Categorical versus gradient properties of handling handshapes in British Sign Language (BSL)

Evidence from handling handshape perception and production by deaf BSL signers and hearing speakers

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Declaration

I, Zdenka Sevcikova 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.

Candidate's signature: [redacted]

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Abstract

Sign languages include partially lexicalised signs (known as depicting constructions, DCs) that have been argued to blend linguistic and non-linguistic components, although it is unclear what these components are. To describe object handling, signers produce handshapes that represent how the hands shape for handling, but it has not yet been fully established whether the continuous object size is described by discrete handshapes in British Sign Language (BSL). The thesis examines whether experience with sign language influences perception and comprehension of BSL handling handshapes. In the first study, categorical perception (CP), using the identification and ABX discrimination tasks, is examined for handling handshapes (HHs) in BSL. The experiments reveal that adult deaf BSL signers and hearing non-signers perceive continuous HHs categorically while remaining perceptive to gradient aperture changes. Deaf BSL signers were more accurate than hearing non-signers when discriminating between handshape stimuli; this is likely due to visual language experience. However, reaction times showed no processing advantage suggesting that categorisation of BSL HHs has a general, visual-perceptual rather than linguistic basis. The second study examines whether deaf BSL signers compared with hearing non-signers express and interpret gradient sizes of manipulated objects categorically in discourse. Handling of objects gradiently increasing in size was recorded in BSL narratives, in English narratives via co-speech gesture and pantomime; recordings were shown to another group of judges who matched handling productions with the objects. All participants reliably associated smaller objects with smaller apertures and larger objects with larger apertures; however, in BSL and co-speech gesture, handshapes were not completely interpreted as gradient variations in comparison with pantomime. When gestures become more strategic or unusual, e.g. pantomime, speakers introduce finer-grained encoding of object sizes. The discontinuous patterns suggest that HHs have underlying representations outside of the linguistic realm; their categorisation arises from visual-perceptual experience that is embodied through interaction with real life entities. In discourse, handling constructions are partly conventionalised and may become decomposable in BSL overtime but it is suggested here that general cognitive and perceptual factors contribute to the conventionalisation, rather than purely linguistic. Further, the findings from both experiments lend support to the argument that HH category structure is graded. This thesis contributes to debates about the relationship between visual perception and language processing and the complex interface between language and gesture and highlights the nature of language as a multimodal phenomenon.

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CHAPTER 1 Introduction

1.1 Categorisation and categorical perception

Categorisation is an important aspect of human cognition as it enables perceivers to make sense of the vast amount of continuously varying stimuli in their environment. The assumption of categoricity in language has informed most linguistic and psycholinguistic research. In the sign language domain, the desire to establish that all productions of signers, similar to the proposed properties of spoken languages, are discrete linguistic and combinable units rather than idiosyncratic and analogue gestures dominated early sign language research (Schick, 1990; Supalla, 1982, 1986). Early research has claimed that signs are composed of handshapes, locations and movements (Stokoe, 1960) akin to phonemes in spoken languages. Recent experimental evidence has backed up the claims that handshapes in lexical signs in American Sign Language (ASL)[1] are discrete components has emerged for example from CP studies.

CP is when certain stimuli are perceived categorically rather than continuously despite a continuous variation in form, for example, gradient variation in colour hue is perceived in terms of bands or colour categories, or variation in speech sounds along voice onset frequencies is perceived in terms of categories which have been argued to coincide with phonemes in the perceiver's language (Liberman, Harris, Horffmann, & Griffith, 1957; Liberman, Harris, Kinney, & Lane, 1961; Schouten & van Hessen, 1992). Even though it has since been shown that CP is a mechanism related to experience or familiarity with stimulus rather than exclusively to linguistic processing, studies in the sign language domain have continued to utilise CP to demonstrate phoneme categories in lexical signs in American Sign Language (ASL) (Baker, Idsdardi, Golinkoff, & Petitto, 2005; Emmorey, McCullough, & Brentari, 2003) or that linguistic experience influences handshape perception (Best, Mathur, Miranda, & Lillo-Martin, 2010; Morford, Grieve-Smith, MacFarlane, Staley, & Waters, 2008). Such findings have led to arguments that only deaf ASL signers develop specialised abilities for perceiving phonemic handshapes and supported

[1] For a list of sign language abbreviations, see Appendix A.

claims that ASL lexical signs are composed of discrete handshape phonemes (see section 2.5.3) The CP principle is derived from the traditional view that assumes commonalities and invariance between category members. However, recent cognitive theories of language accept that category structure is graded (see sections 2.1.1 and 2.5.1 for an explanation). This thesis aims to support the latter view and the argument that certain sign language depicting forms blend gradient and discrete properties.

1.2 Depicting constructions

In addition to lexical signs with invariant meanings, sign languages contain constructions that can analogically (gradiently) depict the spatio-visual properties of entities. These are referred to in the following as *depicting constructions* (Liddell, 2003b) and are further discussed in section 2.1.3.1. Depicting constructions (DCs) express information about the location, movement and properties of referents in space or how objects are handled or manipulated and the handshape is the main component. Two main types of DCs are *entity constructions* where the handshape depicts whole or part of entities (Figure 2.6) and *handling constructions* (Figure 2.7) where the handshape represents the handling or manipulation of or contact with an object. When describing object handling, the signer's handshapes vary according to the described object size and shape. Objects have varying shapes and sizes and the issue of whether gradient object properties are described using categorical or analogic handling handshapes (HHs) remains unresolved. In addition, it remains to be established if HHs are specified in sign languages and how.

DCs have been often excluded from analyses of sign language grammar on the basis of their irregular behaviour. For example, Aronoff, Meir, Padden and Sandler (2003) argue that DCs do not adhere to the constraints found for prosodic words in ASL because they violate the principles of monosyllabicity, selected finger, symmetry and dominance regardless of internal morphological structure. Some describe DCs as visual representations that are highly mimetic and gestural in form (Cogill-Koez, 2000; de Matteo, 1977), while others have argued that they are fully linguistic and componential (Engberg-Pedersen, 1993; Sandler & Lillo-Martin, 2006; Schick, 1990; Supalla, 1978, 1982, 2003; Valli, 1995; Wallin, 1996, 2000).

The terminology used to describe DCs in the sign language literature has been inconsistent (Engberg-Pedersen, 1993; see Schembri, 2003 for further discussion). [2] For example, early sign language researchers (e.g. McDonald, 1982; Supalla, 1978) compared depicting handshapes with classifiers in certain spoken languages (e.g. Navajo) (Frishberg, 1975; Kegl & Wilbur, 1976; Supalla, 1978). This led to the use of the term "classifier" to refer to handshapes that stand for part/whole entities or their handling, which may have not been entirely appropriate. Further, the argument that depicting handshape is an overt morpheme has recently been challenged. Thus throughout this thesis, the term 'depicting handshape' is thus used to refer to meaningful handshapes used to depict whole/part entities and their handling (see also section 2.3).

Further, handling constructions have been particularly under-researched and most assumptions made about the structure or status of handling constructions and the discreteness of HHs have been based on findings from studies on lexical signs, whole/part entity or size and shape depicting constructions (SASS). HHs have rarely been investigated systematically in their own right. Handling constructions may share properties with gestures because of the greater possibility of one-to-one mapping from the signer's viewpoint, but this interaction has not been previously explored in depth. This is the first time CP or object size encoding / decoding has been examined for HHs in any sign language or gesture.

Liddell's idea (1998; 2003b) that DCs combine discrete and gradient properties is becoming increasingly accepted (Liddell, 2003a; Schembri, Jones, & Burnham, 2005). However, what the discrete and gradient properties are and which of the discrete elements are conventional or phonemic/morphemic remains to be determined. Despite the growing focus on DCs in the sign language literature, the

[2] DCs have been assigned various labels in the sign language literature. Most sign languages documented to date, though not all (Nyst, 2007; Zwitserlood, 2012), contain a complex type of partially lexicalised constructions that are believed to blend discrete and gradient properties, variously termed *depicting constructions* (Liddell, 2003b), *spatially descriptive signs* (de Matteo, 1977), *classifier predicates* or *classifiers* (Aarons & Morgan, 2003; Branson, 1995; Cogill-Koez, 2000; Corazza, 1990; Emmorey, 2003; Liddell, 2003b; Sandler & Lillo-Martin, 2006; Schick, 1990; Supalla, 2003; Valli, 1995), *productive signs* (Brennan, 1992), *verbs of motion and location* (Supalla, 1978, 1982), *polymorphemic verbs* (Collins-Ahlgren, 1990; Engberg-Pedersen, 1993; Wallin, 1990), *polycomponential signs* (Quinto-Pozos, 2007; Schembri, 2001, 2003; Slobin et al., 2001) or *depicting verbs* (Dudis, 2004; Johnston, Vermeerbergen, Schembri, & Leeson, 2007; Liddell, 2003b).

extent to which DCs blend discrete and gradient properties, the nature of these and the way they are represented, remain unclear, particularly in handling constructions.

Most analyses of DCs have concentrated on entity or static SASS constructions (Emmorey & Herzig, 2003; Schembri et al., 2005; Supalla, 1982, 1986). These analyses have provided some evidence that entity and SASS handshapes are discrete and that their inventory is closed (Brentari, 1998; Liddell & Johnson, 1989; Sandler, 1989; Zwitserlood, 2003, 2007, 2012). Furthermore, whole/part entity handshapes tend to be more discrete and specified in the sign language inventory than movement or location used with these DCs (Schembri et al., 2005) and differ from handshapes used by hearing speakers when they gesture without speech (i.e. in pantomime). Emmorey and Herzig (2003) found that deaf ASL signers, unlike hearing non-signers, systematically organised handshapes depicting object sizes into categories (e.g. they used /F/ handshapes for small-size medallions and /baby-C/ for larger size medallions) and concluded that these handshapes are discrete morphemes in ASL. [3] Many researchers have cited Emmorey and Herzig's (2003) findings and have argued that both entity and HHs in other sign languages are discrete. Zwitserlood (2003), for example, makes this assumption with caution based on her observations of a collection of classifiers in the Sign Language of the Netherlands (NGT) and acknowledges that occasionally the handshapes were adapted by stretching and tensing of the thumb and index finger. It is unclear whether these features, i.e. finger bending, spreading or finger distance are perceived or used systematically in all depicting handshapes. It is not clear whether discrete encoding of gradient object size in ASL size and shape specifier (SASS) handshapes such as /F/, /O/ or /baby-C/ (Emmorey & Herzig, 2003; Schwartz, 1979) can be extended to size and shape encoding in HHs because comparisons between DCs produced by deaf signers and hearing non-signers with and without speech have been limited (see 2.4.1 for a discussion).

Thus despite the fact that DCs have been documented in most sign languages studied to date, they have received limited attention in sign language research. Researchers have generally assumed that handling constructions are compositionally similar to entity constructions (e.g. Brentari & Eccarius, 2009; Eccarius & Brentari, 2008a, 2010; McDonald, 1982; Slobin et al., 2003; Supalla, 1990; Zeshan, 2003;

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[3] For illustration of handshapes, handshape transcription and glosses, see Appendix B.

Zwitserlood, 2003). With the exception of two recent studies (Eccarius & Scheidt, 2009; Zwitserlood, 1996), assumptions about discrete handling and their linguistic status still lack an empirical grounding. Entity handshapes do not allow for the same degree of gradient modification, which means the number of HHs could potentially be very large. In constructions depicting handling, the handshape represents the way the referent's hand is shaped for handling of objects on a large, real-life scale. This allows for a more analogue form-meaning mapping of continuous object sizes onto handshape forms and may result in less conventionalised handshapes in comparison with entity handshapes, which are more discrete and conventionalised due to the small-scale mapping.

Many sign language forms display gradient patterning and more recent theories of spoken language have accepted the idea that linguistic structures are not strictly categorical and that linguistic structures contain more iconicity and gradience than previously thought. In contrast with the more traditional views of category structure where all members were considered perceptually equivalent, theories of graded category structure argue that certain members are considered as more prototypical than others (see Rosch & Mervis, 1975; Gati & Tversky, 1984; Tversky, 1977; Medin & Barsalou, 1987). Similarly to perceptual or cognitive categories, linguistic categories, e.g. phonetic, have been argued to have a graded structure, with some members perceived as better exemplars of a category than others (Miller, 1977, 1994; Volaitis & Miller, 1992). Early CP research was dominated by the traditional notion of category structure (Liberman, Cooper, Shankweiler, & Studdert-Kennedy, 1967; Liberman et al., 1961). Since then the nature of CP and what it reveals about linguistic representations has been reviewed (Schouten, Gerrits, & van Hessen, 2003) (see section 2.5 for a review). Categorical perception is used here as a tool to assess how perceivers internally represent the categories and how they map the incoming auditory or visual signal onto these representations during processing. The architecture and organisation of categories has an impact on differential attention and processing. Currently, insights into the structure and organisation of categories in sign language have been limited to lexical signs. This research aims to extend findings about categoricity to less lexicalised and less conventionalised constructions in sign languages, such as handling constructions, and provide some insights into the structure and organisation of sign language categories.

1.3 Depicting constructions and the relationship to gesture

Gesture is described as non-linguistic and gradient because it lacks adequate level of conventionalisation (McNeill, 1992; Okrent, 2002). According to Okrent (2002), gesture forms are unconventional and the meaning to form pattern in gesture is gradient, as opposed to categorical (see section 2.2). It is difficult to determine what the conventional elements are based on observational data because less conventional constructions, such as DCs, lexical signs and depicting gestures can appear similar.

Gesture has been increasingly included in linguistic analyses, although it is not yet clear how language and gesture interact in signed discourse. Research comparing DCs with viewpoint gestures, reviewed in section 2.2.5, suggests that handling constructions have different gestural origins than constructions depicting whole/part entities. Slobin et al. (2003) add that depictive HHs are often "literal gestures of an activity, and it is only the factor of conventionalisation in the speech community that distinguishes sign from gesture" (2001, p. 281). For example, Goldin-Meadow and colleagues provided limited evidence that object handling is described using discrete HHs in invented homesign systems (Goldin-Meadow, 1998, 2007), but overall, a systematic distinction between lexical handling and handling depiction has not been made in the sign language research. Experimental evidence will provide useful insights into the nature and representation of handling tokens in lexicalised and less conventionalised contexts.

In this thesis, g*esture* is used as an umbrella term that includes a full range of forms from Kendon's (2004) continuum, ranging from gestural categories such as *co-speech gesture* or gesticulation at one end with *pantomime*, language-like gestures or emblems in the middle and then sign languages at the other end (Kendon, 2004; McNeill, 1992, 2000). *Co-speech gesture* is understood as visible, spontaneous communicative behaviour of the hands, which occurs simultaneously with speech and is linked to what is being said either by its content or form (excluding self-grooming gestures). Co-speech gesture is automatic and speaker-oriented, whereas pantomime is strategic and receiver-oriented. *Pantomime* is understood as non-linguistic gesture strings that are produced in isolation or separate from the linguistic (spoken/signed) output. Gesture in sign language is the expression of imagistic thought during signing (Okrent, 2002). Following Liddell (2003a), the gestural properties of DCs are understood in this thesis as co-occurring simultaneously within a single construction, rather than as separate semiotic units of expression. See more on gesture and language in section 2.2.

1.4 Aims and objectives

The overarching aim of this thesis is to determine whether HHs in BSL handling constructions are discrete or gradient by a) assessing whether HHs are perceived categorically by deaf BSL signers and hearing non-signers and by b) examining the extent to which HHs conventionally depict size and shape of handled objects in discourse. The central question in this thesis is whether sign language experience shapes the perception of certain sign language stimuli, or whether perception is shaped by more general visual experience and familiarity with visible utterances rather than processing specific to a sign language.

Experience, exposure and ritual use play important roles in the degree of conventionalisation of signs and gestures. The central interest of this thesis is in how experience with a sign language and familiarity with specific stimuli might modify perception and comprehension of HHs. This is critical for understanding about the structure of depicting constructions in BSL and the degree to which certain seemingly improvised expressions, such as constructions depicting handling, might be discrete and conventionalised in sign language. The main objective of this research is to provide valuable empirical evidence about the way handling constructions are perceived or decoded in spontaneous interaction to reveal whether or not HHs are conventionalised in BSL and what their structural properties, their nature and representation might be. For example, there is currently limited empirical evidence as to whether elements of handling constructions, such as finger-thumb distance or finger spreading, are conventionalised and categorical or gradient variations in BSL. The thesis aims to provide insights into the role of gesture and conventionalisation in handling constructions and to inform sign language theories of DCs.

Previous sign language studies examined categorical perception for handshapes in lexical contexts or non-signs. Evidence from such studies has been used to argue that sign language handshapes are categorical and that sign language experience mediates CP. No study to date has investigated CP for handshapes in less lexicalised and less conventional contexts, such as DCs, which are characteristic of many one-to-one form/meaning mappings and where category members are treated as less similar to each other (see section 2.1.1). This in turn may lead to less clear CP patterns. In addition, the idea that DCs contain both discrete and gradient elements is becoming increasingly more accepted in sign language research although these elements can have varying linguistic status (see sections 2.1.1 or 2.4). The current experiments ask if sign language experience influences perception and interpretation of partially- or non-lexicalised depicting handshapes, such as HHs, or whether perception and comprehension are mediated by general visual experience and familiarity with visible gestures. This question has not been previously answered in CP studies or studies of DCs in general. Section 2.5 provides a review of previous studies in the spoken (2.5.2) and sign language (2.5.3 and 2.5.4) domain.

The general motivations for this research are both theoretical and practical. The theoretical interests concern the similarities and differences in the linguistic patterning in the visual versus auditory modality – in particular, the level and extent of segmentation, discreteness/gradience of form, iconicity and the interplay between gesture and the linguistic system. Even though both spoken and sign languages contain gradient forms, it could be argued that spoken language elements or constructions do not express gradient information in the same way or the same extent as DCs in sign language.

Thorough descriptions of sign languages, especially DCs, have been lacking. One reason is that the majority of analyses of DCs have assumed that language consists of discrete and highly conventionalised elements (a key tenet within nativist/formalist frameworks that assume that language is a specialised module separate from other cognitive and perceptual systems). Such accounts have not yet provided suitable analytical tools for constructions that mediate information across different modalities in both conventional and non-conventional ways. Comprehension patterns of size encoding in handshapes (see section 2.4) provide insights into the way reality is perceived and encoded in discourse, which in turn contributes to knowledge about the constraints of modality and the extents of human communication capacities.

The practical motivations stem from a need to describe and characterise sign language structures where the assignment of form to meaning is less conventional. Without knowledge about the conventional and non-conventional patterns in constructions depicting handling one cannot begin to make claims about their acceptability or their linguistic status. Further practical motivations arise from a need to understand lexicalisation patterns with handling constructions and also to inform methodologies for teaching sign language as a second or foreign language. This research also bears a crucial importance for interpreting – for example, how is depiction of object handling and manipulation in BSL typically translated into English? Insights into the way handling constructions are structured can contribute to more appropriate translation and transfer of meaning. All in all, this thesis addresses questions pertinent to research on DCs that have often been asked in the literature, yet not sufficiently explored. This thesis stimulates the debate about structural properties of handling constructions, the cognitive and perceptual mechanisms involved in their processing and the nature of language and gesture interface. It supports the view of language as a cross-modal phenomenon. The comparisons between experienced deaf BSL signers and hearing non-signers will also open important questions about the role of sign language experience in visual perception.

1.5 Outline of the thesis

Following a general introduction to the thesis, Chapter 2 goes on to provide a discussion of DCs reviewing key arguments about their structural properties. A critical summary of theoretical accounts of sign language DCs is provided with a focus on handling. This chapter also discusses the sign language lexicon and highlights the distinction between lexical signs and DCs. The differences between entity and handling constructions are outlined by drawing comparisons to character and viewpoint gestures. The relationship between language and gesture in interaction is also briefly taken up. This chapter explains the fundamental distinctions between signs, words and gestures and speaker- vs. hearer-oriented gestures (co-speech gestures vs. pantomime) against the backdrop of the key behavioural and neurolinguistic studies. The chapter makes a point about the fuzzy distinction between lexicalised and less conventionalised depicting forms and gestures.

