason for the negative effect of iconicity in L2 phonological development is the resemblance between iconic signs and co-speech gestures. Experience using their hands for communicative purposes during speech allows learners to access the meaning of iconic signs despite their lack of a visual phonological system. As learners gain proficiency they move away from processing signs as gestures, except for signs depicting actions.

6.1 On the interaction between sign structure, iconicity and gestures

The analysis of articulation errors for each phonological parameter showed that handshape was the most difficult parameter to articulate, followed by movement, orientation and location. This is the same order of reported errors that has been shown for L1 sign acquisition (Conlin et al., 2000; Marentette & Mayberry, 2000; Morgan et al., 2007). The errors produced during L1 acquisition have been attributed to an immature motor system (Newport & Meier, 1985) and children not yet having fully developed body schemata (Marentette & Mayberry, 2000). According to these studies, these two factors converge and make children incapable of producing adult-like sign forms. Because hearing adults have full motor control their sign articulatory errors during acquisition were expected to display a different pattern. However, based on the empirical data in Chapters 3 and 4, it can be argued that the similarities observed between L1 and L2 articulation errors can be attributed to linguistic factors that affect children and adults to the same extent.

Research on spoken languages has previously shown similarities during L1 and L2 development. Brown (1973), for example, found that children learning English as an L1 acquired certain linguistic structures in the same order and that despite some timing differences (i.e., some children acquiring certain structures before others) all children generally follow the same pattern of acquisition. Dulay and Burt (1974) found similar results in the area of L2 acquisition after finding that Chinese and Spanish speaking children learning English as an L2 showed a very similar developmental pattern to native speakers of English. The same picture emerged when comparing these results to adults learning English as L2. Bailey et al., (1974) studied a group of L2 English learners with typologically different native languages and found that regardless of their L1 participants followed a similar pattern of emergence as that of children learning English as an L1 and L2. It was concluded that complexity and frequency of the target L2 structure were explanatory factors behind these similarities (Larsen-Freeman, 1975). Based on the findings from Chapter 3 and 4, it is plausible that this claim holds for language learning in the visual modality and that the structural complexity of signs determine the order of emergence of the phonological parameters not only in L1 but also in L2.

An important finding of this dissertation is that L2 sign acquisition seems to be influenced by the structure of a sign, with more complex structures being acquired at later stages than simpler ones. In contrast to abundant studies on spoken languages, to date there is no available information proposing a hierarchy of structural complexity of signed phonemes or an inventory of errors produced by sign learners. It is therefore difficult to correlate these measures and establish with more certainty the source of articulation errors. However, the available data can help to make inferences about phonological development. In Finnish Sign

Language, for instance, simple movements (path) are the most frequent compared to complex ones (path with hand internal movement) (Jantunen, 2006). Interestingly, signs incorporating both path and internal movements are the phonemes that emerge later in L1 phonological development (Morgan et al., 2007) and the most difficult to discriminate by sign L2 learners (Bochner et al., 2011). This suggests that complexity and frequency of the target structures are interrelated factors that determine phonological emergence in the same way as in the spoken modality.

To date no study has considered the Dominance and Symmetry constraints (Battison, 1978) as a factor influencing phonological development. However, given that signs at the higher levels of complexity (e.g., sign Type 5 and 6) were the signs that exhibited the larger number of errors, it can be concluded that as the phonological components of a sign increase, so does its structural complexity, putting more pressure on learners to identify the components of a sign. This conclusion fits well with the psycholinguistic models put forward to describe word repetition processes. The parameters that are easiest to discriminate will lead to a well-formed mental representation in short-term memory during a sign repetition task (Coady & Evans, 2008). In contrast, the parameters that are more variable and difficult to distinguish will result in a weaker representation. These representations will be rehearsed in the phonological loop (Baddeley & Hitch, 1974) and thus at retrieval, weak representations will be produced less accurately.

The ability to store a robust mental representation in short-term memory is a fundamental part of language acquisition because it allows the creation of a phonological representation in long-term memory (Baddeley et al., 1988). If children and adults display the same degree of difficulty in distinguishing the phonological parameters of a sign, the representation they create in short-term memory will also be affected, and consequently, this will in turn affect the order of emergence. The results from the sign repetition tasks reported in Chapters 3 and 4 suggest that adults experience similar difficulty in distinguishing the parameters of signs as children, which explains the similarities in order of phonological emergence.

Learners of a second spoken language have to make a number of inferences to establish whether two different sounds are distinct phonemes or allophonic variations of a single sound. In the visual modality learners have to focus on which features of a sign are part of the phonological system and which are by-product of sign co-articulation. In addition, the difficulty to perceive the phonological parameters of signs may be exerted by the lack of a written system. Most L2 acquisition in the spoken modality is facilitated by access to a written system which learners exploit to visualise the phonological components of a word. Research shows that access to an orthographic system impacts on L2 phonological acquisition (Bassetti, 2008, 2009). There is no widely used writing system for sign languages and consequently learners may find decoding lexical boundaries and phonological constituents more demanding. The absence of a writing system in sign could place adults in the same position as children in that they do not have a tool to aid phonological differentiation or distinguish what constitutes a sign from the visual input. With naturalistic signing as the only source of visual input, L2 learners rely only on their perceptual system to discriminate the phonological components of signs. This would explain the results that simple structures are mastered before complex ones.

A significant difference with unimodal L2 acquisition is the presence of iconicity. Chapter 4 suggests that the ability to encode features of a referent plays an important role in sign L2 phonological development with iconicity having a negative effect on sign articulation. This dissertation gives robust evidence that pre-existing visual (gestural) representations exert a negative influence during L2 phonological development. This interference is similar to how pre-existing acoustic representations interfere in the perception of novel L2 sounds.

Research on the bilingual lexicon has found that selection of a word in the L1 leads to activation of its unselected cognate in the L2 (Costa, Caramazza, & Sebastian-Galles, 2000). For instance, the English word *bank* is likely to activate its French cognate *banque* in a balanced bilingual because both words have strong phonetic similarities. However, despite strong phonological overlap between *bank* and *banque*, these words do not match completely (they differ in one phoneme: /æ/ and / ɑ̃ /, respectively). The Speech Learning Model (Flege, 1992, 1995) suggests that L2 learners will only be capable of setting up a novel phonological category if the target L2 sound is significantly distant from its closest L1 sound. If L1 and L2 sounds have only slight differences, the perceptual system will detect them as equivalent and will not set up a new phonological category. Referring back to the previous example, the phonemes /æ/ and / ɑ̃/ are very similar hence learners may be incapable of perceiving their slight articulatory differences. It can be predicted that French learners of English aiming to produce the word *bank* may fail to produce the exact phoneme and instead will produce their own structure (i.e., *banque*) resulting in what is commonly known as a foreign accent.