Chapters 3 and 4 report on the experimental studies that provide some evidence about the less conventionalised nature of HH in BSL. Chapter 3 gathers evidence about the perceptual patterns in handshape categorisation and discrimination by deaf BSL signers and hearing non-signers and provides an insight into the lower level processing of handshape forms. It seeks to provide support for claims concerning the status of less conventionalised and more gradient handling forms. The study asks whether handshapes depicting handling or manipulation of flattish, rectangular and cylindrical objects in BSL are perceived categorically by deaf BSL signers and their hearing counterparts. The study aims to establish whether sign language experience mediates the perception of handling forms.

Chapter 4 then bridges the gap between perception and production by examining whether the meaningful and gradient information about graspable object sizes is encoded and interpreted categorically in spontaneous descriptions of handling in signed and spoken discourse and pantomime. Is there a systematic handshape form to meaning mapping (many-to-one) or more gradient (one-to-one) mapping in handling constructions? The study seeks to examine whether the processes underlying production and comprehension of HHs in BSL are similar to those involved in production or comprehension of gestures with or without speech. Most of what is known about the differences and similarities between depicting signs and gestures is based on comparisons between signs and gestures without speech. Given that that information is encoded rather differently in pantomime than in gestures with speech (see also 2.2.2), this study provides a valuable contribution to the knowledge about the nature of cross-modal communication. Depictive manipulative gestures are used abundantly and early on in both signed and spoken communication yet little is known about their role in visual and linguistic processing. A phonological description of the elicited HHs is provided.

The discussion in Chapter 5 brings previous evidence and experimental findings from this thesis together. The findings are considered in relation to linguistic theories of DCs and general theories of language. The findings are also discussed in the light of previous research on object size encoding in SASS / entity constructions in ASL and in homesign gestures. Chapter 6 summarises this thesis, draws conclusions based on the results of the experiments, discusses their limitations and suggests future directions for research.

CHAPTER 2 Theoretical background

2.1 Structural properties of signs

2.1.1 Discrete and analogue patterning in language

Discreteness is an important design feature of language (Hockett, 1960). Despite gradient variation, there is a limited set of discrete and listable sounds or manual units used in a language. Traditionally, segmentation (compositionality) and discreteness have been seen as hallmarks of linguistic systems. Such views have mainly depended on the idea that compositionality is strictly categorical in nature, even though this assumption is not well supported. But the degree to which forms are compositional (discrete) or productive (gradient) might relate to the frequency of use (Bybee & Hopper, 2001; Bybee & McClelland, 2005). Productivity is defined as the tendency for a pattern to apply to new forms and suggest that productive patterns are built up from experience with different exemplars (Bybee, 2001). Frequent forms are less productive, less gradient and more fossilised and formulaic than novel or less frequent forms but there is no dichotomous distinction between productive and unproductive phenomena; rather, there are degrees of productivity.

The present research seeks to address the issue of gradience and compositionality of handling constructions. Although very similar in appearance, these forms differ from lexicalised handling signs that are found in sign languages because their meaning can be strongly tied with context or other discourse factors and they tend to be more productive and gradient. Because depiction of handling also occurs in hearing speakers' gestures, the extent to which linguistic experience influences perception of handling forms is unknown. From a cognitive linguistics perspective, language use shapes cognitive representation through the application of general cognitive principles of human cognition to linguistic input (Bybee and McClelland, 2005). Handling constructions occur in both sign languages (Padden, Aronoff, Meir, & Sandler, 2010) and generally in face-to-face communication by hearing non-signers, the question is whether and how sign language experience shapes the perception of such forms, or via versa, for deaf signers versus hearing non-signing gesturers.

The assumption of categoricity in language has informed much of linguistic and psycholinguistic research. A category contains many members; this allows for arbitrariness and duality of patterning (i.e. a lack of one-to-one mapping between the form and meaning). These characteristics have been argued to be essential for human language (Hockett, 1960), although the view that language contains non-discrete forms is now accepted. In a categorical system, slight alteration of form does not change the meaning of the sign because the variants are identified as indifferent and the boundaries between categories are more clearly definable than in an analogue system. A strictly analogue system consists of one-to-one relationships between form and meaning where forms vary along a continuum. An analogue system is characterised by isomorphism in which cognitive and perceptual factors can influence the degree to which a change in form is associated with a change in meaning (Emmorey et al., 2003).

Recent research into conceptual categorisation supports the view that many natural categories however contain graded structure (Ameel & Storms, 2006; Rosch & Mervis, 1975) where certain members are considered more prototypical than others. For example, the identification of category members is based on common and distinctive features (Rosch & Mervis, 1975; Tversky, 1977). Feature-based approaches have been used to explain the structure and representation of linguistic categories (Bybee, 2001; Tsohatzidis, 1990). Given that many sign language forms display gradient patterning, the idea of graded category membership fits well with the premise of this thesis. The thesis moves away from the idea that category members are treated as indifferent, particularly where highly embodied and iconic forms influenced by several cognitive and perceptual factors are concerned. It examines the extent to which perceivers with or without sign language experience categorise / discriminate between handshapes. In other words, it will help determine the strength of categories by assessing the extent to which variability in the visual signal is ignored for the purposes of efficient communication.

Signed and spoken languages exhibit analogue and iconic forms (Haiman, 1980, 1985; Hinton, Nichols, & Ohala, 1994; Mandel, 1977; Taub, 2001); iconicity is more pervasive in spoken language forms than originally thought (Perniss, Thompson, & Vigliocco, 2010), although sign and spoken languages differ in the extent to which modality permits iconic linguistic forms (Emmorey & Herzig, 2003). Equally, neither sign nor spoken languages are strictly categorical as both allow for a degree of gradience at different linguistic levels (Hinton et al., 1994; Okrent, 2002; Taub, 2001). Iconic forms may encode discrete and arbitrary information (see Taub, 2001 for further discussion about iconicity in sign forms) although DCs in older sign languages, such as ASL, exhibit more arbitrary components than in younger sign languages such as Israeli Sign Language (ISL) or Nicaraguan Sign Language (ISN) (Aronoff et al., 2003). Analogue forms can become conventionalised and more arbitrary over time (Klima & Bellugi, 1979). The problem that iconic forms can represent for linguistic analyses is how such forms which may not be completely discrete can be described (van der Kooij, 2002). Thus, although the distinction between discrete and gradient patterning is relevant for DCs, it should not be understood as a distinction between linguistic and non-linguistic features. The extent to which such highly embodied and partly conventionalised constructions combine analogue and discrete elements has, despite the expanding research on sign languages, not been sufficiently studied. This will be discussed further in sections 2.5 and 2.6.

2.1.2 Lexical signs and their components

One of the most important defining features of human language is *duality of patterning / double articulation* (Hockett, 1960). In English for example, the /b/ and /p/ phonemes differ only in voicing and meaningfully distinguish words such as *pet* and *bet*. Similarly to spoken languages, lexical signs in sign languages can be decomposed into basic phonological parameters, including handshape, location or movement (Stokoe, 1960).

Handshape is the main formational parameter and is the primary focus of this thesis. In the context of phonological / phonetic analysis, handshape as a feature class stands for the specific configurations of fingers, the thumb and the palm; for example, in the /pinky/ handshape of BSL the pinky is extended but the thumb and other fingers are closed (completely flexed) as in the BSL sign WRONG[4].

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[4] English glosses for BSL signs are in small caps. Phonemic handshapes (illustrated in the Appendix B) are labeled with a descriptive English word in lower case in phonemic slashes, e.g. /index/. If cited directly from a source, the original phonemic representation using ASL fingerspelling alphabet has been retained.

a) /pinky/ handshape   b) BSL WRONG

Figure 2.1. Example of a) the ‘handshape’ parameter in b) the BSL sign WRONG

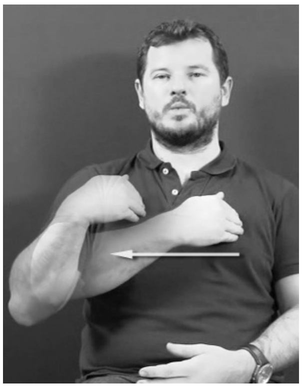
Despite the large number of possible hand configurations that can be produced, each sign language tends to use only a limited number of handshapes. For example, Schembri (1996) reported that 34 distinctive handshapes exist within the lexicon of Australian Sign Language (Auslan), and Brennan (1992) proposed an inventory of 44 handshapes used in lexical and productive signs in BSL, about 38 of which may be used to describe handling, although it is arguable whether this is a definitive and accurate count because there is currently no systematic research available to support these figures.

Location is another sign language parameter and refers to the position of the hand on the signer’s face, body, or area in the signing space. For instance, in the BSL signs THINK and AFTERNOON, the signer’s dominant hand is placed on the temple (Figure 2.2 a) or the chin (Figure 2.2 b) respectively.

a) BSL THINK (temple) b) BSL AFTERNOON (chin)

Figure 2.2. Example of the ‘location’ parameter in BSL signs a) THINK and b) AFTERNOON

Movement describes the action that the hand/arm performs. For example, a movement can be arced or straight as in the sign ASK, a movement from left to right on the signer's chest as in the sign a) MORNING, or as a sign-internal movement such as the short repetitive forearm twist (radio-ulnar joint) as in the sign b) MAYBE in Figure 2.3.



a) MORNING (straight movement across the signer's chest)

b) MAYBE (circular movement of the wrist in front of the signer's torso)

Figure 2.3. Example of the 'movement' parameter in BSL signs MORNING and MAYBE

Orientation was added as a parameter to the phonological structure of signs by Battison (1978). It refers to the direction of the palm in relation to the signer's body. Many linguists recognise that *non-manual features* (e.g. facial expression, mouth gestures or movement of the head and body, such as nods or head tilts) play an important role in the internal structure of signs (Liddell & Johnson, 1989; Sutton-Spence & Woll, 1998).

Lexical signs in BSL can be minimally distinguished by handshape, e.g., the /fist/ and /B/ handshapes generate a minimal contrast between BSL signs a) CHEW and b) MEAN in Figure 2.4.

a) BSL CHEW (circular /fist/ movement)

b) BSL MEAN (circular /B/ movement)

Figure 2.4. Phonemic variation of handshape in BSL signs a) CHEW; b) MEAN

Not all handshape changes trigger a change in meaning; Figure 2.5 shows an example where the pinky extension represents a common phonological process in some sign languages that results in an allophonic variant but with no change in meaning (Lucas, 1998). This is similar to allophonic variation in aspiration of the sound /t/ in 'tie' that can be pronounced as [t^{s}aɪ] or [taɪ] by English speakers without changing the lexical meaning.

a) BSL SEE (pinky unselected) b) BSL SEE (pinky selected)

Figure 2.5. Allophonic variation of handshape in BSL sign SEE; a) pinky unselected, b) pinky selected

Handshape forms can move from the non-native and productive parts of the sign language lexicon into the more lexicalised parts (see also section 2.1.3.2, Figure 2.9). Thus, the nature of minimal contrast in sign languages is more fluid than in spoken languages where the degree of contrast does not vary to the same extent. In sign languages, the transparent meaning of phonemes can reduce the contrast between phoneme categories. Building on Clement's notion of feature phonology (Clements, 1985, 2001), Brentari and Eccarius (2009) describe the varying types of contrast in sign languages, e.g. bare vs. prominent contrast.

The formational parameters of signs consist of phonetic feature classes and function similarly to the phonetic features in spoken languages. The formational features serve as an organisational basis for minimal phonological contrasts (Stokoe, 1960). This system is governed by the grammatical rules of the language and serves as a basis for linguistically permissible forms in its lexical inventory. According to van der Hulst (1995), for each feature class (e.g. handshape, movement) in sign language phonology there is a finite number of features. Brentari (1998) and colleagues have argued that the handshape parameter consists of the following features; the *number of selected fingers* that move/contact the body as a group during a sign production, and the *joint configuration* representing the flexion, extension or spread of selected fingers during articulation of a sign (Brentari, 1998, 2005; Brentari & Eccarius, 2009), see Appendix G for details. For example, the BSL signs CHEW and MEAN (Figure 2.4) both use the same selected fingers but vary in finger flexion vs. extension – flexed vs. extended respectively. The phonological system of Eccarius and Brentari (2008b) is based on the Prosodic Model of Sign Language Phonology by Brentari (1998) and allows for distinctions between the gradient changes in joint configuration or finger spreading in depicting handshapes. The system is based on two handshape features: finger combinations (selected fingers and thumb opposition) and joint configurations (flexed, stacked, spread, etc.). While the finger selection possibilities are somewhat physically constrained, joint configurations can be large in number, making the count of distinct features difficult to determine. It remains to be seen whether such feature-based approaches account well for more gradient aperture variation in handling constructions; this is further discussed in light of my observations in section 4.5.4.

2.1.3 Less conventionalised constructions

2.1.3.1 Depicting constructions

In addition to lexical signs with more or less invariant meaning, sign languages contain constructions that can analogically (gradiently) depict the spatio-visual properties of entities are here referred to as *depicting constructions* (Liddell, 2003b). Depicting constructions (DCs) express information about the location, movement and properties of referents in space or how objects are handled or manipulated. Two main types of DCs have been identified in sign languages, the first of which are *entity constructions* that depict entities and their movement, location and orientation in space (Figure 2.6). The *entity handshape* represents a whole / part of a referent and commonly depicts the semantic class or some salient characteristics of the referent, such as the size, dimension or orientation and is variously known as a [whole] entity classifier, limb classifier or semantic classifier.[5]

[5] Handshapes depicting some aspect of a visual-geometric description objects referred to as size and shape specifiers (known as SASS) are treated here as a subclass of entity handshapes. For other subcategories of DCs, see Supalla (1982, 1986, 2003), Shepard-Kegl (1985), Schick (1990), Kegl (1990), Engberg-Pedersen (1993) (1993), Emmorey (2003) and Zwitserlood (1996; Zwitserlood, 2003).

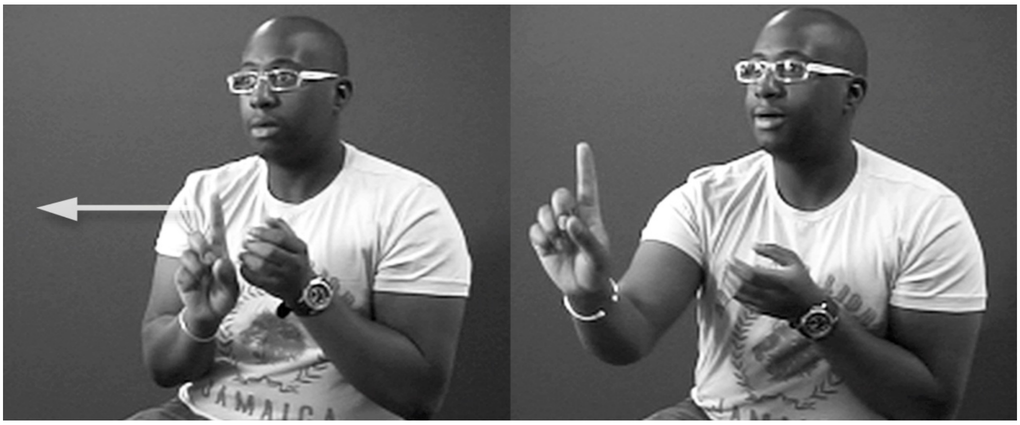


Figure 2.6. Entity construction in BSL representing an upright stick-shaped entity moving from location x to location y, with the handshape depicting the whole entity

The second type of DCs is constructions depicting handling or manipulation of entities, called *handling constructions* (Figure 2.7) (Schick, 1987; Supalla, 1982; Zwitserlood, 2003, 2012). The term *handling handshape* (HHs hereafter) represents the handling or manipulation of or contact with an object, i.e. how the hand is configured when handling a particular referent or a part of it. Common labels for this handshape include handle/handling classifier or touch classifier. When describing object handling, the signer's hand is shaped according to the described object size and shape. The size and shape of object continuously varies. Therefore, the question that arises is whether the size and shape of entities in handling constructions can be described using discrete HHs or whether the handshapes depict object size analogically, whether these handshapes are listable in the sign language inventory.

Figure 2.7. Handling construction in BSL representing the movement of an object from location x to location y, with a handshape that depicts a flat object being handled

In partially lexicalised constructions, handshapes can be used productively, i.e. the relationship between handshape form and denoted meaning is not always one-to-many and handshapes are not decomposable. For example, a straight versus bent index finger in a handshape depicting an upright entity can be gradiently modified to indicate the different degrees of bending of a hunched person. Similarly, the distance between the thumb and fingers in a handshape depicting handling round or cylindrical objects can be gradiently modified to indicate different degrees of thickness of that object. The question is whether the change in joint configuration, represented by the finger aperture, finger spreading or even finger curvature in /C/ handshape variants categorically alter the meaning of the construction in BSL. To illustrate this, Figure 2.8 shows a construction depicting handling of the same referent, a soft toy. One signer uses a /C/ handshape with fingers together as in a) and one with fingers spread in b). Both handshapes contain a short hand internal movement depicting the hand squeezing the soft toy.

a) DC: handle.round.object   b) DC: handle.round.object

Figure 2.8. An example of HH variation in a BSL DC depicting handling of a soft round object

Few studies to date have addressed the question whether depiction of object size/shape is made discretely and whether this systematic marking is unique to sign language, for example, it is not clear whether features of handling constructions, such as finger-thumb distance or finger spreading, are conventionalised and discrete variations in BSL. Overall, existing sign language research has not provided sufficient answers about the extent to which size and shape encoding in DCs is conventionalised.

2.1.3.2 Depicting constructions and the lexicon

This section briefly introduces the sign language lexicon, evaluates how DCs might be represented in the lexicon and highlights the need to account for various degrees of conventionalisation and lexicalisation of DCs. Not all DCs that include handling are fully lexicalised. Furthermore, handling constructions and entity constructions may undergo different conventionalisation processes due to different gestural resources. For example, in Adamorobe Sign Language (AdaSL) (Nyst, 2007) certain signs are adapted from or are very similar to the conventional gestures for depicting size and shape used by hearing speakers. These can become conventionalised and distinctive in the lexicon. In addition, Nyst also comments that HHs occurred in the AdaSL data less frequently than entity handshapes and that they mainly occurred in non-lexical signs depicting how entities move in space. In order to understand this, it is first necessary to outline the proposed structure of the sign language lexicon and the representation of DCs in the lexicon.

Brentari and Padden (2001) propose that ASL lexicon may be divided into subcomponents that contain all the native sign vocabulary, the native lexicon (2) and a non-native component, or lexicon, (1) that is borrowed from English by means of fingerspelling (see Figure 2.9). This model has been widely used to sketch lexical structures of other sign languages.