The results of the experiments in the current dissertation suggest that the predictions of the Speech Learning Model hold in the visual modality. The findings from the sign repetition task described in Chapter 4 showed that participants consistently failed to copy the exact parameters of iconic signs. For instance, they substituted the gO handshape in the sign TO-WRITE with a wide range of handshapes which appeared to be pantomimes of writing (see Appendix H for a list of labels for the most common handshapes in BSL). This is interpreted as participants being unable to distinguish the exact hand configuration of the sign because their own gestural representations interfered with the target BSL structure. When viewing an iconic sign, participants became insensitive to its exact formational parameters because their perceptual system categorised both the sign and the pantomime as equivalent structures despite their subtle differences. Instead of producing the observed BSL handshape, participants produced their own gestural representations. The reason behind this may be that learners are unable to set up a new signed phonological category because the exact phonetic structure of a sign might be overridden by the form of their own gesture. Under this interpretation, co-speech gestures appear to act as 'cognates' during the acquisition of a sign language as L2.

A potential difference in the cognate status between the spoken and visual modality (word-word vs. sign-gesture, respectively) is the nature of their mental representations. Cognates in the spoken modality consist of phonological units and form part of a conventionalised language with an established phonological repertoire. How gestures are represented in the mind is not very clear. With the exception of emblems (Gunter & Bach, 2004; Kendon, 1995) and homesigns (Goldin-Meadow, Butcher, Mylander, & Dodge, 1994; Goldin-Meadow, 2005), gestures are unlikely to have a static representation that can be retrieved in the same form each time. It is likely that the iconic gestures used by the novice sign learners do not have a fixed mental representation and are ephemeral hand configurations that stem from visual representations of actions and objects.

This assertion stems from the results from Chapter 5. Given that action signs are clear representation of their referents (i.e., they are pantomime of actions) and are grounded in human experience, it was expected that they would be accessed faster than perceptual signs, and arguably, have a conventionalised mental representation. Because action and perceptual signs were recognised at the same rate, both types of signs were argued to derive from the same source with neither having a more accessible representation. Behavioural and neurological evidence support these findings. It has been argued that our knowledge of the world consists of discrete internal representations of objects, their shape and how they are manipulated (Labeye, Oker, Badard, & Versace, 2008; Peelen & Caramazza, 2012). For instance, a key and a corkscrew share the same motor representation for how they are handled, in the same way that a coin and a tyre share the neural networks for representing the property of roundness. The action-object distinction is not relevant for hearing adults because both discrete representations are accessible at the same rate and independently from each other. Despite action and perceptual signs showing significantly different iconicity ratings in Chapter 2 this difference was not observed in the behavioural task reported in Chapter 5.

The action-perceptual distinction, however, becomes relevant as learners gain proficiency in a sign language. The results from Chapter 5 showed that action signs are accessed faster than perceptual signs by proficient BSL learners. However, actions signs did not show a different pattern of response from proficient signers suggesting that these are still accessed as pantomimes. Perhaps proficient learners continue processing action signs as gestures but this is an empirical question that can be investigated in future research. In contrast, the slower rate of recognition for perceptual signs is evidence that access to this type of iconic signs is governed by linguistic factors (e.g., polysemy and sign frequency) which also characterise lexical access in spoken languages. To date there is no available information regarding frequencies and neighbourhood densities of signs, so only future research could shed light on the precise factors that slows recognition in perceptual signs.

Why iconicity plays such a distinctive pattern in perception and production tasks during L2 acquisition may have to do with signs and gestures exploiting the same devices to encode meaning in their manual structures. This has been captured for signs in the Dependency Model (Van der Kooij, 2002). This model proposes that in addition to a set of rules that categorise allophonic variations of signed phonemes into a single representation, the Semantic Implementation Rules (SIR) associate some phonological parameters with a specific semantic value (e.g., [head] for 'mental states or activities'). Indeed, in some sign languages the meaning of a high percentage of signs is related to specific phonemes (Pietrandrea, 2002). In BSL, for instance, many signs articulated at the location [chest] are associated with the semantic field ‘emotions’ (e.g., EMOTION and GUILTY) and the B handshape is associated with flat surfaces. However, the association of meaning to a specific body part is not exclusive to sign languages because it is also exploited in co-speech gesture.

Signs are different from gestures because signs have conventionalised forms and systematic rules of usage (i.e., iconic signs follow the phonotactic rules of their sign language). However, the gestures produced by non-signers make some of the same form-meaning associations observed in many iconic signs. For instance, non-signers in most Western cultures will associate the meaning ‘mental states or activities’ with the location [head] and of ‘emotions’ with the location [chest]. Other phonological parameters of signs reflect the same property, for example, movement. In the same way as gesturers can modify the speed of a stroke when producing a pantomime, a signer can modulate the speed of a movement to convey different intensities of motion. If non-signers already know the semantic properties associated with a handshape, location and movement, these are phonological parameters that will not need to be learnt *de novo*.

This observation is not limited to the manual components of signs. Research in sign linguistics has shown that the facial elements of signs convey important prosodic (Sandler & Lillo-Martin, 2006) and adverbial features (Sutton-Spence & Woll, 1999). For example, the BSL sign TO-DRIVE will change its meaning to ‘driving intensely’ if puffed cheeks are added to the manual component of the sign. At the same time, eyebrow raise sets the boundaries of each phrasal constituent, for instance, in conditional clauses (Sandler & Lillo-Martin, 2006). Similar features are observed in gestures. Gesture studies have demonstrated that facial expressions convey important meanings not present in the spoken utterance (Ekman, 2006) and are well synchronised with the phrasal constituents of a sentence (Loehr, 2007). For instance, when talking about a person driving intensely speakers may add facial expressions denoting intensity, and they tend to blink at the end of each sentence.

The data reported in Chapters 4 and 5 confirm that non-signers have a significant knowledge of the building blocks of signs because they exploit the similarities between sign and gesture. Gestural knowledge does not give non-signers the capacity to sign fluently form the onset. Signs are significantly more conventionalised than gestures and their rules of use are different. Thus, non-signers have to learn the specific structural and pragmatic differences between signs and gestures and realise that despite their resemblance, gestures and signs are not isomorphic structures. Before this happens, learners will exploit their gestural system as foundation for the target sign language.

6.2 Directions for future research

The number of studies of cross-modal L2 acquisition is small compared to studies of unimodal L2 acquisition. This dissertation is one of the first attempts to broaden the understanding of how users of a spoken language develop visual phonological categories. It attempts to shed light on the features of L2 acquisition that can be extrapolated to the signed modality and described features that are exclusive to sign language learning. In light of the results obtained in the empirical sections of this dissertation, the following paragraphs highlight some of the areas that could be explored in future work.

Traditional research on phonological development has used the parameters of handshape, location, and movement to describe the emergence of a visual phonological system in L1 (e.g., Marentette & Mayberry, 2000) and to a lesser extent in L2 (Rosen, 2004). Even recent psycholinguistic and neurological studies use the three phonological parameters to explore the nature of sign lexical access (Gutiérrez et al., 2012). However, the sophistication of phonological theories and our current understanding of the features that define signs have expanded and these three parameters no longer suffice in the description of the mechanisms underlying phonological acquisition. The use of current phonological models (e.g., Brentari, 1999; van der Kooij, 2002) could add more detail to the description of phonological acquisition. At present, this level of analysis is not yet possible because few signs languages have produced a comprehensive list of their permissible phonemes e.g., as in Australian Sign Language (Johnston & Schembri, 2007). Apart from one study on L1 acquisition (Morgan et al., 2007) these phonemes have not been used to describe phonological development. In the spoken modality, in contrast, research on phonological acquisition does not restrict its line of enquiry on overall characteristics of sounds (e.g., place vs. manner of articulation), but permits the study of the emergence of individual phonemes (e.g., /d/ vs. /r/). The implementation of a current phonological model and the description of its features will allow a better understanding on the emergence of phonological categories in L1 and L2.

One of the limitations of the results presented in Chapter 3 is that the articulation accuracy of novice signers was measured at only two points in time. In addition, despite the fact that a detailed quantitative examination of the incidence of errors for each phonological parameter was undertaken, this level of analysis reveals little detail about the qualitative properties of these errors. In order to expand on the characteristics of errors in L2 acquisition, future studies should include a longitudinal description of errors produced by learners at different levels of proficiency. In addition to illustrating which of the phonological parameters (handshape, movement, location, and orientation) are more likely to display articulation error, future studies should aim to describe the target structures attempted by learners and associate them with the specific type of error produced. Rather than leaving the phonological analysis at a superficial level (e.g., movement more accurately produced than handshape), the analysis should include order of acquisition of individual phonemes (e.g., if the 1 handshape is produced before the B handshape). In this way it will be possible to establish which phonemes are more difficult to articulate and at what point in time learners succeed in producing them accurately. This will enable a better description of the trajectory of phonological acquisition at a more detailed level of phonetic analysis, which in turn will capture both individual variation and general trends. A longitudinal analysis of this kind will depend greatly on the phonological properties described for the target sign language, and hence such a study will require adherence to a specific phonological model.

It was mentioned in Chapter 3 that it is difficult to specify the source of errors made by L2 learners when imitating signs. A sign repetition paradigm alone cannot distinguish whether an error is the outcome of an inaccurate mental representation or whether it is the consequence of signer's lack of motor dexterity. In order to further investigate this issue, future research should implement a study in which the ability to differentiate sign phonological parameters is correlated with the ability to produce them. Novice, intermediate, and proficient sign language learners could take part in an ABX phonological discrimination task, in which pairs of similar phonemes are presented consecutively and participants have to determine whether a third phoneme matches the first or the second one. This task could be followed by a sign repetition task in which the stimuli from the ABX task are presented individually. By comparing the success rate of both parts of the experiment one may determine the locus of articulation errors. The phonemes that are successfully matched in the discrimination task but are inaccurately produced will be of particular interest. A mismatch between perception and production will indicate that those participants are capable of discerning sign parameters but have not yet mastered the ability to produce them. If participants fail to discriminate and articulate a specific phoneme, this would suggest that the errors lie in their inability to perceive phonemic features.

An example from the data reported in Chapter 3 could help illustrate this hypothetical study. In the sign repetition task, it was observed that signs that included path and hand internal movements were generally produced with path movement only. A phonological discrimination task could include a sign with both types of movement (sign A) and another with only path movement (sign B). Participants would be required to determine whether a third sign (e.g., sign A) matches the first or second sign presented. If participants succeed in matching the third sign with the correct target (sign A) but omit the hand internal movement in the sign repetition task it will show that this error is grounded in motor dexterity. If in contrast, participants match the third sign with the wrong target (sign B) and also omit the internal movement, it would demonstrate that the source of error is participants' inability to perceive this phoneme. These two complementary studies could further our understanding on how learners perceive the phonological constituents of signs and how it affects articulation.

The results presented in this dissertation clearly suggest that sign structure is not the only factor that determines phonological development. Gestures and iconicity also play a relevant role. If iconic signs are interpreted as gestures from the onset of learning a sign language, there are important questions that need to be addressed. Specifically, the two questions that remain unexplored are: 1) at what point do learners stop processing signs as holistic units and start exploiting their phonological parameters for lexical access (i.e., as proposed for perceptual signs in intermediate learners)? and 2) how does activity in the brain reflect these processing differences?

There is compelling evidence supporting the psychological reality of sign phonemes and their involvement in sign processing. A combination of hand configuration and movement constitutes the set of parameters exploited during lexical access (Baus et al., 2008; Dye & Shih, 2006). In contrast, gestures are processed as holistic units (McNeill, 1992) and only emblems appear to have a static representation akin to that of natural signs (Gunter & Bach, 2004). Based on the findings of this dissertation, it could be hypothesised that learners of a sign language have to alter the way they perceive hand articulations in order to follow a mechanism that is based on sign phonology. A form-based lexical decision task could help determine whether hearing learners exploit phonological information during lexical access in the same way as native signers. Sign language learners could take part in a priming study in which prime and target signs share some degree of phonological overlap (e.g. both sharing handshape and movement). If learners have become attuned to the phonological parameters of signs, signs with overlapping parameters should prime each other. It would be expected, for instance, that the BSL sign NAME would prime the phonologically related sign AFTERNOON (as they share handshape and movement but differ in location). The prediction is that non-signers would have a reduced priming effect compared to participants with higher levels of proficiency. Another prediction is that learners with the highest levels of proficiency would show the strongest effect particularly for signs sharing handshape and movement. This would confirm that learners have fully re-structured the way they process hand configurations and that rather than processing them as gestures, learners access signs using the same linguistic mechanisms as deaf signers. In addition, given that deaf signers show a facilitation effect in processing iconic signs (Ormel et al., 2009; Thompson et al., 2009, 2010), another level of analysis could include signs with varying degrees of iconicity.

Not only do sign and gesture differ in their processing mechanisms but also in the brain regions engaged during their production. Hearing and deaf adults activate different brain regions during the production of pantomime and linguistic gesture-like structures. Emmorey, McCullough, Mehta, Ponto, and Grabowski (2011) used positron emission tomography (PET) to investigate the differences in brain activation evoked by signs and gestures depicting manipulation of objects. In this study, deaf and hearing adults were prompted with a picture of an object and asked to produce a pantomime of how to use it (e.g., eating with a fork). In a different condition, only deaf participants were asked to produce a signed verb mimicking the manipulation of an object (e.g., the sign TO-HAMMER depicts someone hammering). The results show that for the pantomime production task, both deaf and hearing adults activated the left parietal cortex. However, the activation was more extensive and bilateral in the deaf group. When comparing the activation associated with the production of iconic verbs (e.g., TO-HAMMER) with the pantomimes produced by hearing people, it was found that only the deaf activated the left inferior frontal cortex. Because hearing adults activated motor regions and not areas associated with lexical retrieval, the authors interpreted these results as the deaf signers having processed signs as linguistic structures and not as gestures despite the structural similarities between both. This raises the question of whether neural activation shifts in learners of a sign language to a more deaf-like activation pattern at advanced stages of proficiency. A replication of the Emmorey et al. (2011) study with hearing learners with different levels of proficiency of a sign language could help determine if and when the neuronal processing network reorganises.