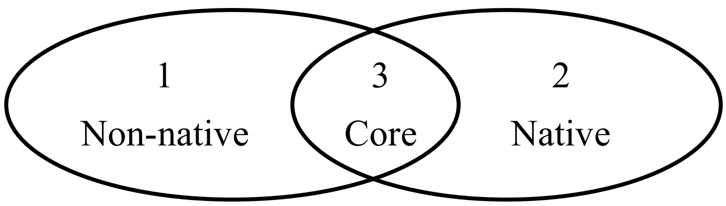


Figure 2.9. Model of the ASL lexicon (adapted from Brentari & Padden, 2001)

Native signs are signs that have developed within signed languages and conform to a set of constraints, such as the constraint that there may be no more than two types of handshape per sign, first proposed by Battison (1978) for ASL. Non-native forms are lexical items in ASL that include fingerspelled representations of words from the surrounding spoken language – in this case, English. The native subcomponent of the lexicon may be subdivided into core and non-core components. As far as DCs are concerned, Brentari and Padden (2001) suggest that these are included in the native part of the lexicon, i.e. part 2 in Figure 2.9 above, whereas signs derived from fingerspelling are represented in part 1 (non-native). The central component of the lexicon (3) is the core native vocabulary which contains all permanent signs that are highly stable and standardised in form and meaning with high frequency of use in a language. These signs are referred to as lexical signs. Lexical signs are "...ready-made, off the shelf lexical items. They are already in existence: the signer simply has to pluck them from her/his mental lexicon and place them in the appropriate lexical contexts" (Brennan, 1992). In contrast, the non-core native lexicon (2) is made up of DCs, which are highly variable and weakly lexicalised. Handshapes and other features in these constructions no longer have a fixed meaning and are subject to productive morphological rules. Several sign linguists, including Brentari (2001), McDonald (1982), Padden (1998), Johnson and Liddell (1984), Johnston and Schembri (1999), Supalla (1982), and Brennan (1990; Brennan, 1992; Brennan, 1994, 2001)have provided descriptions of the lexicon, although their descriptions of its parts differ considerably. Some have extended this model to other sign languages including BSL and Auslan (Cormier, Schembri, & Tyrone, 2008; Johnston & Schembri, 1999). Despite varying descriptions of lexical components, it is agreed that the non-core portion of the native lexicon proposed by Brentari and Padden (2001) includes both entity and handling constructions. Such constructions may differ considerably in the extent to which they are conventionalised. Entity handshapes may be more discrete in comparison but it is unclear whether the same applies to HHs. Thus Brentari and Padden's (2001) model as depicted in Figure 2.9 could be considered too simplistic to cover all the nuances of such constructions.

Further, signs may move between the parts of the lexicon. Aronoff et al. (2003) claim that the ASL sign FALL (Figure 2.10) originated as an entity construction in which the hand represents the legs of a two-legged entity. Over time, this sign has become more general in its semantic interpretation. It is no longer restricted to representing humans and when used as a verb, it may take apples, boxes or rocks as possible subject arguments in ASL. The handshape component of the sign FALL no longer has a link to a specific class of referents, despite it iconically representing two-legged entities (Supalla, 1986).

Figure 2.10. Example of the lexicalised sign FALL in ASL where the handshape is no longer restricted to two-legged entities

The question of how structurally complex, part-lexical, part-gestural forms fit into the sign language lexicon is thus an interesting one and is addressed in the following section.

2.1.3.3 Handling constructions and handling handshapes

Handshapes depicting whole or parts of entities or their handling occur in both the non-core lexicon as partially lexicalised signs and in the core lexicon in lexical signs. For example, the /C/ handshape occurs in a lexical sign DRINK but can also be interpreted as a handling handshape that highlights the way the referent's hand shaped for handling a cup or as an entity handshape that represents the cup. Furthermore, the signer can produce a large arced arm movement to depict someone taking a long drink from a cup, or produce a handshape to represent a particular shape of the cup (narrow/wide). HHs used within lexical signs and constructions that are not as lexicalised tend to be very similar in form. For example, the Indo-Pakistani Sign Language (IPSL) sign NEWSPAPER shown in Figure 2.11a) is based on a 'handling' construction which uses the /intl-T/ handshape and has a literal meaning that suggests the unfolding of a large flat and flexible object (Zeshan, 2003). Similarly, the BSL sign COOK, as shown in Figure 2.11b), is based on a handling construction that also using /intl-T/ and has a meaning that suggests holding a saucepan handle. Zeshan (2003, p. 134) argues that the meaning of the construction has gradually narrowed down so that it is now used to refer to a newspaper as a lexical item in particular. In a BSL example, the /intl-T/ handshape for holding a saucepan handle can be used meaningfully in a DC or as a lexical (plain) verb COOK, or in the noun SAUCEPAN. Due to a lack of historical evidence, the direction of the lexicalisation path remains uncertain; it is unclear whether the handshape was originally used as part of a lexicalised sign or within a DC, or whether they may have evolved simultaneously.

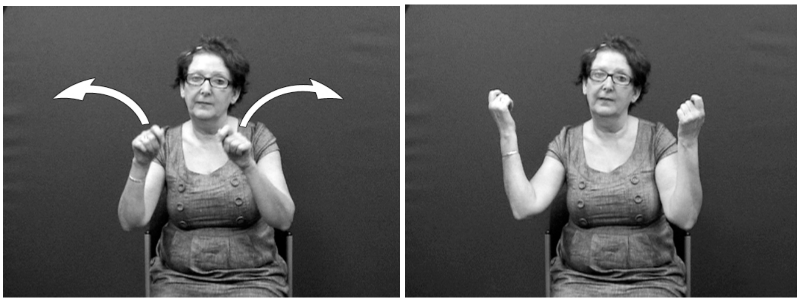


Figure 2.11 a) BSL lexical sign NEWSPAPER with /intl-T/ handshape

Figure 2.11 b) BSL lexical sign COOK with /intl-T/ handshape

The extent to which handling constructions can be compared to fully-fledged lexemes or as monomorphemic forms is unclear because the depicting elements may or may not be componential. Some BSL lexicalised signs, such as COOK, incorporate features that may also function meaningfully on their own if used in a construction that depicts, e.g. how a referent hits another referent with a saucepan. Some DCs have no clearly definable lexical meaning because of the gradient, non-conventional modification of some of its elements, e.g. longer and pronounced movements to indicate effort or modification of handshape aperture or finger spreading to depict the specific way the referent's hand is shaped for handling. Generally, their meaning can be understood from the linguistic (e.g. syntactic) context (Benedicto, 2004; Zwitserlood, 2003).

2.2 The language and gesture interface

There is a consensus that language and gesture are integrated processes in communication but the extent and nature of this integration is under some debate. Current research in linguistics and psychology recognises the importance of non-linguistic strategies such as gesture in all face-to-face discourse and their influence on linguistic structure (Duncan, 2005; Kendon, 2008; Okrent, 2002; Sweetser, 2009). Speech and gesture, for example, interact and influence each other in face-to-face communication (Kendon, 2000; McNeill, 1992), develop in an interdependent fashion in children (McNeill, 1992; Özyurek, Kita, Allen, Furman, & Brown, 2005), share common neurological substrates (Kimura, 1993) and may breakdown together in language disorders (Goodwin, 2000; Mayberry & Jacques, 2000). This section discusses language and gesture at the interface in DCs.

2.2.1 Language and co-speech gesture

Co-speech gestures are visible, spontaneous communicative expressions on the hands, which occur simultaneously with speech and are linked to what is being said either by its content or form. Interlocutors employ gesture as an optional communicative device to express meanings and disambiguating cues in addition to what is conveyed linguistically. Slobin (2001) suggests that "thinking for speaking" involves selecting elements that fit some conceptualisation of the event and elements that are already encoded in the language. Speakers produce utterances that contain pairings between linguistic code and conceptual imagery. Such pairings occur in spoken and signed discourse in interplay between imagistic and linguistic processes and may be conventional to some extent, supporting models of integrated speech and gesture production (Hadar & Butterworth, 1997; Kita & Özyürek, 2003).

Gallese and Lakoff (2005) in their review present a supporting case for embodiment and the link between linguistic and sensorimotor representations. Studies have shown that perceivers activate perceptual symbols during language comprehension; e.g. they mentally represent the shape of objects in language tasks, such as sentence comprehension, where visually presented objects are better recalled if previously mentioned in a sentence (Stanfield & Zwaan, 2001; Zwaan, Stanfield, &

Yaxley, 2002). How are such pairings are manifested in gesture forms produced with speech and without speech (pantomime) has not been extensively studied. In sign language, it is assumed that signers also make use of gestures, though not all aspects of gesticulation that occur with speech have a parallel in sign language (Emmorey, 1999). When describing objects and their manipulation, to what extent do signers rely on perceptual / conceptual representations? Are such mappings conventional and similar to those of hearing speakers when they gesture, or are those representations unique to a sign language? This research will shed some light on the overlap.

2.2.2 Conventional and non-conventional gesture

Gesture has been described as gradient in nature because it lacks adequate level of conventionalisation (McNeill, 1992; Okrent, 2002) (with the exception of conventionalised gestures, such as emblems, which include ‘OK’, ‘thumbs up’ or ‘stop’ gestures). DCs might start as individualistic gradient expressions but through frequent usage and exposure become more conventional and discrete. But discrete patterning may not always be strictly linguistic. Sweetser (2009) suggests that gesture can be compositional and complex just like language. The main difference between conventional co-speech gestures and language is in its modality, not conventionality. Gestures can be analysable into segments referred to as “separable parameters of iconic meaning” (Sweetser, 2009, p. 362). To illustrate, she cites Cienki’s (1998) example where speakers gesture higher for good marks or a job well done but they gesture lower for bad marks or cheating, because height corresponds to positive values of grades or morality. Thus the location parameter of the gesture is distinct and independent of the handshape. Elements of conventionalised metaphorical gestures can be projected into a spoken construction and create a complex utterance which may blend conventional and non-conventional form-meaning mappings. In co-speech gesture, certain grammatical features, such as aspect or negation, can also be systematically encoded. For example, in a multi-modal corpus study Hinnell (2013) observed that speakers used certain verbs together with gestural correlates consistently marking aspectual information. Certain conceptual elements that are conventionally represented in language might have a more general cognitive basis. Therefore, the question is not of whether interlocutors depict object properties or events conventionally, the focus is to reveal the extent to which they do so in spoken vs. signed discourse via the manual articulators.

Recent linguistic theories acknowledge gesture as an important component of language that enriches spoken and signed interaction. Enfield discusses at large how words combine with hand gestures and body movements to create ‘composite utterances’ (Enfield, 2009). Depiction of object handling and manipulation draws heavily on both gestural and linguistic resources so handling constructions can provide a useful window into the relationship between language and gesture. For example, handshapes associated with precision handling become metaphorical gestures in some cultures and can indicate the preciseness of a concept (Kendon, 2004). The visual and haptic processing systems are interdependent (Phillips, Egan, & Perry, 2010), suggesting that handling depiction is mediated by cross-modal experience. The question then is whether, or how, such conventional handling gestures become abstracted into sign language forms.

Researchers attempting to understand the relationship between language and gesture in handling constructions face two main challenges. Firstly, the gradient and the discrete are difficult to tease apart in production due to the use of shared articulators but this difficulty persists for both visual and auditory modalities (Okrent, 2002). The second challenge lies in the interactional context that determines the degree of lexicalisation and conventionalisation in signing (e.g. in lexical verbs vs. DCs). With regard to the first challenge, studies comparing productions by deaf experienced signers with those by hearing non-signers can reveal important similarities or differences between conventionalised constructions in sign language and gesture. The second challenge links to the affordances of visual modality as the same sign language form can often be used more or less conventionally depending on the interactional context, yet this has been much less explored. In order to better understand the context surrounding these issues, the next section will review relevant literature that has explored the relationship between language and gesture.

2.2.3 Dissociation between language and pantomime

When hearing adults and children use their hands to gesture as they speak, those gestures typically do not take on the grammatical properties characteristic of speech (McNeill, 1992), although recent evidence has emerged to support the idea that certain grammatical features, such as aspect, can be systematically encoded in co-speech gesture (Hinnell, 2013). However, when communication is forced to rely only on gesture only, for example in pantomime, gestures must assume the full burden of communication. This means that the manual modality is freed from the constraints imposed on it by speech and can assume some grammatical properties of language (Goldin-Meadow, McNeill, & Singleton, 1996). Goldin-Meadow, McNeill and Singleton (1996) have demonstrated that there are differences between co-speech gesture and pantomime forms. They asked a group of English speaking adults to describe a set of video clips containing objects moving in space once using speech and once using only their hands. Co-speech gestures were qualitatively different from pantomime. Co-speech gestures tended to be produced as single units in time with the spoken items. The handshapes used in co-speech gestures tended to be less crisp and motions less demarcated than in the gestures used without speech. Gestures without speech tended to be higher in lexical content and were more likely to be combined into gesture strings characterised by the consistent ordering of semantic elements compared to gestures produced with speech. Links between spoken words and path or motion encoding in co-speech gesture have been well researched. However, what has been lacking is a systematic examination of handshape forms in co-speech gesture and how they interact with spoken utterances.

It has been also shown that language and pantomime rely on different neural pathways (Corina, Poizner, Bellugi, Feinberg, Dowd, & O'Grady-Batch, 1992; MacSweeney et al., 2004). Studies with aphasic signers have shown that the ability to sign and use pantomime are dissociated (Corina et al., 1992; Poizner, Bellugi, & Klima, 1989), for example, the aphasic signer substituted target signs with non-linguistic gestures (mime), showing how the object was manipulated instead of providing a lexical label for it. However, such constructions could well be instances of DCs and depicting handshapes rather than purely mimes, although there may be some difficulties in determining the difference due similarities in surface form. More recent studies showed that observing ASL verbs of handling (e.g., 'brush hair') and non-pantomimic verbs (e.g., YELL) activate Broca's area but observing tool-use pantomime does not (Choi, Na, & Kang, 2001; Saxe, Xiao, Kovacs, Perrett, & Kanwisher, 2004). The problem is that most studies have primarily contrasted the production or processing of lexical material with pantomime or speech with co-speech gesture. Little is known about the integration of gesture and depictive constructions in sign language and even less is known about the relationship between production or processing of co-speech and pantomimic gestures.

2.2.4 Characterising complex utterances

Given that elements of DCs may be gestural or conventionalised to some extent, it is useful to consider productions in terms of the hierarchy of lexicalisation in sign languages as proposed by Johnston and Schembri (1999). The gestural hierarchy and sign typology is simplified in Figure 2.12 and allows us to think about handling constructions as more fluid forms that can be used more or less conventionally depending on the contextual and linguistic environment. Signed productions vary in the degrees of conventionalisation from fully lexical signs – tokens with highly stable, predictable and established links between form and meaning at the centre of the model - to partially lexical constructions such as DCs in the middle, which incorporate some gestural and non-lexical material. Non-lexical constructions, depictive gestures and mimetic and non-conventional forms, are placed on the outside of this model. A highly conventionalised gesture that is not part of the lexicon, yet it is somewhat conventionalised and used by a community of signers would be placed between gestures / mime and DCs, although it may depend on the degree of conventionalisation.

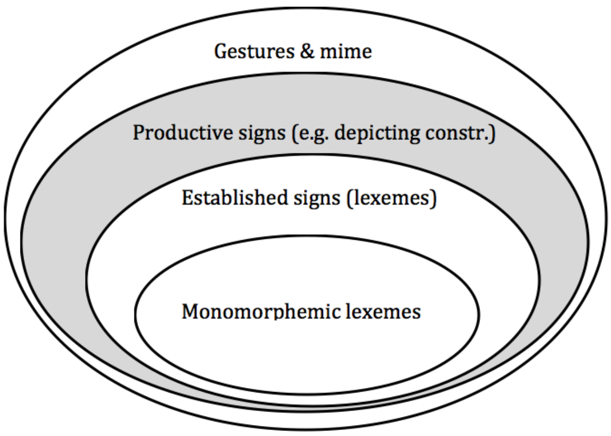


Figure 2.12. Gestural hierarchy and sign typology adapted from Johnston & Schembri (1999)

There are cross-linguistic and cross-cultural differences in the way the same type of constructions, such as handling, is used despite the similar gestural origins.

Zeshan (2003) comments on the properties of handling constructions in IPSL and suggests that they differ from those described in other sign languages. The IPSL handling constructions seem to be improvised and gestural in nature, although the handshape does seem to reflect the relationship between the objects handled and the handshape used. According to Zeshan (2003), the subsystem of handling constructions in IPSL is not grammaticalised enough to be described as a discrete system. However, it may be moving toward true grammatical or lexical categorisation. Elements of DCs, specifically handling constructions, perhaps undergo different degrees of conventionalisation. Thus it must be first ascertained to what extent handling tokens are conventionalised and discrete before making claims about their linguistic status. The extent to which a handling handshape is isolatable from the rest of the construction and can be listed as a linguistic form depends on whether the construction is perceived and used conventionally or in a discrete manner.

2.2.5 Handling constructions and viewpoint gestures

DCs produced in sign languages and co-speech gesture by hearing non-signers appear to be formationally similar (McNeill & Duncan, 2000; Parrill, 2010; Schembri et al., 2005). Mainly, there appear to be similarities between the entity constructions used by signers and corresponding observer viewpoint gestures used by non-signers with speech. Handling constructions occur in transitive contexts (Beattie & Shovelton, 2002; Church, Baker, Bunnag, & Whitmore, 1989, cited in McNeill, 1992; Parrill, 2010) because the manipulated referent is inherent; there is a strong true-to-life mapping between the form and meaning, i.e. between the act of object handling (meaning) and the way the articulators are shaped to depict the act (form). Handling constructions thus correspond to character viewpoint gestures. These synchronic similarities between DCs and co-speech gestures suggest that DCs have gestural origins, but the gestural origins for handling and entity constructions appear to be different. Further to this, Cormier et al. (2012) have suggested that due to differences in viewpoint, DCs display different lexicalisation patterns in sign language.

The idea that DCs across unrelated sign languages share properties with gestures has been explored by Schembri, Jones and Burnham (2005). Constructions depicting whole entities produced by signers of Auslan and ASL were compared with those of related gestures from hearing non-signers (without speech). Constructions were elicited using the Verbs of Motion Production Test (Supalla et al., n.d.). Despite great similarities in the use of space between deaf signers and hearing gesturers (without speech), there were clear differences in handshape. Overall, the match between the non-signers' handshapes and the signer's handshapes was low. The non-signers' handshapes displayed a greater variation than the signers' handshapes. The drawback of this study is that only constructions produced by non-signers without speech were compared with signed language constructions, so the question remains as to whether handshapes would be qualitatively different if the gesturers actually used speech during the task.

Another piece of evidence from cross-linguistic studies has shown that depicting handshapes are perhaps more conventionalised than the rest of the DC. Deaf signers' handshapes depicting the whole/part of an entities or their handling appear to differ from handshapes produced by non-signers in pantomime, specifically in finger selection and joint specification. In a cross-linguistic study across various sign languages, Brentari, Copolla, Mazzoni and Goldin-Meadow (2012) examined the use of entity and handling constructions produced by signers of Italian Sign Language (LIS) and ASL and entity and handling gestures produced by non-signing Italian and English speakers in pantomime. Adult participants were asked to describe what they had seen in vignettes that depicted either static objects or the manual manipulation of objects. The analysis of handshape was based on Brentari's notion of selected finger complexity (Brentari, Coppola, Mazzoni, & Goldin-Meadow, 2012; Eccarius & Brentari, 2008a). The signers (LIS and ASL) patterned similarly and the gestures produced by Italian and English speakers patterned similarly to each other, but the signers differed from the gesturers. In comparison, handling gesturers in both languages exhibited higher selected finger complexity than the signers. Gesturers remained faithful to the handling that they had witnessed in the vignettes. In contrast, sign language HHs complied with the respective handshape inventories of those sign languages. Brentari et al. (2012) suggest that higher finger complexity is characteristic of entity handshapes for signers. It is achieved by mapping the referent properties onto the hand or parts of it. This is a strategy that is not readily exploited by gesturers with no visual language experience. In spontaneously invented gestures, the hand-as-hand iconicity might be more pervasive than in conventionalised and established sign systems (Brentari et al., 2012). Brentari et al. (2012) have however pointed out that their results may have been an artefact of the task design. Iconicity that is embodied and rooted in action is more accessible when producing HHs as compared to entity handshapes, where iconicity is rooted in perception of objects (Perniss, Thompson & Vigliocco, 2010).

The studies above point to differences between DCs and gestures, namely in the use of entity handshapes, that is, mapping of certain handshape features onto object shape is conventional for signers but not for non-signing gesturers. This led the authors to suggest that deaf signers draw from a conventionalised set of depicting hand configurations rather than analogue, meaning-to-form handshapes. However, the question that still remains open is whether object sizes are also encoded or expressed systematically in the depiction of object handling.