6.3 Concluding remarks

This dissertation has taken a linguistic perspective to answer the question of how hearing non-signers learn a visual phonological system. The terminology and conceptual stance employed are the same as that used in sign linguistics, which in turn is borrowed from the field of spoken language linguistics. Sign elements like mouthing patterns, head nods, facial expressions, and body parts have been associated with linguistic terms such as prosodic features, adverbs, and phonology. This has been helpful. However, the use of these terms in sign linguistics has not been uncontroversial (e.g., Liddell & Metzger, 1998). It has been argued that some signs have been categorised using linguistic terms such as classifiers and pronouns despite them not fulfilling all the characteristics of their spoken language counterparts. This suggests that sign language research is possibly too embedded in a spoken language linguistics tradition and that this has made the field overlook certain properties that are shared between signs and gestures.

Gesture studies have gathered a wealth of knowledge on the different types of forms, their properties, their relationship with language, and how they contribute to language processing and acquisition. Research in this field acknowledges that gestures and sign languages lie on a continuum (McNeill, 1992) with sign languages being the most conventionalised gestural forms. It has also been observed that a gestural system can develop the level of sophistication of signs and make the transition from one end of the continuum to the other, i.e., from gesture to a conventionalised sign language (Sandler, Meir, Padden, & Aronoff, 2005). It is possible to argue that a scaled-down version of this phenomenon is what is observed during acquisition of a sign language as L2. The general conclusion of this dissertation is that non-signers set out with experience in perceiving and producing gestures during speech which provides them with some of the same tools exploited by any sign language (e.g., depiction of a referent with the hands). Learners have to develop the ability to distinguish the subtle differences between co-speech gestures and signs. They also must acquire the rules that govern the novel linguistic system in the visual modality.

Because sign linguistic research has been strongly influenced by the field of linguistics of spoken languages, the strong presence of gestural elements in sign languages has been disregarded. Non-signers are not a blank slate at the onset of sign language learning because they already have experience in exploiting their hands for communicative purposes. Sign and gesture share a large common ground so it is logical that non-signers will exploit these resources during L2 sign acquisition. This dissertation suggests that non-signers draw elements from their gestural repertoire at the beginning of sign learning and through instruction they refine their gestures to fit the conventionalised structure of signs. A gestural perspective could provide additional understandings to research questions asked in this dissertation.

Hearing adults learning an L2 in a second modality set out to acquire a highly conventionalised manual communicative system which includes signs with no resemblance to its referent (arbitrary signs) and signs that have strong similarities with their co-speech gestures (iconic signs). With regard to phonology, a successful learner will be one who develops the skill to a) discriminate sign parameters and b) distinguish signs from less conventionalised gestural forms. The degree of complexity of signs will regulate the rate at which parameters are acquired with the more complex ones being mastered after simpler ones. Iconic signs will offer an extra level of difficulty because in addition to the complexity of the structure of a sign, learners will have to differentiate these forms from co-speech gestures. The data from this dissertation suggest that by default adult learners exploit their existing gestural system as scaffolding of the target sign language, and over time, they tune their perceptual system to distinguish subtle phonological differences in signs.

In sum, this dissertation demonstrates that hearing learners have a rich gestural communicative system which is the root from which sign languages emerge. Exposure to a natural sign language transforms learners' gestures into phonologically rich structures and modifies their underlying mechanisms to process manual structures.

7 Appendix A

List of signs and their iconicity ratings by hearing non-signers (Chapter 2)

	GLOSS	RATING		GLOSS	RATING
1	AMSTERDAM	1.20	51	CHAIR	3.27
2	ADDRESS	1.53	52	CHEESE	2.00
3	AERIAL	4.33	53	CHERRY	2.47
4	AEROPLANE	4.47	54	CHOCOLATE	1.47
5	AFTERNOON	1.40	55	CHURCH	2.67
6	AGREE	4.33	56	CLOCK	5.40
7	ALARM	3.33	57	CLOTHES-PEG	5.00
8	ALL-RIGHT	2.20	58	CLOUD	4.93
9	AMAZED	1.87	59	CONFIDENT	2.40
10	ANNOUNCE	5.33	60	COOK	3.00
11	ARGUE	4.33	61	COPY	1.67
12	ARRIVE	4.33	62	CORKSCREW	6.47
13	ASK	2.60	63	COUGH	4.67
14	BANK	2.33	64	CRAWL	5.87
15	BASINGSTOKE	1.13	65	CREATE	2.80
16	BE-SHOCKED	2.47	66	CREDIT-CARD	4.33
17	BE-STRUCK-BY	5.53	67	CROCODILE	6.67
18	BED	2.27	68	CRUEL	2.60
19	BELGIUM	1.60	69	CRY	6.67
20	BELIEVE	2.47	70	CURTAINS	5.73
21	BELT	6.67	71	CUT-DOWN-TO-SIZE	2.93
22	BICYCLE	5.60	72	DASH	2.80
23	BINOCULARS	6.13	73	DAY	1.07
24	BIRTHDAY	1.53	74	DECIDE	4.00
25	BISCUIT	1.20	75	DEER	5.67
26	BLACK	1.33	76	DEMAND	4.67
27	BLOW-ONES-TOP	5.53	77	DETERMINED	1.60
28	BOMB	4.13	78	DIE	2.13
29	BOOT	2.00	79	DIGITAL	2.20
30	BORE-TO-DEATH	2.20	80	DISAPPEAR	1.87
31	BOTTLE	3.53	81	DIVE	5.07
32	BOX	5.00	82	DOG	2.33
33	BOY	1.20	83	DRAW	6.07
34	BREAD	3.53	84	DREAM	4.27
35	BREATHE	5.67	85	DRESS	4.47
36	BRONZE	1.00	86	DRILL	4.73
37	BROWN	1.20	87	DROP	5.87
38	BRUSH	6.07	88	DROWN	3.27
39	BULGARIA	1.33	89	DUCK	6.07
40	BULLY	1.47	90	DVD	1.93
41	BUTTERFLY	6.67	91	EASY	1.73
42	BUY	2.13	92	EAT	6.33
43	CALENDAR	1.27	93	EGG	2.40
44	CAMERA	7.00	94	EMAIL	2.07
45	CAN	5.93	95	EMOTION	3.53
46	CANOE	6.40	96	ENGLISH	1.07
47	CANT-BE-BOTHERED	2.80	97	EUROPE	1.33
48	CANT-BELIEVE-IT	4.07	98	EVENING	1.13
49	CARDS	5.80	99	FEBRUARY	1.07
50	CASTLE	2.27	100	FIGHT	3.80

Appendix A (continued)

	GLOSS	RATING
101	FINALLY	1.40
102	FINISH	1.93
103	FIRE	2.60
104	FISHING	5.73
105	FLOWER	1.47
106	FOOTBALL	2.67
107	FRIEND	4.40
108	FROM	2.40
109	GERMANY	1.93
110	GET-OWN-BACK	1.47
111	GIRL	1.00
112	GIVE-IT-A-TRY	1.20
113	GLASGOW	1.27
114	GO-ON-AND-ON	4.13
115	GO-OVER-ONES-HEAD	4.53
116	GOLD	1.40
117	GOSSIP	6.33
118	GREEDY	1.73
119	GUILTY	2.27
120	HAMMER	6.33
121	HEARING-AID	6.33
122	HELICOPTER	5.40
123	HELP	3.00
124	HOLIDAY	1.33
125	HOLLAND	3.00
126	HONG-KONG	1.47
127	HOPE	6.40
128	HORRIBLE	2.73
129	HOSPITAL	1.53
130	HOUSE	4.40
131	ICE-CREAM	4.67
132	ICE-SKATE	3.60
133	IGNORE	2.60
134	I'LL-BE-DAMNED	2.53
135	IMPORTANT	1.73
136	INJECT	6.93
137	INSURANCE	1.67
138	INTERPRETER	2.87
139	INTRODUCE	4.33
140	IRON	5.80
141	IT-WILL-DO	4.67
142	JACKET	6.07
143	JAPAN	1.73
144	JUGGLE	6.80
145	JUMPER	3.47
146	KANGAROO	6.13
147	KEEP-STRAIGHT-FACE	1.27
148	KEY	6.73
149	KITCHEN	1.00
150	KNIFE	5.67

	GLOSS	RATING
151	LAUGH	2.33
152	LESBIAN	1.40
153	LETTER	1.53
154	LIE	2.27
155	LIGHT-BULB	6.13
156	LIGHTER	6.20
157	LIMP	2.67
158	LOCK	6.13
159	LOOK	4.80
160	LOUD	5.20
161	LUCKY	1.20
162	MAGIC	2.67
163	MAKE-DO	2.93
164	MALAYSIA	1.13
165	MARCH	6.60
166	MEET	4.87
167	MELBOURNE	1.20
168	METAPHOR	1.67
169	MONKEY	3.27
170	MOON	4.40
171	MORE	2.47
172	MORNING	1.73
173	MOTHER	1.27
174	MOUSE	1.60
175	MSN	1.40
176	MUSIC	4.20
177	NAME	1.80
178	NEVER	2.13
179	NEW	1.33
180	NO-GOOD	1.47
181	NORWAY	1.93
182	NOT-CARE	3.53
183	NOT-KNOW-SOMEONE-	1.53
184	NOT-SEE-FOR-LONG-TIME	2.53
185	NOT-SURE	2.93
186	NOT-YET	2.20
187	NUT	1.73
188	OF-COURSE	2.20
189	OFF-THE-POINT	5.40
190	OOPS-SORRY	2.53
191	PAINT	3.53
192	PAPER	1.53
193	PARENTS	1.20
194	PARIS	4.87
195	PEOPLE	1.20
196	PERFUME	6.07
197	PILLOW	3.87
198	PINK	1.20
199	PLEASED	1.47
200	POINT	3.07

Appendix A (continued)

	GLOSS	RATING		GLOSS	RATING
201	POLICE	1.93	251	SLEEP	2.67
202	POOL	5.73	252	SLEEP-YOUTH	3.07
203	POOR	1.33	253	SMILE	5.53
204	POP	3.87	254	SORRY	2.60
205	POTATO	1.53	255	SPOT-ON	2.53
206	PRETEND	1.13	256	START	1.80
207	PRINT	1.47	257	STIR	6.80
208	PROMOTE	2.33	258	STOP	2.87
209	PROPOSE	2.93	259	STRAWBERRY	1.67
210	PROTECT	1.87	260	STRICT	2.13
211	PULL	6.60	261	SUBTITLES	4.40
212	PULL-ONES-LEG	1.20	262	SUGGEST	3.33
213	PUSH	6.20	263	SUMMARISE	4.53
214	PUT-UP-WITH	2.00	264	SWALLOW	5.93
215	QUEUE	2.87	265	SWING	4.67
216	RABBIT	6.33	266	SWITZERLAND	4.47
217	RAKE	4.93	267	TEACH	1.53
218	REALLY-ANGRY	3.33	268	TELL	4.93
219	REALLY-ENJOY	4.13	269	THANKS-FOR-NOTHING	2.93
220	RED	1.00	270	THEATRE	1.20
221	REFUSE	2.13	271	THINK	6.33
222	RELAX	4.73	272	THURSDAY	1.33
223	RESPONSIBILITY	4.93	273	TIE	6.47
224	RHINO	4.93	274	TIME	6.87
225	RIGHT	2.47	275	TOMATO	1.40
226	RUBBISH	1.27	276	TRANSLATE	2.47
227	RUDE	2.73	277	TREE	3.80
228	RUGBY	5.13	278	TROPHY	2.73
229	SANDWICH	4.27	279	TROUSERS	5.33
230	SATURDAY	1.07	280	TRUE	3.47
231	SAW	5.80	281	TURTLE	3.73
232	SCARF	3.47	282	UNIVERSITY	1.67
233	SCHOOL	1.33	283	UP-TO-YOU	3.67
234	SCOTLAND	2.53	284	VERY-BAD	3.20
235	SHABBY	1.47	285	VIOLIN	6.47
236	SHAME-ON-YOU	3.33	286	VOMIT	3.40
237	SHAMPOO	5.67	287	WAIT	1.47
238	SHINE	3.20	288	WALES	1.93
239	SHIRT	3.47	289	WATER	1.07
240	SHOP	1.67	290	WEBCAM	1.53
241	SICK	4.33	291	WEIGH	6.27
242	SICK-AND-TIRED	2.27	292	WHAT	1.53
243	SIGN-LANGUAGE	2.60	293	WIN	1.67
244	SILVER	1.13	294	WORK	1.60
245	SING	2.27	295	WORRIED	3.73
246	SINGAPORE	1.20	296	WORTH	2.67
247	SISTER	1.00	297	WRITE	5.80
248	SKI	6.47	298	YELLOW	1.27
249	SKIRT	NA	299	YESTERDAY	1.47
250	SLAP	6.60	300	YOUNG	1.20

8 Appendix B

List of signed stimuli per sign Type used in the sign repetition task (Chapter 3)