2.2.6 Handling as constructed action

A common strategy employed by deaf signers known as constructed action (CA) employs the use of the signer's own body (hands, arms, torso or head) to depict actions, utterances or thoughts of a character from the character's own perspective. The signer tends to use the whole upper body and much larger signing space than in regular signing in order to reconstruct the character, taking on aspects of the character's body as their own. An example of CA involving hands, but not handling, is when a signer depicts a person waving their arm to greet someone. Handling constructions or lexical signs can be used in conjunction with CA. For example, when the signer describes a person waving their arms holding a handkerchief, the /intl-T/ handshape may be used to represent handling of a thin object (the handkerchief), while the arm enacts the referent's arm and torso moving. Both strategies allow direct pictorial and analogue representation of the way a character's hand manipulates an object, encouraging direct mapping of the object's size and other properties it affords onto the handshapes.

Comparable to CA, Clark and Gerrig (1990) describe similar depictive strategies in spoken language, called 'demonstrations' or 'quotations' and argued that these are component parts of language use. These strategies allow interlocutors to depict selected aspects of the referents or events. Although the authors refer to some conventionalised 'sound quotations' in English (e.g. *pitapat* or *knock knock,* p. 788) they discuss to a limited extent to which such strategies are conventionally embedded in language use but do not elaborate on depiction beyond linguistic and vocal gestures, making comments about the use of body and manual gesture to depict referents and actions only in passing. Nevertheless, it is assumed here that quotative strategies are pertinent in sign language and that they are mostly analogue and individualistic.

Views on the nature of CA differ. It has been described as a gestural phenomenon by some (Liddell, 1998; Quinto-Pozos & Mehta, 2010), while the same phenomenon has been considered by others to be part of a linguistic system (Supalla, 1982, 1986, 2003). The consensus is that CA is generally different from gestural depictions by hearing non-signers (Quinto-Pozos, 2007; Quinto-Pozos & Mehta, 2010). The linguistic nature of HHs that occur in the CA context is unclear because any given handling token could vary in the degree of conventionalisation from fully gestural and gradient depiction of handling to a part lexical or a lexical sign. Recent studies have suggested that certain gestures pass through stages of conventionalisation to become lexicalised (Johnston & Ferrara, in press; Wilcox, 2004). For example, over time, depictive HHs can become associated with a small object of a particular shape. Ferrara (2012) provides some support for such claims based on Auslan corpus data but to date, experimental evidence is lacking. It is not clear whether this holds for most or some HHs. Thus an investigation of the shared properties between BSL handling constructions and depictive gesture is at the forefront of this research study. Constructions depicting handling vary in the degree to which they are conventionalised or lexicalised and it is vital to examine what the categorical and gradient aspects of handling constructions are and suggest methods of analysis that take both linguistic and non-linguistic aspects into account.

2.3 Depicting constructions: previous theoretical accounts

Previous theoretical accounts of handling constructions have been limited. This section reviews and discusses existing analyses of DCs and depicting handshapes generally, beyond just handling. The aim is to identify whether descriptions of DCs can be extended to handling constructions. Analyses of phonological parameters of signs have differed widely and there have been many attempts to describe an inventory of handshape features (see also Lillo-Martin, 2006). Handshapes in lexical signs are said to be internally structured, e.g. according to the number or type of selected fingers or how the joints are configured, although the debate about types and organisation of handshape features is ongoing. In depicting handshapes, there are one-to-one form-to-meaning mappings alongside one-to-many representations but it is unclear if / how such mappings conventionally combine.

2.3.1 Traditional approaches to depicting constructions

In general, few studies have included DCs in their analyses of sign language grammar perhaps due to their irregular behaviour. For example, Aronoff, Meir, Padden and Sandler (2003) argue that DCs do not adhere to the constraints found for prosodic signs in ASL because they violate the principles of monosyllabicity, selected finger, symmetry and dominance regardless of internal morphological structure. Sandler (1989) makes reference to the same behavioural characteristics but pays limited attention to these constructions in her phonological model for ASL. Sandler makes suggestions about phonological generalisations of depicting handshapes based on a feature inventory (Sandler, 2009: 149). This approach avoids positing special features for irregular handshapes; however, it risks overgeneralisation of features unique to less conventional handshapes, such as handshapes depicting size / shape of objects and their handling. Other researchers, such as Brentari (1998), attempt to incorporate such shapes into their feature inventories to be able to characterise all handshapes with features.

The question is whether such models are sufficient to fully account for the phonological features of DCs due to a lack of adherence of DCs to phonological principles. Although there has recently been a growing focus on DCs, there is still no unified linguistic account of DCs as the linguistic analyses and terminology used to refer to these types of constructions vary widely (see also note 2 in 1.2). The use of terminology often indicates how the author conceives of the structural properties of DCs, although this is not always the case. For example, the term *polycomponential signs* (Quinto-Pozos, 2007; Schembri, 2001, 2003; Slobin et al., 2001) is ambiguous as it is not instantly clear whether the different components of DCs are viewed as linguistic or non-linguistic, discrete or gradient. The main approaches will now be discussed.

Earlier studies describe DCs in sign languages such as ASL as highly mimetic and gestural in form. DeMatteo (1977) calls these constructions ‘spatially depictive signs’. Similar views are expressed by Cogill-Koez (2000) who suggests that DCs are visual, non-linguistic systems of schematicised visual representations created on the hands. Such an approach presupposes that DCs convey meaning analogically as wholes and that they are non-morphemic and thus cannot be broken down into sub-componential elements. This approach treats all depicting tokens as similar in nature. It does not allow for the possibility that certain parts of such constructions may be more conventional and discrete.

Such holistic approaches to DCs contrast with claims by Supalla (1978, 1982, 1986), Frishberg (1975) and Kegl and Wilbur (1976) that despite the obvious iconicity and gradience, depicting handshapes in ASL are discrete morphemes. Supalla (1978, 1982) argued that verbs of motion and location (referred to as DC in this thesis) contain a finite number of morphemes which mark familiar distinctions of meanings and combine in familiar ways (Supalla, 1978). Supalla (1986, 2003), among others, attempted to compile a list of phonological specifications of discrete /C/-based handshapes and argued that ASL has four discrete handling morphemes to describe small, medium and large bundles of stick-like objects, e.g. the /F/ handshape denotes handling a single stick-like object or the two-handed /C/ handshape for handling large bundles. He dismissed the use of analogue depicting handshapes in ASL because it contradicts the traditional assumption of discreteness of linguistic form. Eccarius & Brentari (2010) support Supalla's assumptions and argue that although object size can be varied gradiently, flexion of the base (knuckle) joint can represent at a maximum four categories of size in ASL (when combined with contact between finger and thumb for the two smallest sizes). Despite this, it must be stressed that evidence pointing to whether the number of size categories is exactly four and whether this holds for all / some depicting handshapes has been limited (see section 2.4 for a review of such evidence from sign language studies).

Another significant issue with the analysis of depicting handshape as an overt morpheme concerns their underlying complexity. The handshape itself can be morphologically complex in some handling and entity constructions because the fingers (thumb) or palm orientation can act as separate morphemes (Boyes-Braem, 1981; Engberg-Pedersen, 1993; Newport, 1982; Schick, 1987; Shepard-Kegl, 1985; Supalla, 1982, 1986; Wallin, 1990). For example, the thumb and fingers in the handshape depicting a vehicle can be bent to denote a degree of wreckedness in Swedish Sign Language (STS) (Wallin, 1996), though it is debatable if this is, in any way, a discrete linguistic feature. Similar question applies to the debate about object size depiction in HHs. Assumptions about the componentiality of these utterances must be made with caution; section 2.5 discusses some of the issues.

Some researchers viewed DCs as polymorphemic (Engberg-Pedersen, 1993; Newport & Supalla, 1992; Supalla, 1982). Noting the productive nature of DCs, alternative approaches to DCs were suggested to allow for various amounts of gradient features; e.g. the movement morpheme IMIT that mimics a real-world activity, such as the movement or behaviour of entities in space, but not in a completely analogue manner (Schick, 1990; Supalla, 1978, 1982). The problem with these approaches was that the views as to what counts as a morpheme differed across researchers without sufficient experimental evidence that elements of DCs are actually discrete and specified for sign language. In addition, most observations were based on whole/part entity handshapes which appear to be more discrete than HHs.

Another difficulty is that some continue to use the term ‘classifier’ to refer to meaningful handshapes used to depict whole/part entities and their handling (Duncan, 2005; Supalla, 2003; Zwitserlood, 2003) despite the fact that its use has been challenged on a number of grounds (Cogill-Koez, 2000; Edmondson, 1990; Engberg-Pedersen, 1993; Liddell, 2003b; Schembri, 2001; Slobin et al., 2003). HHs can be selected depending on the shape or size of the handled object, e.g., /C/ handshape as ‘handle large object’ and /baby-O/ as ‘handle small object’ (Brentari et al., 2012) but the hand only stands for the object indirectly because it represents the shape of part of the manipulated item. For example, if a large drawer and a small drawer are both handled in the same way, it may not be possible to distinguish between the two based on the HH.

Other factors can also determine the choice of HH, such as a) prototypicality to reflect a conventional versus unusual way handling of objects (e.g. holding a mug by its handle vs. by the rim) or handling oddly shaped objects (Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976, see also Boyes-Braem 1981, Schick 1987 and Zwitserlood, 2000 for further discussion on prototypical handling); b) emphasis to indicate that an object was held in an unusual way (e.g. holding a wet cloth vs. dry cloth), or c) function reflecting pervasive functions of the hand, such as grasping, pushing and touching (either with fingertip, knuckle, palm or thumb), the level of resistance (low, medium or high) and manner such as dropping, putting, pulling and taking (Boyes-Braem, 1981). Boyes-Braem (1981) pointed out that signers tend to use the “best example” of manipulation of the object and that modification of handshape at a conversational level depends on the signer’s personal style and adeptness at sign language. Thus the choice of handshape is subject to discourse-pragmatic conditions and individual preference. In line with Slobin et al. (2003), the function of depicting handshapes is therefore not to classify, but to identify or designate. Further, the idea of prototypicality fits well with arguments for a graded category membership, which is discussed in this chapter (see also 2.1.1).

To summarise thus far, there are several problems with the existing linguistic approaches to DCs. Taking the gestural and mimetic stance on DCs may be too simplistic and reductionist because it may obscure any patterns of conventionalisation and the complex relationship between form and function in the depiction of events. There are also problems with the morphemic (poly-morphemic/sub-morphemic) analyses of DC, especially for constructions depicting handling. As mentioned above, previous analyses of depicting handshapes as classifiers have not always been accurate because they were a) based on some earlier misinterpretations of classifier definitions, and b) the morphological status of the depicting handshape has been disputed. There are considerably more factors at play in determining the handshape form in handling constructions than in entity constructions and handling handshapes do not strictly fit the classifier or morpheme criteria. Secondly, there are a larger number of possible form-to-meaning correspondences in handling constructions and handling handshapes than there are in entity handshapes. However, there is currently no evidence as to whether any of these correlations are indeed conventional and established in the BSL inventory. This makes it difficult to determine whether a particular token is conventional and linguistic or ad-hoc and gestural because of the similarities in appearance. As Schembri (2001) states, “signed (and spoken) may be best analysed as heterogeneous systems in which meanings are conveyed using a combination of elements, including gestures” (pp. 197-198). Thus models that enable researchers to include less conventional forms in the analysis are necessary. However, what such conventionalised and less conventionalised units are and the way such elements are blended together, such as in DCs, remains poorly understood.

2.3.2 Depicting constructions as grounded blends

Liddell (1998; 2003a) attempted to explain the potential structural complexity of DCs by suggesting that DCs contain blends of both linguistic and gestural elements. While this is an attractive suggestion in the light of linguistic theories that accept gradience in language, Liddell does not discuss what the linguistic and gestural components are in constructions depicting handling in great detail. It is also unclear how such hybrid structures might be represented in the mental lexicon. Pointing to some minimal pairs in DCs, Liddell (2003a) suggests that DCs in ASL are lexical elements for which handshape and movement (but not location) are specified. Generally, it seems to be agreed that depicting handshapes, at least those used in some ASL DCs, are discrete and locations and movements are more gradient and gestural (Schembri et al., 2005). Nevertheless, Liddell's idea that DCs blend linguistic and non-linguistic, discrete and gradient properties is worthy of further attention.

The concept of grounded blends was originally proposed by Fauconnier and Turner (1996). The main idea of blending theory is that the speaker constructs mental models, i.e. mental spaces, that act as inputs to a new blended space in which the speaker's surroundings and the imagined space are both represented. The real space is understood as the current physical space surrounding the interlocutors. One good example of this is illustrated by Parrill and Sweetser (2004), where the speaker uses a hand in the shape of a fist to represent a ball. One input to the blend is the fist, the other is the imagined ball, and the resulting blended space is the conceptualisation of the fist as a ball. The interpreter of the utterance understands this conceptualisation as a ball without losing the ability to see a human hand. This is because he or she also constructs a partially structured mental model, or space, which contains the ball. This space is blended with another mental space in which the speaker's physical surroundings are represented, including the speaker's gesture. The resulting blended space thus enables the interpreter to understand what the physical gesture represents.

Grounded blends may consist of grammatical elements, gesture or gradient auditory or visual information, such as variation in pitch, loudness, voice quality, aspects of prosody, facial expression or visible gestures. These components of the grounded blends are visual or auditory illustrations of events within the grounded blend. Liddell (2000, 2003) extends the concept of grounded blends to sign languages to account for constructions in which gestural and linguistic elements blend together in the visual modality to convey complex meanings, such as simultaneous depiction of two or more characters in a scene where the signer uses both lexical and non-lexical elements. The grounded blends theory helps to account for the elements that are projected into the blend (Parrill & Sweetser, 2004). Thus the notion of grounded blends is particularly relevant for an account of how HHs combine conventional and less conventional features; in addition to the real-scale space, the referent's body, arms and hands can be directly transferred onto the signing space and the signer's articulators. It is hypothesised that both discrete or conventionalised elements together with gradient representations are projected into the blend. This will be further discussed in section 5.6. The model is also useful in terms of disembodiment of the hands in handling constructions, e.g. when the signer's hands are referring to the referent's hands but the rest of the body represents the signer's own.

2.4 Categoricity of depicting handshapes – insights from empirical research

As discussed in the introduction and section 2.3.1, several researchers have attempted to compile an inventory of handshapes in depicting signs (e.g. Zwitserlood, 2003 for NGT and Brennan, 1992 for BSL). Some researchers have suggested that HHs are taken from an inventory of commonly used handshapes for depicting how everyday objects are manipulated with the hands (Boyes-Braem, 1981; Brennan, 1992; Schembri, 2003; Schick, 1987). Others have added that HHs may differ from the ways in which the hand(s) would be configured while manipulating the actual object (Brennan, 1992). Such observations have often lacked empirical basis or have been based on observational insights, rather than experimental evidence. Nevertheless, some experimental evidence has emerged to support the assumption that some handshapes depicting entities, or size and shape of objects (SASS), are discrete morphemes in ASL (Supalla, 1982; Newport, 1981, 1982; Schwartz, 1979; Emmorey and Herzig, 2003; Eccarius and Scheidt, 2009). The following sections will review such evidence and discuss its implications for HHs.

2.4.1 Size and shape encoding in depicting constructions

In a series of experiments, Emmorey and Herzig (2003) attempted to demonstrate that deaf ASL signers, unlike hearing non-signers, systematically organised handshapes depicting the size of medallions increasing in diameter into categories according to the size of the medallion described, e.g. the /F/ handshape was used for small-size medallions while for a larger size the ASL signers used one-handed or two-handed constructions with wide /C/. They examined whether deaf ASL signers produced and interpreted continuous SASS handshapes categorically and concluded that hand configurations are treated categorically as morphemic representations. The way size was expressed was determined by the way the handshapes were interpreted by another group of deaf signers.

In one experiment, a group of participants viewed a videotape of a native ASL signer describing the shape of a medallion hanging from a necklace. The ASL signer produced a continuum of 10 handshapes from a “squeezed” /F/ (index finger contacts the base of the thumb) to a wide /baby-C/ handshape (representing a very small to large round flat object), which were then matched with 10 stickers of varying diameter. ASL signers treated the /F/ handshape and the /baby-C/ handshape as morphemes. Hearing non-signers were more sensitive to the iconic potential of these handshapes to represent gradient specifications of size than deaf signers. In another experiment, Emmorey and Herzig (2003) examined whether signers produce depicting ‘classifier’ constructions that express medallion size in a categorical or in a gradient manner. They used a technique pioneered by Schwartz (1979), in which gradient versus categorical expression is assessed by determining how the descriptions are interpreted by another group of deaf judges. Participants were asked to describe a small set of pictures while being naïve to the contrast set of medallion sizes, i.e. they only saw one of the ten medallions. Videos of the 10 descriptions (each by a different signer) were then shown in random order to another group of six deaf ASL signers. The deaf signers (judges) chose from a set of 10 stickers that varied continuously in size and placed the sticker at the end of a necklace chain hanging from the neck of a person in a drawing. The results revealed a significant correlation between the picture choices of the deaf judges and the pictures described by the deaf signers across size categories (defined by the researchers), but not within a size category (the medium-sized category was the only category with enough members to test for a correlation). ASL signers who were naïve to the contrast set of medallion sizes used three handshapes to describe medallions of various sizes: /F/ was used to indicate a relatively small-sized medallion; /baby-C/ was used to indicate a medium-sized medallion and a two-handed construction with /C/ with a narrow gap between the finger tips and the thumb was used to indicate a large medallion size. Deaf signers did not produce gradient variations in handshape size that captured the continuous variation in medallion size. Emmorey and Herzig (2003) argued that continuous variation in size is not expressed by analogue or gradient alterations of handshape size and that size is encoded categorically by a set of distinct classifier handshapes; this finding was consistent with Schwartz (1979).

There are several issues to consider regarding such claims about the morphemic status of depicting handshapes presented by Emmorey and Herzig (2003). Firstly, a methodological issue, specific to the latter experiment described above, relates to the lack of comparisons between descriptions of size produced by ASL signers with those produced by hearing non-signers. No hearing judges were involved in the interpretation of handshapes and medallion sizes. This calls for re-examination of the assumption that depicting handshapes are discrete and if so, whether they are indeed linguistic. This concern can be supported by recent comparisons made between depicting handshapes in sign languages and viewpoint gestures used by hearing non-signers in co-speech gestures and mimetic gesture without speech. For example, Schembri, Jones and Burnham (2005) pointed to correspondences between entity constructions used by signers and corresponding action gestures used by hearing non-signers, at least in the use of movement or location. It is not clear to what extent HHs in sign language share similarities with gesture handshapes due to lack of systematic comparisons to date.

Secondly, a study by Emmorey and Herzig (2003) yielded several handshape types that differed in the dimension of selected fingers as well as joint configuration. They made a comparison between handshapes used to represent the size and shape of very small round medallions to large round medallions, rather than between handshapes within a single gradient continuum of handshapes in which the same selected fingers are used throughout. The change in the configuration of fingers from /F/ to /C/ marks a natural boundary and thus a change in category. This is different from handshapes used for handling of cylindrical or flattish rectangular objects that vary along one dimension of aperture with no such boundary. Therefore, claims about the categorical and linguistic nature of SASS handshapes cannot be directly extended to HHs and must be carefully examined. Additionally, size and shape specifiers (SASS) handshapes are rather different to handling handshapes in that they tend to depict objects with two-dimensional characteristics compared with handling hanshapes which often depict how a three-dimensional object was manipulated in space. For example, tracing SASSes can relay three-dimensional information and some depth by finger selection, often in a categorical manner. HHs tend to be more dynamic and convey more depth gradiently than SASSes as they often involve depiction of movements with objects or effort exerted on the objects by the referent. Again, comparisons between types of tracing or SASS handshapes and HHs thus should be made with caution.

More recent evidence about categorical encoding of object size was provided by Eccarius and Scheidt (2009). Eccarius piloted a study with one ASL signer using a cyber glove to show whether the gradient increase in the size of layers on a 5-tier wedding cake was encoded categorically in ASL using iconic handshapes. The data revealed that the ASL signer used discrete depicting handshapes to encode the gradient increase in size of the layers. Although the cyber glove may provide for a more accurate measure of categoricity of depicting handshapes, no conclusions about discrete handshapes depicting size and shape based on Eccarius and Scheidt's study (2009) can be made unless a larger sample of participants is tested. In addition, it is unclear whether discrete encoding would occur if a hearing participant described the cake layers using co-speech gesture or pantomime. Also, it is not clear whether such discrete encoding can be extended to constructions depicting handling. The studies discussed below provide some evidence for discrete size encoding in gestures by deaf children with no sign language exposure, suggesting that HHs are more conventional than enacting gestures.

2.4.2 Discrete encoding of size in conventional gestures

Singleton, Morford and Goldin-Meadow (1993) examined systematic object size to handshape mapping in entity and handling constructions. They used the VMP (Supalla et al, n.d.) task to elicit gestures invented by deaf children in communication with their hearing mothers over several years, otherwise known as homesign.[6] They compared children's gestures with the mothers' gestures and DCs in ASL. Differences in handshapes between normally developing deaf and hearing children show that there is a fundamental difference in the way the two groups generate gestures. When the hearing children generated a gesture (without speech), their goal was to produce a handshape that adequately represented the object. Their choice of handshape appeared to be constrained only by their imagination and the physical limitations imposed by the hands themselves. For example, one of the hearing children produced a different handshape each of the five times she represented an aeroplane. Each handshape captured an idiosyncratic property (often the differently shaped wings) of the aeroplane pictured in an event. In contrast, the deaf children's handshape choices were guided not only by how well the handshape captured the features of an object, but also by how well that handshape integrated within the set of handshapes allowed in their individual gesture systems.

Categorical encoding of object size has been found in the gestural systems of deaf homesigning children (Goldin-Meadow, Mylander, & Butcher, 1995; Goldin-Meadow, Mylander, & Franklin, 2007). Goldin-Meadow and colleagues argued that deaf homesigning children in the US develop a categorical system in which they use categorical handling handshapes, whereas their hearing gesturing mothers do not. Moreover, the children's handling handshapes were different from the gestures they invented on the fly. They suggested that the children produced gestures that were not unsegmented wholes but rather combinations of handshape and movement morphemes (Goldin-Meadow et al., 1995; Goldin-Meadow et al., 2007). For example, one child used a /fist/ handshape to represent grasping an object less than 1 inch in diameter and greater than 5 inches in length in combination with different movement morphemes to create gestures with systematically different meanings (e.g. stir with a spoon or draw with a pencil).

Further, in terms of size and shape encoding, the deaf children used two handshape parameters systematically in their handling descriptions, a) the distance between the thumb and fingers (aperture) and b) the shape of the hand. They used thumb–finger distance as the basis for their 'handle' categories. A systematic pairing

[6] Homesign systems arise where deaf individuals live within a hearing family or community and devise a method for communicating through gestures that appear to become systematic (Frishberg, 1997; Kendon, 1980, Goldin-Meadow, 2003)

between form and meaning was found when the hand forms were organised in terms of the thumb-finger distance, e.g. the "/O/ Touch" and "/O/ Small" handshapes were systematically used for objects 0-2 inches in diameter, "/O/ Medium" handshapes were used to describe objects 2-3 inches in diameter and "/O/ Large" handshapes described objects wider than 3 inches. In the /O/ Touch handshape category, the fingers and thumb were touching. In the /O/ Small category, the fingers and thumb were about 1 inch apart. In the /O/ Medium, category the fingers were about 1-3 inches from the thumb and in the /O/ Large category, the distance between the thumb and fingers was larger than 3 inches. Table 2.1 summarises the children's handshape mapping in relation to the object sizes. The first column shows the size of object described in inches and millimetres, the second column shows the aperture of handshape elicited, the third column shows the category Goldin-Meadow et al. (1995) ascribed to those handshape types based on the aperture and the last column lists examples of handshape types produced in their study.[7]

[7] Handshape glosses and illustrations are provided in Appendix B.

Table 2.1.

Summary of handshape categories from Goldin-Meadow et al. (1995, 2007)

Object width inches (mm)	Thumb-finger distance produced by deaf children	HS category	HS type used
<1 (3-10)	thumb touches fingers	touch	/flat-O/
			/O/
		fist	/S/
1-2 (25-50)	fingers <1in from thumb	small	/flat-C/, /C/
2-3 (50-80)	fingers 1-3 in from thumb	medium	
>3 (80-110)	fingers >3 in from thumb	large	

Furthermore, the authors observed that the hearing adults' gesture forms tended to be highly constrained by the object or action they represented, while the deaf children's invented gestures were constrained by a form-to-meaning relationship in their conventionalised system. The authors conclude that deaf children with no spoken language input construct morphological structure out of the input that is handed to them, even if that input is not linguistic in form (Goldin-Meadow et al., 2007). This suggests that the ability to represent size and shape may play a special role in human communication and may be incorporated into grammatical systems, although it is questionable if the homesign system in young pre-schoolers provides sufficient syntactic context to reliably determine the grammatical properties of DCs. Nevertheless, the fact that they identified HH categories in deaf children with no sign language input suggests that these categories are not unique to sign languages and thus this system would be a good candidate for testing for categories in deaf signers and hearing non-signers.

As a final note, it is likely that the hearing mothers' gestures found in Goldin-Meadow et al.'s (1995, 2007) studies were quite different from the speaker-oriented, co-speech gestures. The authors did not observe categorical encoding of object size in the hearing mothers' gestures. Thus, it seems that the mother's gestures would be more similar in nature to a type of receiver-oriented gestures, such as pantomime. In ad-hoc, non-conventional gestures without speech, gesturers remain faithful to an accurate representation of the event and thus their gestures, and by extension their handshapes, are more likely to be analogue. This thesis will examine depicting handshapes in both types of gestures, with speech and without speech to determine whether there are differences in the way handshapes are used for depiction of handling.

There is evidence that conceptual organisation and embodied experience play important roles in storage and retrieval of linguistic labels. For example, functional knowledge has been regarded as conceptual in nature (Myung, Blumstein, & Sedivy, 2006). Functional information consists of knowledge about the intended or typical use or the purpose of an object, i.e. what is an object used for and knowledge how to use or manipulate an object to successfully carry out the intended action. Myung et al. (2006) explored the question of whether common manipulation features lead to a word priming effect when the words are not otherwise semantically or associatively related (e.g. *typewriter* and *piano*). Manipulation knowledge of words assists the retrieval and constitutes a part of the lexical-semantic representation of objects. This could provide some clues about the nature of representation of handling handshapes.

With the exception of few studies that report on discrete HHs in various sign languages (Brentari et al., 2012; Eccarius & Scheidt, 2009; Goldin-Meadow et al., 1995; Goldin-Meadow et al., 2007; Zwitserlood, 1996; Zwitserlood, 2003), there is limited evidence to suggest that deaf native signers discretely encode the gradient variation in graspable object sizes in handling constructions, and if so, what these discrete handshapes would be. Despite the fact that previous evidence from research into homesign gestures showed that mapping between the referent properties (e.g. object type, size and shape) and handshape form (e.g. finger aperture, palm breadth, selected fingers) might be to some extent systematic, this evidence alone cannot be used to argue that such handshapes are morphemes or that they will develop into full-fledged linguistic elements.

Thus, the empirical question that remains is whether the gradient size of objects is indeed depicted by the means of discrete handshapes in spontaneously produced constructions depicting handling or whether HHs vary analogically to reflect the size of handled objects. When hearing speakers describe handling and manipulation of objects, they produce spontaneous, ad-hoc gestures depicting the way their hand or the hand of the referent was shaped when manipulating an object in synchronisation with speech. These gestures are complementary to speech, non-analysable and cannot be isolated from the rest of the utterance. Handling constructions articulated by BSL signers and communicative non-linguistic handling gestures (co-speech or pantomime) can appear remarkably similar. Comparisons between deaf BSL signers and hearing non-signers' gesture reveal whether HHs are conventionalised and specified in the sign language inventory. The extent to which linguistic experience or certain perceptual predisposition influences the perception of sign language forms has been investigated in a few CP studies that have tried to establish that certain sign language handshapes are discrete, isolatable (phonemic). The following section reviews this evidence and discusses what CP studies reveal about the nature and representation of sign language forms.

2.5 Insights from categorical perception research

2.5.1 Categorical perception: a definition

Signed and spoken interactions are characterised by a quick succession of rapidly fading handshapes and movements and, in the case of visual and acoustic information with speech and gesture, a large volume of concurrent information is presented cross-modally. Face-to-face communication involves rapid, ambient conditions so changes in meaning are likely to be marked by the largest perceivable distances in form. Categories are thus learnt for the purpose of efficient discrimination between stimuli in rapid visual and auditory display. For example, increased exposure to stimuli such as newly learnt faces can lead to rapid construction of categories for the stimulus (Levin & Beale, 2000).

Our environment is inherently ambiguous and unlabelled. Categorical perception (CP) is a psychophysical phenomenon in which certain stimuli are perceived categorically rather than continuously despite a continuous variation in form (Liberman, Cooper, Shankweiler & Studdert-Kennedy, 1967). During the process of perceptual categorisation, an individual may treat non-identical objects and events as equivalent (Epstein, 1996). Members in the same category are less easily discernable than two members from different categories, even if there is an equal perceptual distance between them (Harnad, 1987). Categorisation plays an important role in perception, thinking and language and is also a significant factor in motor performance. The ability to classify concrete objects of a recurring class is a crucial cognitive function that relates to thought or linguistic processing. Despite the continuous variation in the auditory and visual signal, perceivers learn to discriminate between phoneme categories along various acoustic/visual continua and develop sensitivity to naturally occurring boundaries through extensive exposure to language (Liberman et al, 1967; Repp, 1984).

A general cognitive approach assumes that natural categories are graded. It is implied that boundaries between categories are fuzzy and the status of category members is inconsistent. Cognitive linguists have extended this approach to explain the categorical structure of linguistic phenomena. Graded category structure is determined upon several factors. Broadly speaking, these are, for example, the exemplar's similarity to the category prototype, perceived familiarity or frequency of instantiation (Barsalou, 1999). The traditional theories of phonological processing work under the assumption that variability in the auditory / visual signal is ignored if perceivers perceive idealised tokens of intended types. In contrast, exemplar or usage-based theories propose that variability in the signal is not ignored and is used to shape perceptual processing (Bybee, 2009, 2010; Bybee & Hopper, 2001; Rosch & Mervis, 1975; Rosch et al., 1976). The notion of CP is based on the traditional principles derived from research on auditory signal perception and discreteness. Thus the CP paradigm is used here to allow for comparisons between previous CP studies for speech and sign in order to find out whether perceiving certain sign language stimulus yields similar or different processing patterns in comparison with those found for speech. Does sign language experience mediate perception similarly to spoken language? The research reported in this chapter aims to assess the non-traditional theories of graded category architecture. First, let us provide some definitions and show how CP can be utilised to assess perceptual sensitivity to visual stimuli with respect to the amount of exposure to such stimuli. The principles of CP will be described in more detail in Chapter 3.

2.5.2 Categorical perception in speech

Liberman et al. (1957) pioneered the traditional CP model and were the first to hypothesise that the existence of phoneme categories to which language users assign gradient auditory stimuli enforce discrimination between these categories. If two stimuli are identified as belonging to two distinct categories then it should be relatively easy to discriminate between them, leading to a sharp discrimination peak. In their seminal studies on CP for syllable-initial stop consonants, Liberman et al. (1957, 1961) used synthetic speech to generate a series of 14 consonant–vowel syllables varying continuously in the consonant onset frequency between /b/ - /d/ - /g/ to find out how these speech sounds are labelled and discriminated by listeners. In the identification task, participants identified random presentations of the consonants within the consonant-vowel syllables as [be], [de] and [ge]. Studies on perception of speech sounds typically examine the target parameter within its typically occurring environment, the English syllable. For example, plosives /b/ and /p/ can be manipulated to create a continuum of variants which are presented in the context of a first (VOT) or second formant, resulting in parametric combinations of vowels [be] or [de]. The participants' performance was discontinuous as they reliably categorised the speech sounds into perceptual categories. The discrimination task used the forced choice, or ABX, paradigm, where X is identical to either A or B. The authors conclude that the rough correspondence between identification and discrimination performance confirms the hypothesis that perception of these syllable-initial consonants is categorical (Repp, 1984). Liberman et al. (1961) further also reported CP for the /d/ versus /t/ contrast, and Liberman, Harris, Eimas, Lisker, and Bastial (1961) found similar results for the intervocalic /b/ versus /p/ distinction.

CP is not related to all speech contrasts however; vowels forming an /i/ - /ɛ/ - /œ/ continuum were discriminated equally well within and between phonetic categories (Eimas, 1963; Fry, Abramson, Eimas, & Liberman, 1962). Perception for other properties of vowels such as duration (Bastian, Eimas, & Liberman, 1961), intonation (Abramson, 1961) and affricate/fricative consonant distinction (Ferrero, Pelamatti, & Vagges, 1982; Rosen & Howell, 1987) has also been shown to be continuous. It should also be noted that when perception is non-categorical, it does not have to be continuous. Continuous perception is when discrimination rates remain more or less similar across the continuum. In non-categorical perception, discrimination ability may increase or decrease at various points along the continuum without a peak on the category boundary, or they could be higher on one endpoint than on the other.

A growing body of research has demonstrated that CP is a function of task demands and can be influenced by stimulus presentation procedures (Boersma & Chladkova, 2013; Gerrits & Schouten, 2004; Rogers & Davis, 2009). Gerrits and Schouten (2004) have demonstrated that if the conditions are favourable and the task disallows direct auditory comparison, vowels can be perceived categorically to some extent. Gerrits and Schouten (2004) have pointed to two different perceptual strategies: auditory comparison during discrimination and phonetic categorisation. They further suggest that the relationship between discrimination and categorisation is variant and point to listeners' ability to distinguish speech sounds on the basis of acoustic differences rather than phonemic labels. Thus, the question of whether discrimination is achieved by using a categorical (phonemic) representation of speech sounds remains controversial. In addition, aspects of speech perception are not restricted to human perceivers and other species such as Japanese quail and chinchillas can be trained to respond categorically to a class of speech sounds (Diehl, Lotto, & Holt, 2004; Kluender & Kiefte, 2006). Thus, the role of CP in linguistic signal processing remains to be discussed.

Reaction times (RT) in categorisation and discrimination have been argued to yield robust and reliable patterns of discrimination sensitivity (Campbell et al., 1999). Previous research on discriminability of voice-onset times (VOT) in speech and colour hues (Bornstein & Korda, 1984) showed that stimuli from the same category were judged faster if participants were asked to respond whether the stimuli were 'same' than if they were asked to respond 'different'. Likewise, stimuli from different categories were judged faster if participants were asked to decide if the stimuli were 'different' than if they were asked to respond 'same'. These studies suggest that patterns for discrimination RTs might indicate the degree of sensitivity to a category boundary. However, it should be noted that RTs have not been explored in any depth in relation to perception of sign language handshapes.

2.5.3 Handshape perception in sign language

Only a handful of studies have examined CP of manual contrasts in sign language. Earlier studies followed the traditional assumption that CP is driven by linguistic processing and claimed that elements of lexical signs in ASL are categorical phonemes. Handshape perception was believed to be mediated by sign language experience. However, to date, limited number of studies on perception of a variety of handshapes in lexical and less lexicalised signs, such as DCs is available. However, note that comparisons between CP studies in the speech and sign language domain are difficult to make due to various methodological aspects. In the spoken language domain, CP for speech sounds has been examined in non-lexical contexts, that is, sounds varying continuously in voice onset or other properties were presented within a syllable rather than a word. In sign language, the syllable has been described as a 'location-movement-location' combination (Liddell & Johnson, 1989; Perlmutter, 1992; Sandler & Lillo-Martin, 2006). The issue is that most lexical signs are monosyllabic where making the context in which handshapes are presented potential meaningful (lexical context). Because it has been shown that the lexical context can influence phoneme perception (see 2.6.4) it is difficult to determine whether the perceived handshape contrast is due to the contrast between phoneme categories or due to the semantic contrast between the lexical signs. As discussed earlier, experiments that examined perception of handshapes in non-lexical contexts have not always recorded CP. Furthermore, previous studies attested CP for handshapes in lexical signs where elements do not vary gradiently. HHs might be phonemic in lexical signs, such as NEWSPAPER (Figure 2.11 a) but in constructions depicting handling, this has not been previously tested. A review of some of these studies and their implications for the present research is discussed below.

Emmorey, McCullough and Brentari (2003), following Supalla and Newport's study (reported in Newport, 1982), used an ABX discrimination task (i.e. matching to sample paradigm) and computer generated handshapes varying in equal steps along a continuum with lexical signs from ASL as endpoints: PLEASE and SORRY which differ in the use of a flat handshape versus fist handshape, MOTHER and POSH which differ in the number of selected fingers from five to three, and SAY-NO-TO in which the handshapes differ in aperture from most open to most closed. Both deaf and hearing groups performed similarly in the identification tasks but only deaf ASL signers exhibited a CP effect for phonemic handshapes.

In a later study, Baker, Idsardi, Golinkoff & Petitto (2005) used identification (i.e. binary forced choice) and AX discrimination tasks (i.e. same or different) to assess CP for the same phonemic handshapes as in Emmorey et al. (2003) except that they used naturally produced handshape exemplars. A deaf ASL signer articulated contrastive lexical signs with handshapes varying along three handshape continua: [B]-[A] (as previously used in Emmorey et al., 2003), [5]-[flat-O], and [5]-[S] (see Appendix B for illustrations of handshapes). Baker et al. (2005) claimed to have found a CP effect for the first two handshape continua. Both studies suggest that the enhanced discrimination at the category boundary shown by deaf signers was due to linguistic knowledge and not due to general visual perception or discrimination of visual stimuli. These findings were used to argue that phonemic categories in ASL have a perceptual as well as linguistic basis but only deaf ASL signers develop specialised abilities for perceiving phonemic handshapes in ASL lexical signs. The lack of CP effects by the deaf signers for the third continuum, [5]–[S] contrast pair was due to the fact that there was a third phoneme category at the midpoint of the continuum, the /claw/ handshape. In the identification task, the variants in the middle of the continuum were categorised by chance, leading the authors to suggest that the deaf ASL signers were aware that neither endpoint was the correct choice. The authors conclude that due to the midpoint being from a different category, the discrimination scores were consistently high across the continuum and did not decrease until the end of the continuum near [S]. Thus this behaviour was interpreted as being due to the presence of a third category, which lends support to the argument that the ASL signers were using linguistic knowledge rather than visual perceptual knowledge (see discussion in 3.6).

As mentioned above, not all studies have found a CP effect for handshapes. Emmorey et al. (2003) found no CP for the hand configuration varying from 'open-N' to 'closed N' (as in the ASL sign SAY-NO-TO), leading the authors to conclude that the aperture in this lexical sign is allophonic. In this thesis, I examine CP for HHs that also vary in aperture from most closed to most open and differ from the handshape in SAY-NO-TO in the number of selected fingers. The difference is that the aperture in the lexical sign SAY-NO-TO cannot be used gradiently to indicate different degrees of that sign, while in the handling sign, aperture is used to indicate different size of the handled object which makes the use of finger and thumb distance a meaningful feature. Best, Mathur, Miranda & Lillo-Martin (2010) also failed to find CP for ASL handshape continua varying in finger spreading between the two handshapes /U/ and /V/. Unlike previous CP studies which presented handshapes in the context of lexical items, these two handshapes were presented in meaningless dynamic signs created by morphing various video recorded productions by a skilled signer. They used the location, movement and orientation of the ASL sign for STOP but replaced its dominant handshape /B/ with /U/ and /V/ to make the endpoint pseudosigns. The study used a forced choice AXB discrimination task. Despite the fact that Best et al. (2010) failed to obtain a CP effect for handshape phonemes, they argued that perception of phonetic variations underlying the phonemic contrasts is influenced by sign language experience. Similarly, Boutora and Karypidis (2007) failed to find a CP effect for the [U]-[V] handshape continuum in French Sign Language (LSF), although they reported that the LSF [V]-[X][8] handshape continuum was perceived categorically by hearing non-signing speakers of French. It is thus arguable if this handshape continuum may represent meaningful contrasts for French speakers. Neither of these studies obtained a CP effect for the /U/-/V/ handshapes because the discrimination performance was best on the endpoint of the continuum (i.e. fingers closed vs. only slightly spread apart) and increasingly poorer toward the /V/ end of the continuum, suggesting progressive increase in 'just noticeable difference' due to a psychophysical power function. The results of the studies above point to a visual comparison strategy – the perceivers were highly perceptive to the change between the fingers touching as opposed to when they were slightly spread apart. This visual strategy prevented a potential peak at mid-point. It is likely that these two handshapes do not represent distinct phonemes in ASL and LSF.