	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6
1	WHAT	BULGARIA	FIRE	SLEEP	GET-OWN-BACK	COPY
2	FROM	REFUSE	MAGIC	INTERPRETER	WORK	DIGITAL
3	SATURDAY	BED	TEACH	MSN	RUBBISH	CALENDAR
4	EUROPE	YELLOW	DOG	MALAYSIA	NEW	LESBIAN
5	SCHOOL	CRUEL	DIE	UNIVERSITY	TRUE	THEATRE
6	NORWAY	BROWN	VERY-BAD	PAPER	ENGLISH	IMPORTANT
7	MORE	RUDE	COOK	WORTH	CHEESE	PROMOTE
8	WALES	SISTER	LIMP	QUEUE	TRANSLATE	PROPOSE
9	MOON	INJECT	ICE-SKATE	BINOCULARS	SAW	DRILL
10	AEROPLANE	HEARING-AID	ARGUE	RABBIT	CORKSCREW	CLOTHES-PEG
11	IRON	DUCK	BICYCLE	CAMERA	MEET	HELICOPTER
12	LIGHT_BULB	TIME	CRAWL	BELT	CARDS	LOCK
13	LIGHTER	SMILE	JUGGLE	CRY	TIE	STIR
14	HAMMER	RHINO	GOSSIP	RELAX	VIOLIN	CLOCK
15	SLAP	DREAM	CURTAINS	SHAMPOO	KNIFE	WRITE
16	KEY	ICE-CREAM	INTRODUCE	DEER	DEMAND	BE-STRUCK-BY

9 Appendix C

Table displaying all possible comparisons between the different articulation accuracies for each sign Type. Values < 0.05 denote significant differences between sign types (Chapter 3)

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Type1 - Type2	.00467	.07239	.01869	-.03542	.04476	.250	14	.806
Pair 2	Type1 - Type3	.04200	.04784	.01235	.01551	.06849	3.400	14	.004
Pair 3	Type1 - Type4	.01200	.06259	.01616	-.02266	.04666	.743	14	.470
Pair 4	Type1 - Type5	.02533	.06323	.01633	-.00968	.06035	1.552	14	.143
Pair 5	Type1 - Type6	.04867	.06717	.01734	.01147	.08587	2.806	14	.014
Pair 6	Type2 - Type3	.03733	.08779	.02267	-.01128	.08595	1.647	14	.122
Pair 7	Type2 - Type4	.00733	.05934	.01532	-.02553	.04019	.479	14	.640
Pair 8	Type2 - Type5	.02067	.08964	.02314	-.02897	.07031	.893	14	.387
Pair 9	Type2 - Type6	.04400	.09811	.02533	-.01033	.09833	1.737	14	.104
Pair 10	Type3 - Type4	-.03000	.06876	.01775	-.06808	.00808	-1.690	14	.113
Pair 11	Type3 - Type5	-.01667	.05640	.01456	-.04790	.01457	-1.144	14	.272
Pair 12	Type3 - Type6	.00667	.06925	.01788	-.03168	.04501	.373	14	.715
Pair 13	Type4 - Type5	.01333	.06287	.01623	-.02148	.04815	.821	14	.425
Pair 14	Type4 - Type6	.03667	.09021	.02329	-.01329	.08662	1.574	14	.138
Pair 15	Type5 - Type6	.02333	.07669	.01980	-.01913	.06580	1.178	14	.258

10 Appendix D

Phonological information of the signed stimuli in the arbitrary and iconic condition for the signed stimuli used in the sign repetition task (Chapter 4)

	CONDITION	
PHONEME	ARBITRARY	ICONIC
Movement		
Path	27	25
Local	14	14
Both	7	9
TOTAL	48	48
Handshape		
Marked	21	24
Unmarked	22	19
Change	5	5
TOTAL	48	48
Location		
Arms	1	1
Cheek	1	1
Chest		1
Ear	1	1
Elbow	1	
Eyes	1	2
Finger	8	6
Hand	5	3
Head	3	4
Mouth	1	3
Neck	1	1
Nose	1	1
Palm	8	5
Waist		1
Wrist		1
Signing space	16	17
TOTAL	48	48

11 Appendix E

List of arbitrary signs and their phonological properties for the stimuli used in the sign repetition task (Chapter 4)

ARBITRARY

	GLOSS	ICONICITY	SIGN TYPE	MOVEMENT	LOCATION	HANDSHAPE
1	WHAT	1.53	Type 1	Local	Signing space	Unmarked
2	FROM	2.40	Type 1	Local	Signing space	Unmarked
3	SATURDAY	1.07	Type 1	Local	Signing space	Unmarked
4	EUROPE	1.33	Type 1	Path	Signing space	Marked
5	SCHOOL	1.33	Type 1	Path	Signing space	Marked
6	NORWAY	1.93	Type 1	Path	Signing space	Marked
7	MORE	2.47	Type 1	Path	Signing space	Marked
8	WALES	1.93	Type 1	Both	Signing space	CHANGE
9	BULGARIA	1.33	Type 2	Both	Mouth	CHANGE
10	REFUSE	2.13	Type 2	Both	cheek	CHANGE
11	BED	2.27	Type 2	Path	Head	Marked
12	YELLOW	1.27	Type 2	Local	ear	marked
13	CRUEL	2.60	Type 2	Local	Side neck	Unmarked
14	BROWN	1.20	Type 2	Path	Elbow	Unmarked
15	RUDE	2.73	Type 2	Path	Arm	Marked
16	SISTER	1.00	Type 2	Path	Nose	Marked
17	FIRE	2.60	Type 3	Both	Signing space	Unmarked
18	MAGIC	2.67	Type 3	Both	Signing space	CHANGE
19	TEACH	1.53	Type 3	Path	Signing space	Marked
20	DOG	2.33	Type 3	Path	Signing space	Marked
21	DIE	2.13	Type 3	Path	Signing space	Marked
22	VERY-BAD	3.20	Type 3	Path	Signing space	Marked
23	COOK	3.00	Type 3	Path	Signing space	Marked
24	LIMP	2.67	Type 3	Path	Signing space	Unmarked
25	SLEEP	2.67	Type 4	Local	Eyes	CHANGE
26	INTERPRETER	2.87	Type 4	Local	Finger	Marked
27	MSN	1.40	Type 4	Path	Palm	Unmarked
28	MALAYSIA	1.13	Type 4	Path	Head	Unmarked
29	UNIVERSITY	1.67	Type 4	Path	Head	Unmarked
30	PAPER	1.53	Type 4	Path	Hand	Unmarked
31	WORTH	2.67	Type 4	Path	Hand	Unmarked
32	QUEUE	2.87	Type 4	Path	Finger	Marked
33	GET-OWN-BACK	1.47	Type 5	Local	Hand	Marked
34	WORK	1.60	Type 5	Path	Finger	Unmarked
35	RUBBISH	1.27	Type 5	Path	Hand	Unmarked
36	NEW	1.33	Type 5	Path	Palm	Unmarked
37	TRUE	3.47	Type 5	Path	Palm	Unmarked
38	ENGLISH	1.07	Type 5	Local	Finger	Unmarked

39	CHEESE	2.00	Type 5	Local	Palm	Unmarked
40	TRANSLATE	2.47	Type 5	Local	Palm	Unmarked
41	COPY	1.67	Type 6	Both	Palm	Unmarked
42	DIGITAL	2.20	Type 6	Both	Finger	Marked
43	CALENDAR	1.27	Type 6	Local	Finger	Unmarked
44	LESBIAN	1.40	Type 6	Local	Palm	Marked
45	THEATRE	1.20	Type 6	Local	hand	Marked
46	IMPORTANT	1.73	Type 6	Path	Palm	Unmarked
47	PROMOTE	2.33	Type 6	Path	Finger	Marked
48	PROPOSE	2.93	Type 6	Path	Finger	Marked
	mean iconicity:	**1.98**				

Appendix E (continued)

List of iconic signs and their phonological properties for the stimuli used in the sign repetition task reported in Chapter 4

	ICONIC					
	GLOSS	ICONICITY	SIGN TYPE	MOVEMENT	LOCATION	HANDSHAPE
1	MOON	4.40	Type 1	Both	Signing space	CHANGE
2	AEROPLANE	4.47	Type 1	Path	Signing space	Marked
3	IRON	5.80	Type 1	Path	Signing space	Unmarked
4	LIGHT_BULB	6.13	Type 1	Local	Signing space	Marked
5	LIGHTER	6.20	Type 1	Local	Signing space	Unmarked
6	HAMMER	6.33	Type 1	Path	Signing space	Marked
7	SLAP	6.60	Type 1	Path	Signing space	Unmarked
8	KEY	6.73	Type 1	Local	Signing space	Marked
9	INJECT	6.93	Type 2	Both	Arm	CHANGE
10	HEARING-AID	6.33	Type 2	Path	Ear	Marked
11	DUCK	6.07	Type 2	Local	Mouth	Unmarked
12	TIME	6.87	Type 2	Local	Wrist	Unmarked
13	SMILE	5.53	Type 2	Local	Mouth	CHANGE
14	RHINO	4.93	Type 2	Path	nose	Marked
15	DREAM	4.27	Type 2	Path	Head	Unmarked
16	ICE-CREAM	4.67	Type 2	Path	Mouth	Marked
17	ICE-SKATE	3.60	Type 3	Path	Signing space	Marked
18	ARGUE	4.33	Type 3	Path	Signing space	Marked
19	BICYCLE	5.60	Type 3	Path	Signing space	Unmarked
20	CRAWL	5.87	Type 3	Path	Signing space	Marked
21	JUGGLE	6.80	Type 3	Both	Signing space	CHANGE
22	GOSSIP	6.33	Type 3	Both	Signing space	Unmarked
23	CURTAINS	5.73	Type 3	Path	Signing space	Marked
24	INTRODUCE	4.33	Type 3	Both	Signing space	Unmarked
25	BINOCULARS	6.13	Type 4	Local	Eyes	Marked
26	RABBIT	6.33	Type 4	Local	Head	Marked
27	CAMERA	7.00	Type 4	Local	Eyes	Marked
28	BELT	6.67	Type 4	Path	Waist	Marked
29	CRY	6.67	Type 4	Path	Cheeks	Unmarked
30	RELAX	4.73	Type 4	Local	Chest	CHANGE
31	SHAMPOO	5.67	Type 4	Path	Head	Unmarked
32	DEER	5.67	Type 4	Path	Head	Unmarked
33	SAW	5.80	Type 5	Path	Finger	Unmarked
34	CORKSCREW	6.47	Type 5	Both	Hand	Unmarked
35	MEET	4.87	Type 5	Path	Hand	Unmarked
36	CARDS	5.80	Type 5	Local	Finger	Marked

37	TIE	6.47	Type 5	Path	neck	Marked
38	VIOLIN	6.47	Type 5	Path	Signing space	Marked
39	KNIFE	5.67	Type 5	Path	Finger	Marked
40	DEMAND	4.67	Type 5	Path	Palm	Unmarked
41	DRILL	4.73	Type 6	Both	Palm	Marked
42	CLOTHES-PEG	5.00	Type 6	Both	Finger	Marked
43	HELICOPTER	5.40	Type 6	Both	Finger	Unmarked
44	LOCK	6.13	Type 6	Local	Palm	Marked
45	STIR	6.80	Type 6	Local	Hand	Marked
46	CLOCK	5.40	Type 6	Local	Palm	Unmarked
47	WRITE	5.80	Type 6	Path	Palm	Marked
48	BE-STRUCK-BY	5.53	Type 6	Path	Finger	Unmarked
	mean iconicity:	**5.72**				

12 Appendix F

List of action and perceptual signs and the iconicity ratings by hearing non-signers (Chapter 5)

	Action	Rating	Perceptual	Rating
1	CAMERA	7	BUTTERFLY	6.67
2	INJECT	6.93	CROCODILE	6.67
3	STIR	6.8	BELT	6.67
4	JUGGLE	6.8	HEARING AID	6.33
5	KEY	6.73	RABBIT	6.33
6	SLAP	6.6	GOSSIP	6.33
7	MARCH	6.6	KANGAROO	6.13
8	PULL	6.6	DUCK	6.07
9	TIE	6.47	DEER	5.67
10	CORKSCREW	6.47	BICYCLE	5.6
11	VIOLIN	6.47	SMILE	5.53
12	SKI	6.47	HELICOPTER	5.4
13	CANOE	6.4	CLOCK	5.4
14	HAMMER	6.33	CLOTHES PEG	5
15	EAT	6.33	BOX	5
16	WEIGH	6.27	RHINO	4.93
17	PUSH	6.2	CLOUD	4.93
18	LIGHTER	6.2	RAKE	4.93
19	LIGHT BULB	6.13	AEROPLANE	4.47
20	BRUSH	6.07	DRESS	4.47
21	DRAW	6.07	MOON	4.4
22	PERFUME	6.07	HOUSE	4.4
23	CAN	5.93	AERIAL	4.33
24	DROP	5.87	SICK	4.33
25	CRAWL	5.87	PILLOW	3.87
26	CARDS	5.8	TREE	3.8
27	WRITE	5.8	TURTLE	3.73
28	IRON	5.8	BOTTLE	3.53
	MEAN	**6.32**	**MEAN**	**5.18**
	SD	**0.356**	**SD**	**0.968**

13 Appendix G

List of action signs with their respective target words: 1) semantically related, 2) semantically unrelated, 3) non-word one, and 4) non-word two (Chapter 5)