It is questionable whether the morphing technique is suitable for creating natural looking and unconstrained handshapes. Manipulating images of handshapes articulated by a signer by morphing in Adobe Photoshop may decrease the quality and naturalness of the stimuli and decrease natural perceptual sensitivities to categories in deaf native ASL signers. Another possible drawback of the Boutora and Karapidis (2007) study was that they presented their stimulus handshapes as still images, which may have led to a visual judgment strategy of finger distance.

Interestingly, Boutora and Karapidis (2007) also reported that the LSF [V]-[X] handshape continuum was perceived categorically by hearing non-signing speakers of French. This suggests that this handshape continuum may represent meaningful contrasts for French speakers. Similarly, the possibility that non-signers perceive

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[8] The authors based their handshape description on the LSF fingerspelling alphabet. LSF [U] - [V] are the same handshapes in ASL; LSF [X] is articulated as ASL [V] but fingers are curled, see Appendix B.

handshapes as meaningful gestures is further explored in the present study in the context of handling. CP for semantic (meaningful) contrast has been reported in other sign language studies examining perception of facial expressions, bringing to light important evidence about the importance of visual and cognitive processing in communication.

2.5.4 Categorisation of familiar gestures

McCullough and Emmorey (2009) examined perception of linguistic and affective facial expressions. The linguistic faces grammatically mark question type in ASL, e.g., furrowed eyebrows indicate 'wh' questions and raised eyebrows with eyes wide open indicate 'yes-no' questions. The affective faces continuum varied from 'happy' and 'sad', or 'angry' and 'disgusted'. These binary oppositions were morphed into continua consisting of 11 equidistant images. Standardised identification and ABX discrimination were then used to examine whether linguistic experience influenced CP. Both deaf ASL signers and hearing speakers of English perceived the linguistic facial markers categorically. This was probably because the non-signers could have interpreted the raised-furrowed brows as categories of affect. Further, affective facial expressions were categorically perceived only by hearing non-signers. In line with previous studies, affect expressed on the face is perceived categorically (Etcoff & Magee, 1992; Kiffel, Campanella, & Bruyer, 2005; Roberson, Damjanovic, & Pilling, 2007), regardless of linguistic experience. These facial expressions are visual displays which might be conventionalised through social interaction and have to be learned.

To support this argument, Campbell et al. (1999) showed that hearing signers who acquired sign language late as a second language displayed categorisation effects for certain sign language features comparable to that of deaf signers who acquired BSL as a first language in childhood. However, the authors argue that experience with processing linguistic stimulus nevertheless influences perception of affect; when the linguistic expressions were presented prior to affective expressions there were changes in face processing mechanisms, that is, different attentional and perceptual strategies subsequently influenced the perception of the affective expressions. Thus, the possibility of whether perceivers with no sign language experience display similar categorisation patterns to the non-signers in McCullough and Emmorey (2009) study will be explored.

It seems that regardless of perceivers' linguistic experience, certain visual stimuli are perceived categorically because they represent salient visual or perceptual contrast. This argument is further supported by evidence from studies on CP for non-linguistic stimuli, e.g. plucking and bowing sounds (Jusczyk, Rosner, Cutting, Foard, & Smith, 1977), pure tones (Pisoni, 1973), colour (Bornstein & Korda, 1984; Özgen, 1998) and for faces (Beale & Keil, 1995; Campbell et al., 1999). Evidence that non-linguistic familiar stimuli are categorically perceived supports a psychophysical approach to CP (Braida & Durlach, 1972). Discrimination ability in humans for acoustic or visual stimuli is a result of general perceptual processing and has not evolved specifically for speech. There is now substantial evidence that CP effects may be accounted for by natural sensitivities to specific types of auditory or visual stimuli, rather than by specially evolved mechanisms for speech (Aslin & Pisoni, 1980; Emmorey et al., 2003; Jusczyk et al., 1977). CP is also not limited to human perceivers; Japanese quail and chinchillas can be trained to respond categorically to a class of speech sounds (Diehl et al., 2004; Kluender & Kiefte, 2006).

The above studies assessed whether experience with handling handshapes gained through repeated exposure to visible gestures sufficient to give rise to CP. Does sign language experience modify perception of handling handshapes? The present studies have shown that the relationship between linguistic processing and categorical perception is variable. Manipulative gestures convey salient information for deaf signers and hearing speakers. But Morford et al. (2008) claim that familiarity alone, or even experience with co-speech gesture or homesign, is not sufficient to shape handshape perception in the way that early exposure to a signed language does. They examined the effect of ASL experience and age of acquisition on perceptual categorisation of handshapes using dynamic synthetic stimuli with lexical ASL signs based on Emmorey et al. (2003) handshape pairs. In their study, sign language experience (AoA) affected the perception of ASL, but not as they had predicted. Although the deaf native signers showed the most pronounced difference between within- and across-category discrimination, all participants, regardless of language background, displayed discontinuities in their ability to discriminate between phonetic variants of handshapes. The authors argue that the deaf native signers' sensitivity to visual changes has been shaped by the influence of phoneme category prototypes on perceptual processing. However, it could be suggested that repeated exposure to visual stimuli is what drives systematic categorisation, rather than ASL phoneme categories. Morford et al. (2008) did not examine whether sign-naïve perceivers also display discontinuities for handshapes. Hearing speakers are likely to be familiar with handling constructions that occur in co-speech gesture rather than lexical signs. This leaves arguments about linguistic vs. familiarity effects on handshape categorisation open to debate.

Furthermore, CP studies have not always returned consistent results in both signed and spoken languages. CP is an inconsistent phenomenon as even the same stimuli may or may not be perceived categorically in different situations (Cutting, 1982; Repp, 1984, 1987). A number of factors are at play that influence whether or not stimuli are perceived categorically. The literature on CP suggests that *categorical* was originally intended to mean *absolute* (Liberman et al., 1957; Liberman et al., 1961; Studdert-Kennedy, Lieberman, Harris, & Cooper, 1970) and that CP as an 'ideal situation' is rarely observed in the laboratory (Healy & Repp, 1982).

There is another crucial problem pertaining to linguistic analyses of DCs, particularly constructions depicting handling. This concern relates to previous claims that HHs, similarly to handshapes in lexical signs and handshapes depicting whole entities are discrete and listable units. In fact, as the following section argues, there is currently limited evidence to suggest that these claims can be extended to HHs. Furthermore, it is unclear whether deaf BSL signers describe the size and shape of objects in a categorical or gradient manner in narratives.

2.6 Summary and conclusions

To summarise, recent theories of language recognise that categoricity (or discreteness) is neither a necessary nor a sufficient condition for linguistic patterning. Evidence from sign language and gesture research reviewed above supports the view endorsed by this thesis that signed and spoken languages combine discrete and gradient features to form a variety of meaningful symbols, drawing from linguistic and non-linguistic resources to form complex utterances. For example, it has been clearly shown that gesture is well incorporated into signed (Kendon, 2004, 2008; Wilcox, 2000, 2001) and spoken (Sweetser, 2009) language. Isolating the discrete aspects of language from the gradient aspects of gesture has long been a primary concern of linguists and dominated early sign language research, although such distinctions may not be appropriate given that prosodic or intonation patterns in spoken languages are not always strictly discrete yet they are used in more or less conventional ways by their speakers (Armstrong & Wilcox, 2007; Okrent, 2002).

This chapter showed that certain sign language forms, such as DCs, combine discrete and gradient, and conventional and ad-hoc forms. Due to the relative youth of sign language research and limited attention to these forms to date, their compositional nature and representation remains poorly understood. Specifically, constructions depicting object handling and manipulation in BSL and gesture have not been systematically scrutinised. Therefore, this thesis was borne out of the need to examine handling constructions in their own right. The issue pertinent to research within handling constructions is how to best account for structural complexities and blending of discrete and non-discrete forms.

Furthermore, sign language studies have typically used similar measures of analysis for entity and handling constructions, which may have obscured important differences between these constructions. Handling constructions are rather different to entity constructions or lexical signs due to different gestural origins, contextual use, conventionalisation or acquisition patterns. Thus this thesis calls into question whether analyses of depicting handshapes, which are predominantly based on whole entity handshapes or SASS may be extended to handling.

It seems that there are several cognitive and perceptual factors that underlie the processing and representation of handling constructions. The extent to which such processes shape the structuring and organisation of handling constructions remains an open question. Exposure to sign language from birth appears to enable deaf signers to develop a specialised system for rapid discrimination between discrete forms that occur in their language and other gradient forms (McCullough & Emmorey, 2009). Findings from categorical perception, which will be explored in the next chapter, can point to whether or not language exposure or frequency of use mediate the way such embodied and contextually rich forms are perceived and represented in the mind. A comparison between signers and non-signers' perceptual patterns can provide some evidence to help determine whether the underlying representations have a linguistic or a more general cognitive basis. This in turn may lead to better insights into the role of visual cognition in language processing. The following chapter attempts to shed light on the conflicting outcomes based on existing CP studies reviewed above.

CHAPTER 3 Categorical Perception for Handling Handshapes in British Sign Language

3.1 Introduction

Linguistic systems have been described as discrete and combinatorial while gesture has been seen as mainly gradient. The linguistic system of sign languages, like those of spoken languages, is made up of categories where a slight change in form does not change the meaning of the sign because the variants are identified as same category members. Within a category, there is a lack of systematic one-to-one mapping between the form and meaning. An analogue system comprises many one-to-one relationships between the form and meaning and thus a slight alteration of form alters the meaning of the sign. Non-discrete, gradient forms have no definable boundaries and vary along a continuum, and certainly not all iconic forms are gradient.

The distinction between categorical versus gradient patterning is particularly relevant to partly lexicalised constructions in sign languages – such as DCs. Sign languages capitalise on the visual modality and allow for more gradient form-to-meaning mapping, such as in gestures. The question concerning the discreteness of HHs has been repeatedly raised in the literature to date, but there remains a lack of empirical evidence. This thesis thus examines whether HHs are perceived categorically by deaf BSL signers in comparison with their hearing counterparts. Study seeks to examine whether sign language experience influences handshape categorisation and discrimination.

3.1.1 Conditions and criteria for categorical perception

CP is a psychophysical phenomenon in which certain stimuli are perceived categorically rather than continuously despite a continuous variation in form (Liberman, Cooper, Shankweiler & Studdert-Kennedy, 1967). The ability to classify concrete objects of recurring class is a crucial cognitive function that aids thought and linguistic processing.

Previously, CP has been understood as an important mechanism for segmenting discrete linguistic stimuli from other non-linguistic properties of sound/human voice, for example. Perceivers learn to discriminate between linguistic categories along various acoustic/visual continua through extensive exposure to language (Liberman et al, 1967; Repp, 1984). Discrimination can be predicted by identification performance. Liberman et al. (1957) pioneered the traditional CP model and were the first to hypothesise that the existence of phoneme categories to which language users assign gradient auditory stimuli enforce discrimination between these categories. If two stimuli are identified as belonging to two distinct categories then it should be relatively easy to discriminate between them, leading to a sharp discrimination peak. This peak is often predicted to occur on the category boundary, as shown in Figure 3.1.

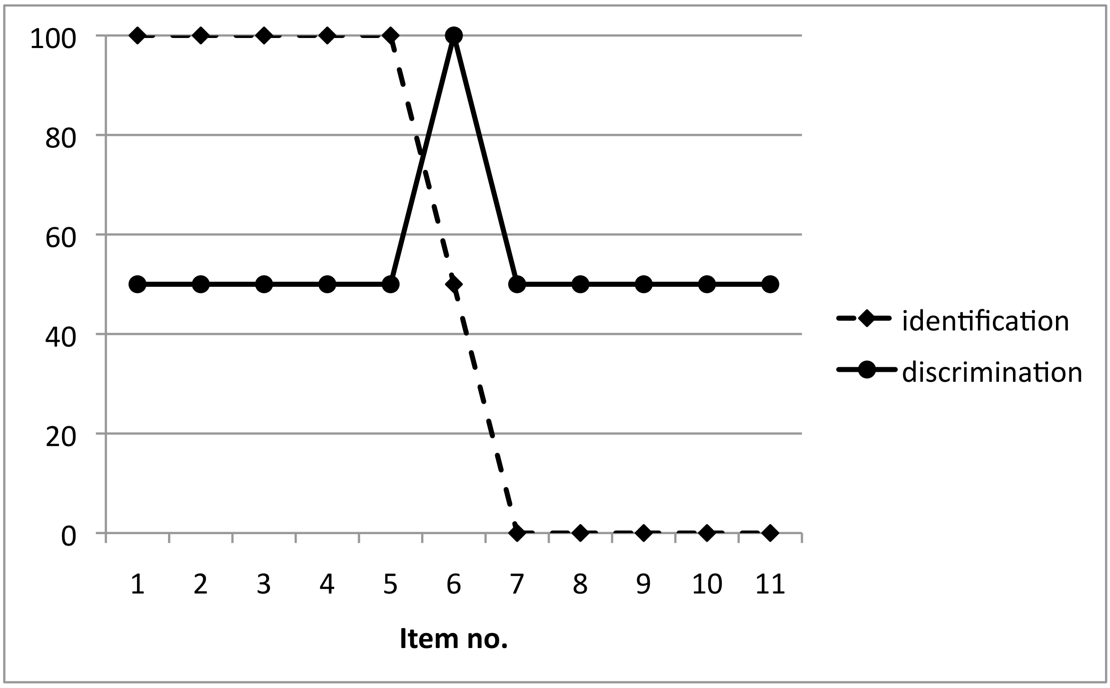


Figure 3.1. Idealised function (adapted from Studdert-Kennedy, Liberman, Harris & Cooper, 1970). Stimuli items are plotted on the 'X' axis, % accuracy of correct responses are plotted on the 'Y' axis. Dotted lines indicate responses in the identification task and solid line indicates responses in the discrimination task. Discrimination performance plots indicate proportion of correct matches in a forced choice task.

Figure 3.1 shows idealised identification and discrimination functions plotted according to the four criteria for absolute categorisation as listed in Table 3.1.

Table 3.1.

Operational criteria for CP as proposed by Studdert-Kennedy et al. (1970, in Repp et al., 1979)

a.	Sharp identification function: distinct labelling of categories with sharp boundary
b.	Discrimination performance peaks at the category boundary
c.	Discrimination for within-category pairs is at chance level (50%)
d.	The actual discrimination performance closely corresponds to the identification performance – this is based on the assumption of absolute categorisation

Identification performance plots indicate the proportion of stimuli identified as item no. 1. In identification tasks, participants assign the stimulus variants from anywhere on the continuum to either category endpoint. Performance on this identification or labelling task is then compared with a discrimination task in which participants decide which one of two stimuli matches a target stimulus. This is known as the ABX paradigm and it is explained below. The prototypical test used for assessing CP is ABX forced choice discrimination (Gerrits & Schouten, 2004). In this task, three stimuli are presented in the ABX order where A and B are always different and X is always identical to either A or B. The perceivers are asked to decide whether X is identical to A or B. Massaro and Cohen (1983) hypothesised that perceivers fall back on the phonetic labels they assign to items A and B by the time X is presented because the auditory memory span is relatively short. As a result of such phonological labelling, a strong CP effect can be observed. Response bias towards B can be eliminated by reversing the presentation of A and B for half of the trials (Schouten et al., 2003).

Studies of CP typically compare identification proportions with accuracy on a discrimination task, using stimuli ranging in perceptually equal steps along a continuum. A continuum is perceived categorically if the operational criteria for CP shown in Table 3.1. A strict definition of CP stipulates that discrimination performance must be phonetically mediated, i.e. it should be predictable from labelling performance, and labelling responses must be independent of the stimulus context. For example, it is possible to isolate speech sounds, e.g. the bilabial consonants /b/ and /p/ if aspiration is manipulated using a synthesiser to ensure the environment is carefully controlled and perception is phonetically mediated and independent of the context. However, others, such as Healy and Repp (1982), emphasise the importance of context and suggest that consonants varying along a continuum are perceived categorically only when presented in the context of vowels.

CP is an inconsistent phenomenon as even the same stimuli can be sometimes perceived categorically, but sometimes not (Cutting, 1982; Repp, 1984, 1987). This may depend on the context in which the stimulus is presented or stimulus quality. The literature on CP suggests that *categorical* was originally intended to mean *absolute* (Liberman et al., 1957; Liberman et al., 1961; Studdert-Kennedy et al., 1970) and that CP as an 'ideal situation' is rarely observed in the laboratory (Healy & Repp, 1982). In practice, a sharp category boundary and near-chance discrimination within category are difficult to obtain, often due to other interfering factors, such as context or stimulus quality. Some researchers have therefore been lenient in terms of adherence to the criteria shown in Table 3.1., particularly criteria a) and c). In addition, there are clearly a number of factors that may play a part in determining if a stimulus is categorically perceived. There are two particularly important factors in this respect: the context in which the stimuli are presented and stimulus quality; these will be discussed in more detail below.

The auditory modality allows for temporal ordering of phonemes. The timing of stimulus presentation should be carefully adjusted to take into consideration the time it takes for auditory processing to identify the sounds without falling back on memory for phoneme category labels. This fast succession of sounds helps to recreate the rapid stream of speech sounds. It is therefore possible to observe CP in a laboratory setting. In comparison, the visual modality disfavours sequential ordering of phonological features as they tend to be simultaneously articulated. The simultaneous articulation of sign language parameters makes isolating stimuli sign languages more problematic when detecting CP for handshapes, including orientation, location or movement. It thus seems that the context in which exemplars are presented is crucial. One such context in which phonemes occur is a syllable.

Studies on perception of speech sounds typically examine the target parameter within its typically occurring environment, the English syllable (see 2.6.2). For example, plosives /b/ and /p/ can be manipulated to create a continuum of variants which are presented in the context of a first (VOT) or second formant, resulting in parametric combinations of vowels [ba] and [pa]. For ASL, the sign language syllable has been described as a 'location-movement-location' component (Liddell & Johnson, 1989; Perlmutter, 1992; Sandler & Lillo-Martin, 2006). Although there are various views on what constitutes a sign language syllable, the consensus for ASL, NGT and other sign languages is that movement is the defining feature (van der Kooij, 2002; Wilbur, in press). Therefore in order to examine CP for sign language handshapes, handshape features can be manipulated to create a continuum of variants which are presented in the context of movement and location. The nature of spoken and signed syllables however presents a potential problem – most signs are monosyllabic so each syllable would also be a meaningful sign. Studies on CP for speech phonemes have not typically examined perception of sounds in the lexical context. Therefore, outcomes from such studies may not be directly comparable because the semantic context could have shaped perceptual categorisation differently.

The degree of CP observed in speech perception experiments might depend on the stimulus quality (Schouten et al., 2003; Schouten & van Hessen, 1992). Poorer stimulus quality makes discrimination harder, which might decrease the CP effect. It should be stressed, however, that stimulus quality or naturalness is not the only determinant of CP because various degrees of CP have been observed even with synthetic stimuli. The CP effect has been well established for synthetic speech that has been created by computerised manipulation of its properties. Similarly, in the sign language domain, morphing or animation techniques have also been used to investigate CP for phonemes in ASL (see section 2.5.3). The advantage of using synthetic, computer-generated stimuli to test for CP is that it gives the researchers good control of the exemplar. For example, morphing techniques have been attested in studies investigating CP for facial expressions (Campbell et al., 1999; McCullough, 2009). However, there are some issues with using morphing techniques. Although morphing techniques might suffice in, e.g. the perception of faces, where the primary perceivable changes in facial expression can be seen in two dimensions, they also tend to limit the number of fine finger and joint configurations, which might result in unnatural looking exemplars. To reflect the greater depth of field and complex, dynamic nature of hands and body movements, animation techniques based on modelling realistic human poses seem more suitable. Such techniques take into account the fine detail of joint movements and finger positions in depicting handshapes, such as HHs. This results in natural-looking, high definition exemplar and makes the intermediate handshapes look less constrained than if they were created by a morphing technique. In addition, animation methods such as the key frame animation method are more reliable and accurate in creating equal distances between the thumb and fingers than if a human signer articulated the handshape variants.