Action sign - word pairs

Sign prime	Target word			
	Related	Unrelated	Non-word 1	Non-word 2
BRUSH	hair	girl	ciff	wef
CAMERA	photo	net	sap	knush
CAN	tin	t.v.	sem	pud
CANOE	rapids	watch	flince	slome
CARDS	cards	wood	flane	slart
CORKSCREW	wine	wheel	stroob	tud
CRAWL	animal	bed	spom	pebe
DRAW	paint	sun	crolt	tarbam
DROP	break	ill	gern	poy
EAT	food	square	stilch	rilm
HAMMER	nail	clothes	spirpe	slunt
INJECT	needle	teeth	rop	thafe
IRON	shirt	beer	clut	hup
JUGGLE	clown	deaf	cep	creum
KEY	lock	carrot	snurf	rern
LIGHT BULB	light	fly	trebe	reuth
LIGHTER	fuel	grass	vapse	splon
MARCH	army	bird	swot	speem
PERFUME	smell	garden	croice	cluft
PULL	push	pond	lan	stould
PUSH	pull	sky	pib	gral
SKI	snow	fly	ceeb	spresh
SLAP	hand	talk	twark	sout
STIR	spoon	buckle	grourn	slont
TIE	neck	forest	bamth	fub
VIOLIN	string	face	wof	trewt
WEIGH	heavy	mud	fusk	flob
WRITE	letter	sea	gral	pib

Appendix G (continued)

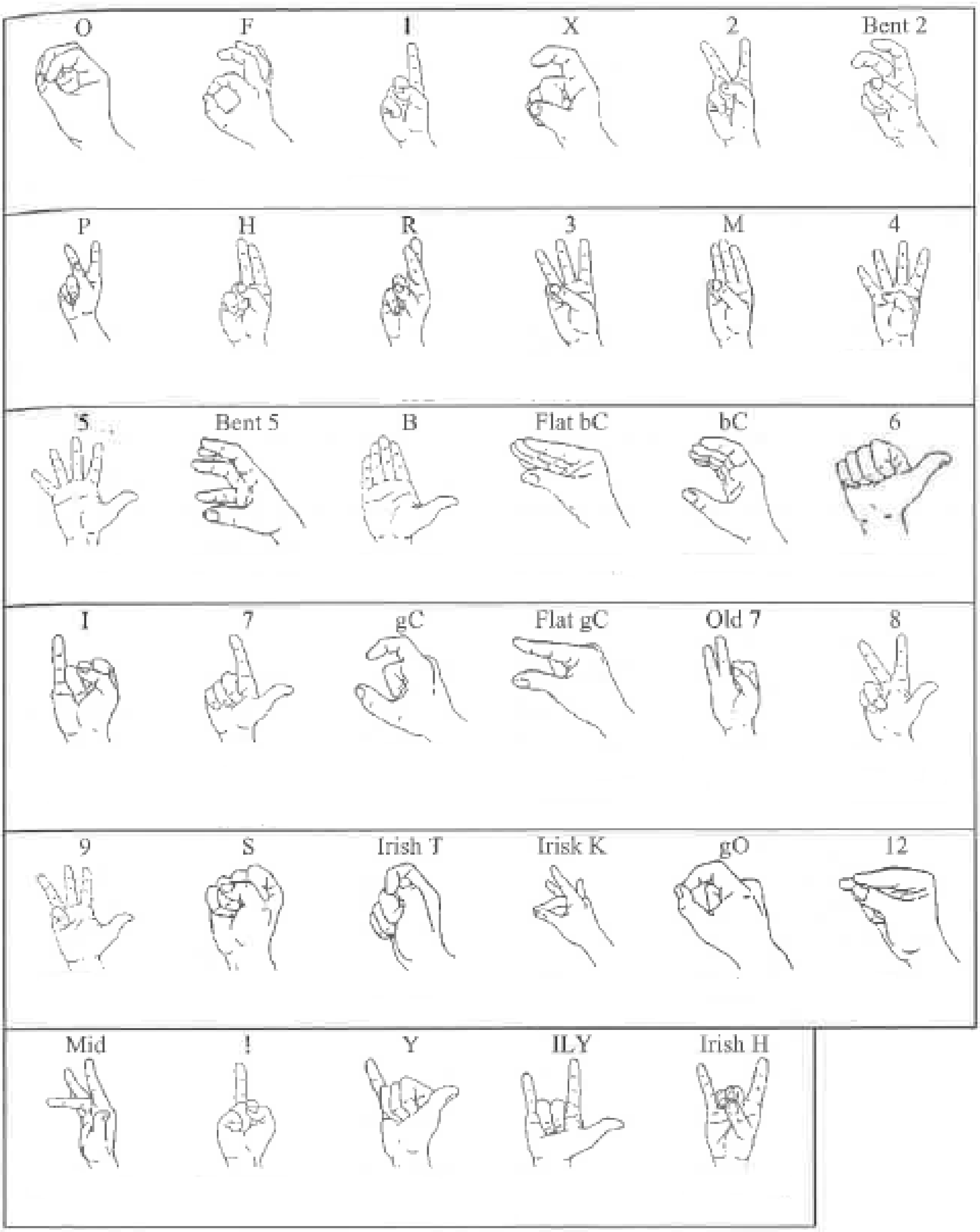
List of perceptual signs with their respective target words: 1) semantically related, 2) semantically unrelated, 3) non-word one, and 4) non-word two (Chapter 5)

Perceptual sign - word pairs

Sign prime	Target word			
	Related	Unrelated	Non-word 1	Non-word 2
AERIAL	t.v.	tin	pud	sem
AEROPLANE	fly	light	biefen	knurke
BELT	buckle	spoon	slont	grourn
BICYCLE	wheel	wine	tud	stroob
BOTTLE	beer	shirt	hup	clut
BOX	square	heavy	rilm	stilch
BUTTERFLY	net	photo	knush	sap
CLOCK	watch	rapids	slome	flince
CLOTHES-PEG	clothes	nail	slunt	spirpe
CLOUD	sky	pull	reuth	trebe
CROCODILE	teeth	needle	thafe	rop
DEER	forest	neck	fub	bamth
DRESS	girl	hair	wef	ciff
DUCK	pond	push	stould	lan
GOSSIP	talk	hand	bothe	stave
HEARING-AID	deaf	clown	creum	cep
HELICOPTER	fly	snow	spresh	ceeb
HOUSE	garden	smell	cluft	croice
KANGAROO	jump	army	speem	swot
MOON	sun	paint	tarbam	crolt
PILLOW	bed	animal	pebe	spom
RABBIT	carrot	lock	rern	snurf
RAKE	grass	fuel	splon	vapse
RHINO	mud	food	flob	fusk
SICK	ill	break	poy	gern
SMILE	face	string	trewt	wof
TREE	wood	cards	slart	flane
TURTLE	sea	letter	brulk	plail

14 Appendix H

Common handshapes in BSL and their labels. Adapted from Johnston and Schembri (2007)



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