3.1.2 Categorical perception for sign language handshapes

CP has been used extensively to investigate the effects of linguistic categorisation on various types of acoustic signal, although categorical perception is not limited to speech or linguistic processing. CP can be utilised to assess perceptual sensitivity to visual stimuli with respect to the amount of exposure to such stimuli.

Previously, CP has been demonstrated in speech for syllable-initial stop consonants, e.g. /b/ - /d/ - /g/ (Liberman et al., 1957; Liberman et al., 1961; Schouten & van Hessen, 1992) but vowels forming an /i/ - /ɛ/ - /œ/ continuum are not typically perceived in a categorical fashion (Bastian et al., 1961; Eimas, 1963; Ferrero et al., 1982; Fry et al., 1962; Rosen & Howell, 1987) (see section 2.5.2). CP methods have been used to demonstrate that linguistic categorisation mediates sign language perception and that elements of lexical signs (handshapes, locations) are akin to spoken language phonemes.

Four studies on CP for handshapes in lexical signs or pseudosigns have been published to date (Baker et al., 2005; Best et al., 2010; Emmorey et al., 2003; Morford et al., 2008). CP has been established for phonemic contrasts in ASL lexical signs (Emmorey et al., 2003; Baker et al., 2005) (see review in 2.5.3). These authors used their findings as evidence that some phonemic categories in ASL have a perceptual as well as linguistic basis but only deaf ASL signers develop specialised abilities for perceiving phonemic handshapes.

However, linguistic processing is not a necessary condition for a CP effect to occur. For example, studies on perception of facial expressions and other types of visual or acoustic stimuli showed that both deaf signing and hearing non-signing perceivers make categorical distinctions between certain stimuli that are semantically distinctive in sign language (e.g. furrowed eyebrows indicate ‘wh’ questions and raised eyebrows with eyes wide open indicate ‘yes-no’ questions) (Campbell et al., 1999; McCullough & Emmorey, 2009). Hearing speakers of English are familiar with certain facial expressions that can be used with questions in English or can be interpreted as expressions of affect. Stimuli which are familiar to the perceiver, or those which are conventionally used in spoken communication, might be categorically perceived regardless of the perceivers' language experience.

This opens up the important question as to whether experience with visual stimuli gained through repeated exposure to visible gestures on the hands during speech (co-speech gesture) might give rise to a CP effect for handshapes regardless of linguistic exposure. Morford et al. (2008) claim that familiarity alone, or experience with co-speech gesture or homesign, is not sufficient to shape handshape perception in the way that early exposure to a signed language does. As I already discussed in 2.5.3, there are several problems with previous claims because they are either based on perception of handshapes in lexical contexts or they did not compare deaf and hearing perceivers, leaving arguments about familiarity effects on CP for HHs still open to debate. Handshapes in less conventional signs, such as handling constructions, have not been examined.

The current study explores the question of whether CP in the visual domain can occur for depicting handshapes. The previous assumption that CP effects only occur for linguistically contrastive stimuli is tested. Firstly, it asks whether handling handshapes that are commonly used in BSL depicting signs to describe object handling and manipulation are perceived categorically by deaf signers of BSL or whether they analogically depict varying object size. Secondly, handshape perception is compared with hearing non-signers, native speakers of English. Handshapes used to depict handing of flattish rectangular and cylindrical objects are examined. These handshapes use the same selected fingers (i.e., all fingers and thumb) and thus only vary along the dimension of aperture, represented by the base joint configuration (Brentari & Eccarius, 2009). Base joints refer to the angle and configuration of primary or secondary selected fingers, such as bent, straight, stacked etc. For example, in handshape used to depict handling of flattish rectangular objects the fingers are bent and straight. If perception of handling handshapes is facilitated by phonemic categories in BSL, then deaf BSL signers, but not hearing non-signers, should exhibit CP. However, if CP effects are found for both deaf signers and hearing non-signers, it will suggest that category boundaries fall along natural visual-perceptual or cognitive categories and that CP for visual handling handshapes does not emerge as a result of language processing. If neither group exhibits a CP effect, handling handshapes represent the object size in a gradient manner.

3.2 Research questions

In the experiments reported here, the effects of perceptual predisposition and language experience on categorisation and discrimination of visual stimuli from British Sign Language. Specifically, I explore the question of whether CP in the visual domain can occur for depicting handshapes as well as for gestures. Firstly, I ask if HHs in BSL signs depicting handling are perceived categorically by deaf signers of BSL in comparison with hearing non-signers. I examine perception of handshapes depicting handing of flattish rectangular and cylindrical objects in BSL varying in aperture from most closed to most open. It is expected that only deaf BSL signers will exhibit CP if perception for HHs is mediated by linguistic categories in BSL, e.g. phonemes. If both deaf signers and hearing non-signers display CP, this will suggest that category boundaries fall along natural visual-perceptual or cognitive categories and that CP for visual HHs does not emerge as a result of merely linguistic processing. If neither group exhibits a CP effect, it will suggest that HHs do not represent discrete categories in BSL and may instead depict gradient object size in an analogue, non-categorical manner.

3.3 Study design

To determine whether handshapes in BSL handling constructions are categorically perceived, a standardised CP method will be used. HHs used to depict handling of flattish rectangular objects and cylindrical objects in BSL were used to create two handshape continua endpoints, with the most closed handshape on one end of the continuum and the most open handshape on the other. These handshapes use the same four selected fingers and thus only vary along the dimension of aperture, represented by the base joint configuration (Brentari & Eccarius, 2009). In other words, they only vary in the extent to which selected fingers are bent or curved.

Firstly, a group of deaf BSL signers and hearing non-signers completed a binary forced choice identification task. In this task, participants assigned handshapes spanning along the continua to either endpoint. A forced choice ABX discrimination task then followed. Discrimination was predicted by identification performance. If two stimuli are identified as belonging to two distinct categories then it should be relatively easy to discriminate between them, leading to a sharp discrimination peak. This peak was predicted to occur on the category boundary. This is plotted in Figure 3.1 above, which represents the idealised CP function. If the criteria for CP laid out in Table 3.1 are satisfied, a CP will be assumed. The effect of linguistic categorisation on the perception of HHs will be examined through a comparison of identification and discrimination performance between deaf BSL signers and hearing, native speakers of English. It was hypothesised that deaf BSL signers, unlike hearing non-signers, will exhibit CP if perception of HHs is mediated by phonemic categories in BSL. However, if perception of HHs is mediated by general visual perceptual experience with familiar stimuli, both deaf and hearing perceivers would perform similarly. In other words, a CP effect may or may not be observed, regardless of their linguistic experience. RTs were also measured during the identification and discrimination of stimuli as an additional measure of CP. Differences in RTs between signers and non-signers on handshapes of different category membership may suggest a presence of different processing mechanisms.

3.4 Method

3.4.1 Participants

Participants consisted of 14 deaf BSL signers (age range 18-38; 6 male, 8 female) and 14 hearing native English speakers matched to BSL signers in age and gender. Much of the evidence from existing CP studies on sign languages is based on similar sample sizes – for example, ten deaf participants in Best et al. (2010), 13 in Morford et al. (2008), 15 in Baker et al. (2005) and 17 deaf participants in Emmorey et al. (2003).

All deaf participants reported BSL as their preferred method of communication and reported acquisition of BSL before age 6 from a primary caregiver. Only participants who acquired BSL before age 6 and would have life-long experience using BSL as their main and preferred language of communication and those who were born and lived in South-East of England participated in our studies. The majority of deaf children are born to hearing parents and do not begin to acquire sign language from birth, from deaf signing parents. In this respect, it could be suggested that the deaf signers do not resemble hearing native English speakers in their native-like command of BSL. However, as Campbell et al. (1999) showed (see section 2.6.4), deaf signers who acquired BSL as a first language in childhood, and who would be expected to have full grammatical mastery showed as a group no more evidence of categoricity for certain sign language features than did hearing signers who acquired sign language late as a second language. Therefore, it is unlikely that any differences found between deaf signers and co-speech gesture would be a result of the native/non-native status of the deaf BSL sample.

Deaf participants were recruited through the online participation pool website administered by the Deafness Cognition and Language (DCAL) Research Centre (UCL) or through personal contacts in the deaf community. Hearing participants were recruited through the UCL Psychology online participation pool website. The experiment took place in a computer laboratory at DCAL.

3.4.2 Materials and stimuli

Two HH continua were created using a key frame animation technique in the animation software package Poser 6.0™ (Curious Labs, 2006). This technique incorporates all parameter information on joint or body positions from the starting and ending poses and calculates equal increments between the endpoints. The result is a naturalistic and carefully controlled animated exemplar. The exemplars were handshapes used in BSL to depict handling of flattish rectangular objects (books) and cylindrical objects (jars). Figure 3.2 shows the handshape continuum used to manipulate flattish, rectangular objects, progressing in aperture from the most closed /flat-O/ to most open /flat-C/ handshape. Figure 3.3 shows a continuum of handshapes used to manipulate cylindrical objects, progressing from the most closed /S/ handshape to most open /C/ handshape.

Figure 3.2. Handshapes depicting handling of rectangular objects (/flat-O/ – /flat-C/)

Figure 3.3. Handshapes depicting handling of cylindrical objects (/S/ – /C/)

The 9-step, 11-item continua were designed to create a visual homologue to typical CP experiments for speech (e.g., Liberman et al., 1957) and ASL (Emmorey et al., 2003). Handshapes were labelled from 1 (most closed) to 11 (most open). Exemplars were presented as dynamic video clips involving a straight, right arm movement positioned on the right side of the signer's torso in neutral space, moving in a short straight movement from right to left. The arm was anchored to the shoulder and bent at an angle of 45 degrees (see Figure 3.4).

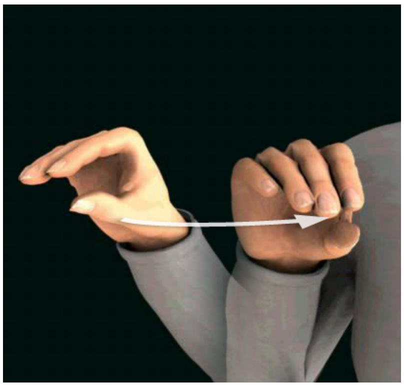


Figure 3.4. Still image representing movement shown in actual stimulus item (animated video)

Within the handling exemplars used in this study, the movement, location and orientation remained constant for all steps. The movement was characterised by a short straight movement to the centre. The orientation of the palm and fingers was facing away from the signer. The location was neutral to the right of the signer's torso. The handshapes were articulated by the right hand and consisted of four primary selected fingers, represented by the feature [all], with the thumb opposed for all exemplars for both object types and the metacarpal-phalangeal joints specified. Handshapes depicting handling of flattish rectangular entities (Figure 3.2) consisted of angled finger/thumb joints, whereas handshapes depicting handling of cylindrical objects (Figure 3.3) consisted of curved finger/thumb joints with fingers together (not spread). This finger bending feature is the distinguishing feature between handling of a flattish rectangular object and an object of a cylindrical shape. Within each continuum, the handshapes varied continuously in one parameter value only – the distance between the thumb and fingers (aperture). The aperture changed from [closed] (as used in constructions depicting handling a piece of paper or thin rod) to [open] (as in handshapes depicting handling a wider rectangular object such as a book or cylindrical object such as a large jar). Thus, it could be argued that handshapes differed in finger and thumb distance.

3.4.3 Procedure

CP was examined using identification and ABX discrimination tasks. Accuracy rates and RTs were recorded. Prior to each task, participants were primed for HHs by looking at images of a person reaching for handling rectangular and cylindrical objects of varying sizes with the person's handshape blurred. The reason was to distinguish between similar /C/ handshapes that occur frequently in lexical signs or in initialised signs which are different in nature. Thus it was important that the perceivers focused on the handshape form as it occurs in depiction of handling action rather than in lexicalised contexts. The distinction between handshapes in partly-lexicalised handling constructions and handshapes in lexical signs of handling is crucial in this study. For the hearing participants, A block of practice trials with an unrelated HH continuum (/fist/ handshape, /intl-T/ progressing from thumb fully closed to open and bent) preceded each task. Each continuum was tested separately.

The identification task was a binary forced choice task. The order of stimulus presentation is schematised in Figure 3.5. Participants were asked to assign items that were selected randomly from anywhere on the continuum to either endpoint. The identification task was divided into three blocks of trials. The blocks were separated by a pause during which the participants rested. At the start of each block, both endpoints were shown to the participants on opposite sides of the screen. These endpoints disappeared after being played for 500ms followed by a 1000 ms blank screen. Then, items from anywhere from the continuum, including the endpoints, were consecutively presented in the middle of the monitor. Items were randomised across all three test blocks and participants. A blank screen during which the participant recorded their responses followed each item presentation. Participants pressed the left arrow key if they thought the third handshape was similar to the handshape on the left of the screen and the right arrow key if the handshape was similar to the handshape on the right. The experimenter asked participants to record their responses quickly. The endpoint handshapes were not available to the participants during the trials but they were shown again at the start of a new block. Each participant saw each handshape variant 4 times, resulting in 44 trials. The instructions for deaf participants were provided in a BSL video. Hearing participants were instructed in written English. Instructions to the participants are provided in Appendix C.

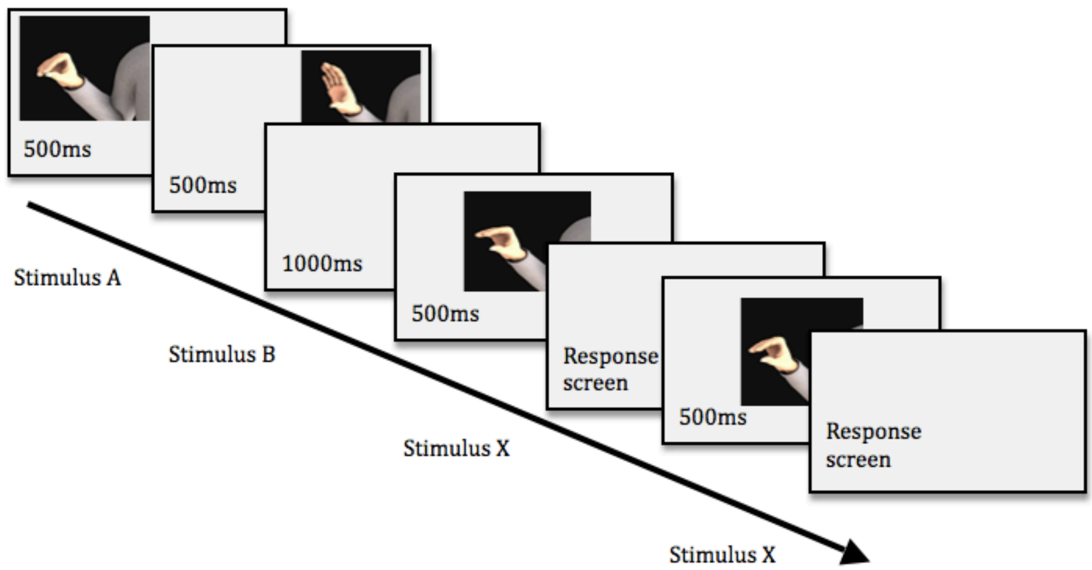


Figure 3.5. Order of stimulus presentation in identification; A and B are the endpoints and X is randomly selected from anywhere on the continuum

The discrimination task is based on the ABX matching to sample paradigm previously used by Beale and Keil (1995), Emmorey et al. (2003) and McCullough and Emmorey (2009). The same stimuli were used as in the identification task described above. There were a total of 36 trials divided into three test blocks, preceded by a practice block. Each trial consisted of a handshape triad where the first two handshapes (A and B) were always two steps apart on the continuum (1-3, 2-4, 3-5, etc.) and the third handshape (X) was always identical to either handshape. Participants pressed the left arrow key if the third handshape was identical to the handshape on the left (A) or the right arrow key if identical to the handshape on the right (B). The order of presentation of items A and B was reversed for half of the trials and items were randomised across trials and participants. The order of presentation of stimuli in the discrimination task is schematised in Figure 3.6.

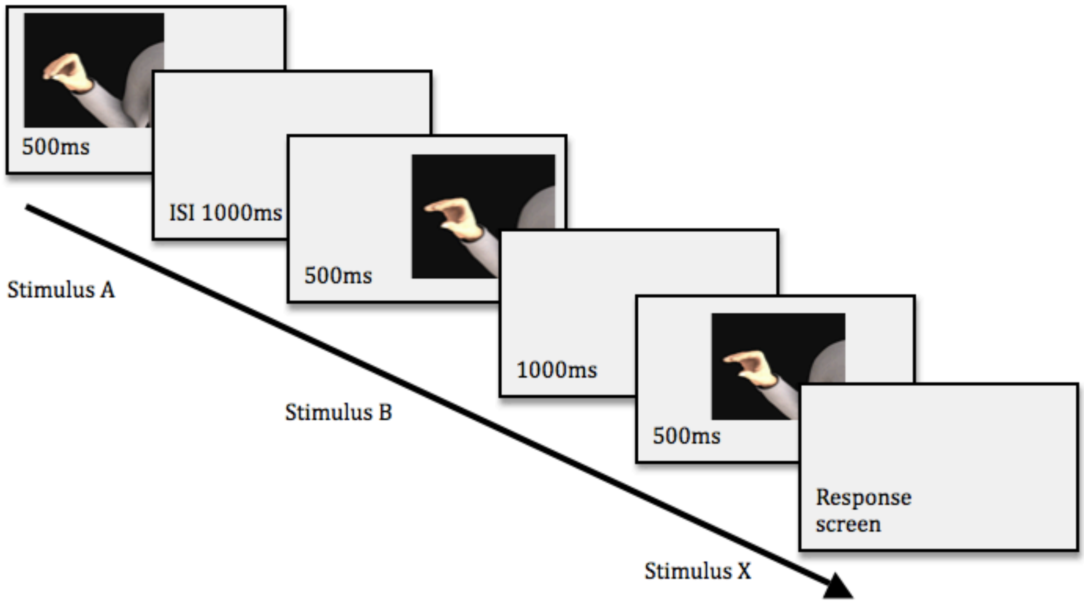


Figure 3.6. Order of stimulus presentation in discrimination; an example of an ABX triad where A and B are always two steps apart on the continuum and X is identical to either A or B

3.5 Results

The results in the identification task reveal that deaf BSL signers and hearing non-signers categorised the handshapes along the continua into two binary categories in a similar sigmoidal fashion and displayed similar category boundaries for the two continua. The discrimination task shows that both deaf and hearing perceivers discriminated significantly better between handshapes on the boundaries than within the categories thus displaying a CP effect; however, both deaf and hearing participants remained perceptive to gradient aperture changes as within-category accuracy remained relatively high for both deaf and hearing participants. Deaf BSL signers were more accurate than hearing non-signers overall when discriminating between handshape stimuli. In addition, category boundaries recorded no difference in RTs for deaf signers compared to hearing non-signers thus no effect of linguistic processing between groups was observed.

3.5.1 Handling handshape identification

For the continua tested, both deaf and hearing participants categorised stimuli as belonging to distinct categories. Inspection of identification performances plotted in Figures 3.7 and 3.8 indicate that deaf and hearing participants displayed a sigmoidal shift in category item assignment. Figure 3.7 shows the average proportion of handshapes identified as item 1 plotted on the Y-axis for the /flat-O/–/flat-C/ continuum and figure 3.8 plots identification of handshapes as item 1 for the /S/–/C/ continuum. Identification performance was almost identical for signers and non-signers when collapsed across both continua (as shown in Figure 3.9).

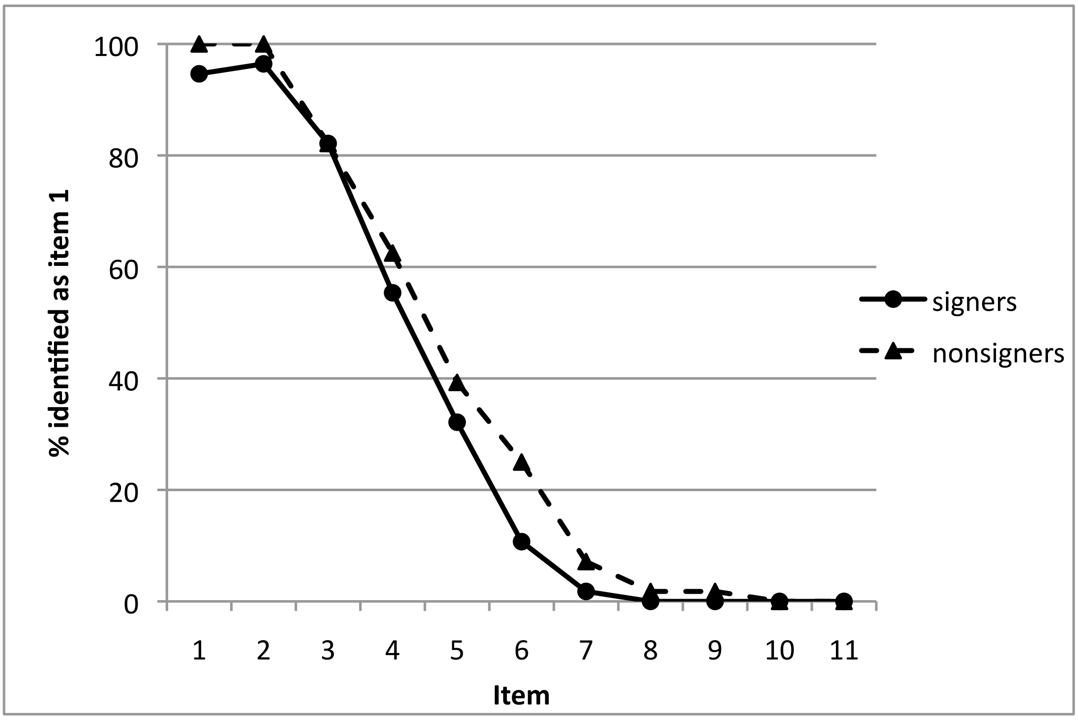


Figure 3.7. Average identification of items as item 1 for the /flat-O/-/flat-C/ handshape continuum

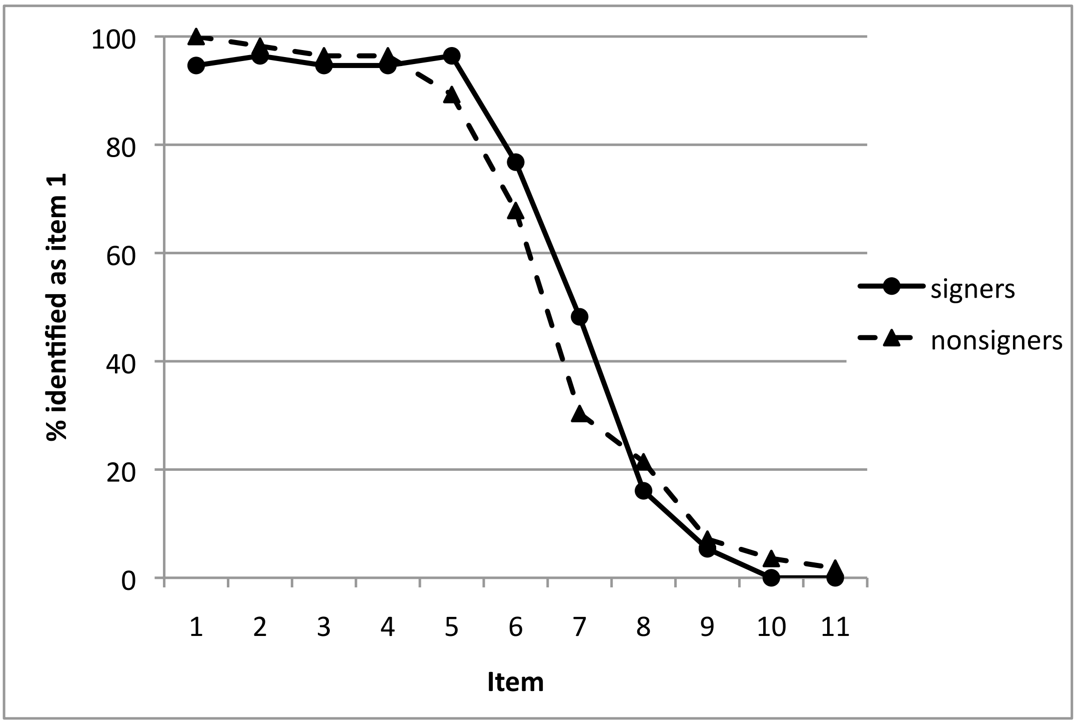


Figure 3.8. Average identification of items as item 1 for the /S/-/C/ handshape continuum

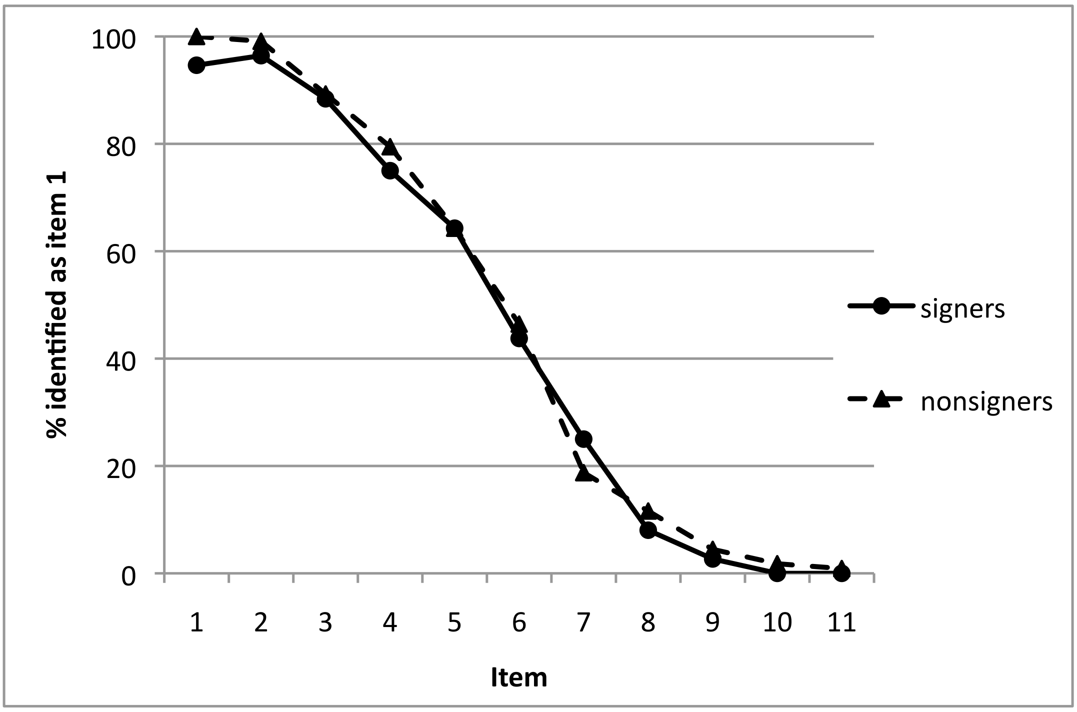


Figure 3.9. Average identification of items as item 1 for both handshape continuum

Data plots in Appendix B, figures 1 and 2 show the range of performance based on a sample of the first nine individual identification performance from each group with the individual's category boundary marked with a dotted line. Identification task average performance per group is plotted above in Figures 3.7 and 3.8. The category boundary was calculated as follows. The dependent measure was the proportion of items labelled as item 1. Items were assumed to be on an equal interval scale. A steepness of the slope coefficient of identification function was obtained by logistic regression and is provided for each group in Table 3.2. Individual category boundaries were then calculated by dividing the slope constant by the intercept on the Y-axis, with the category boundary defined as 50% of participants' responses. Both signers and non-signers placed the category boundary in approximately similar locations for both continua.[9] The mean group category boundaries are provided in Table 3.2.

Table 3.2.

Mean intercept on the Y-axis, slope coefficient and category boundaries per group for both handshape continua

	/flat-O/-/flat-C/		/S/-/C/	
	signers	non-signers	signers	non-signers
Mean intercept on Y-axis	6.24	6.33	3.77	4.16
Slope coefficient	-21.96	-25.76	-22.59	-26.06
Mean cat. boundary (item)	4.23	4.69	6.74	6.66

The mean slope gradient was compared across groups to find out whether the two groups differed in the categorisation of stimuli. Independent samples *t*-test revealed no significant differences between signers and non-signers for the /flat-O/-/flat-C/ continuum, $t(31) = .648$, n.s. and similarly no differences on the /S/-/C/ continuum, $t(31) = .908$, n.s. Both groups, i.e. the deaf BSL signers and the hearing non-signers, exhibited similar patterns in categorisation of these HH continua.

Reaction times (RTs) in the identification task for both continua were subjected to an ANOVA with one within-subjects factor - handshape category membership with three levels (with items to the left of the boundary labelled as 'pre-

[9] Individual category boundaries for both groups and continua are provided in Appendix D.

boundary and items to the right of the boundary labelled as ‘post-boundary’ and ‘boundary’ items), and group as a between-subjects factor (signers vs. non-signers). The boundary items were items 4 and 5 on the /flat-O/-/flat-C/ continuum and items 6 and 7 on the /S/-/C/ continuum. As the boundaries were in an approximately similar location on both continua in the two groups, RTs were collapsed across continua to increase statistical power. Outliers were eliminated using the 2 standard deviations rule.

The main effect of group was non-significant, $F(1, 98) = .68$, n.s. Both groups were slower categorising items that straddled the boundary than items elsewhere on the continuum. The main effect of category membership of handshape was significant, $F(2, 196) = 41.53$, $p < .001$, *partial* $\eta^2 = .30$, indicating that responses slowed down for categorisation of items on the boundary compared to elsewhere on the continuum. There was no interaction between category membership of handshape and group, $F(1, 98) = .08$, n.s. Dependent samples *t*-tests further revealed that deaf signers were significantly slower at labelling handshapes on the boundary (M = 927, SD = 152) than pre-boundary handshapes (M = 839, SD = 94); $t(51) = -5.00$, $p < .001$. They were also slower at labelling handshapes on the boundary than post-boundary handshapes (M = 815, SD = 82); $t(51) = 7.20$, $p < .001$, as well as slower at labelling pre-boundary items than post-boundary items, $t(50) = 2.44$, $p < .05$. Hearing non-signers displayed a similar pattern showing slower RTs on the boundary (M = 917, SD = 140) than pre-boundary (M = 872, SD = 135), $t(51) = -3.27$, $p < .05$ or post-boundary (M = 844, SD = 118), $t(51) = 5.42$, $p < .001$. For non-signers, the difference between pre- and post-boundary items was marginally significant; pre-boundary items yielded slower RTs than post-boundary items, $t(51) = 2.02$, $p < .05$. Identification RTs for both continua are shown in Figure 3.10 below; significant differences are marked with an asterisk.

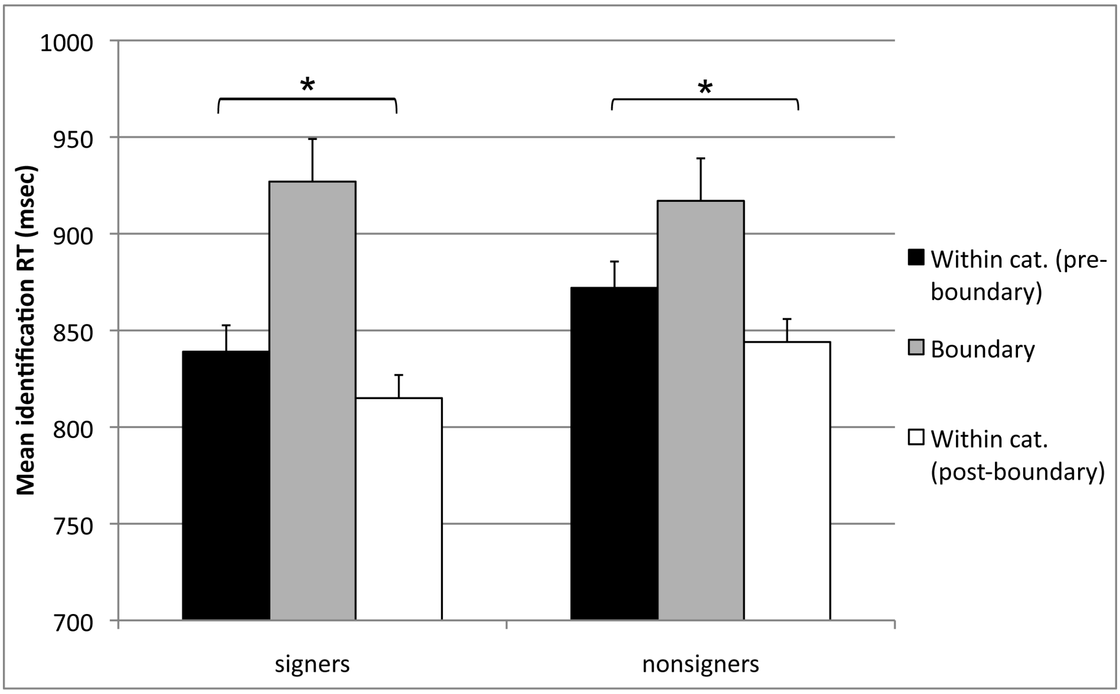


Figure 3.10. Mean identification task RT comparison across groups on both handshape continua

Figures 3.11 and 3.12 show the overall identification RT plots for both handshape types. It can be seen that both signers and non-signers' RTs slowed down on the category boundary for the /flat-O/-/flat-C/ continuum (Figure 3.11) and the /S/-/C/ continuum (Figure 3.12) suggesting that assigning handshapes to binary categories was indeed hardest at the boundary, which was located between items 4 and 5 for /flat-O/-/flat-C/ continuum and between items 6 and 7 for /S/-/C/ continuum.

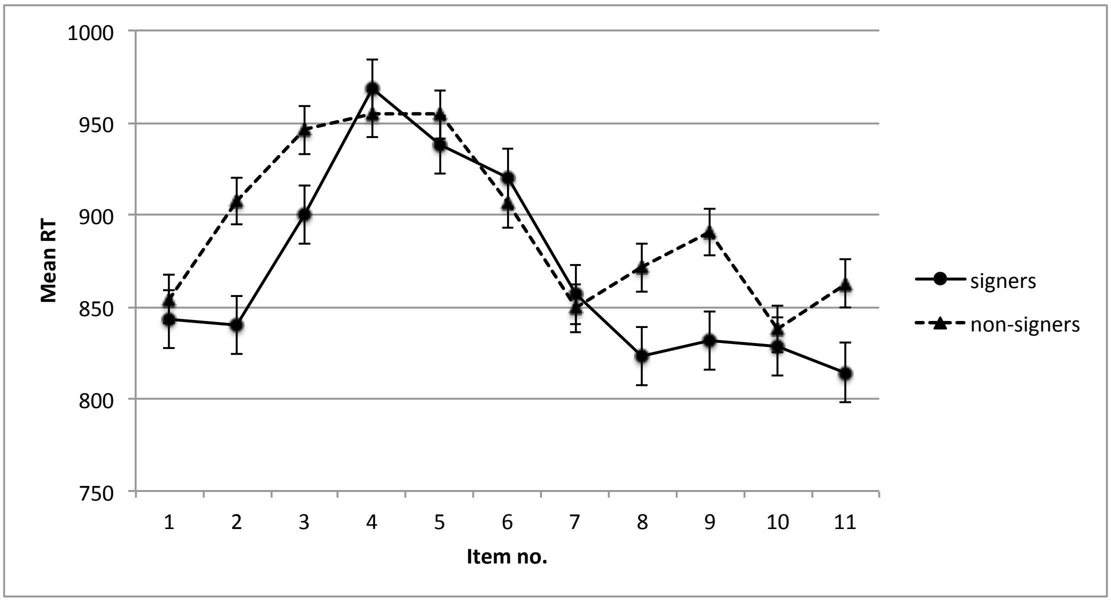


Figure 3.11. Identification task RTs for individual items on the /flat-O/-/flat-C/ continuum

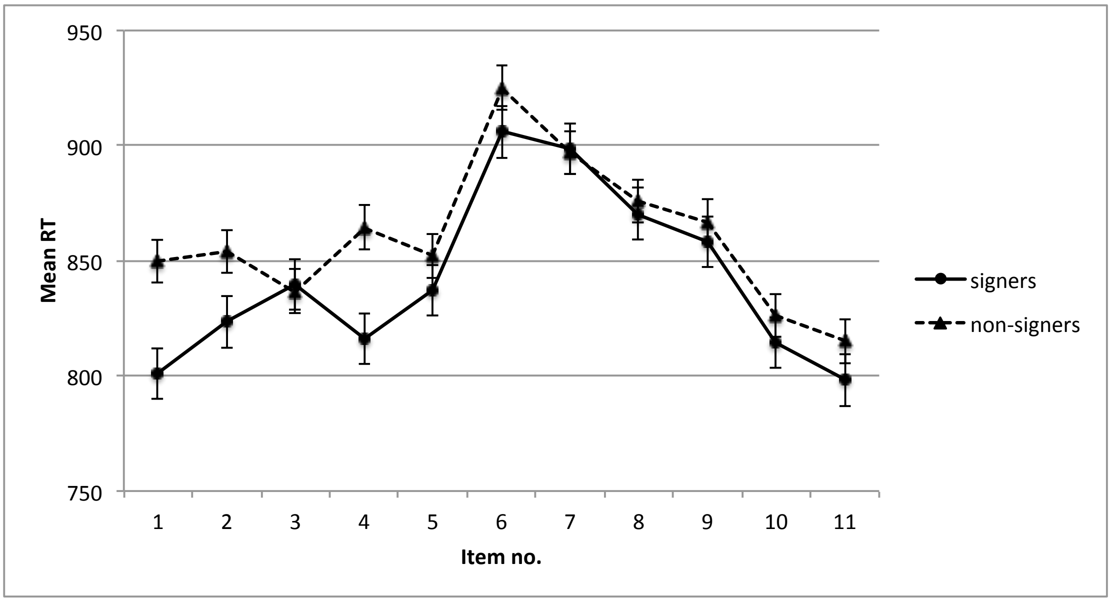


Figure 3.12. Identification task RTs for individual items on the /S/-/C/ continuum

3.5.2 Handling handshape discrimination

In the discrimination task, mean accuracy for pairs straddling the boundary was contrasted with mean accuracy on all other pairs combined. The effect of language status with two levels (group: deaf signers; hearing non-signers), status of handshapes with three levels (category membership: within category; boundary items; endpoint items) and handshape type as a covariate with two levels (flattish rectangular vs. cylindrical) on handshape discrimination accuracy was examined using 2 x 3 x 2 repeated measures ANOVA.

The results revealed a significant main effect of group, $F(1, 44) = 7.64$, $p < .01$, *partial* $\eta^2 = .15$, and main effect of category membership, $F(2, 88) = 3.69$; $p < .05$, *partial* $\eta^2 = .08$, pointing to differences in mean discrimination accuracy on the boundary, within categories and on the endpoints and also significant differences between the two groups. The main effect of handshape type was non-significant, $F(1, 44) = .13$, n.s. There was no interaction between group and category membership, $F(2, 88) = .59$, n.s., or between handshape type and category membership, $F(2, 88) = 1.11$, n.s. Dependent samples *t*-tests revealed that deaf signers' accuracy on the boundary (M = .93, SD =. 07) was higher than within category (M = .87, SD = .06), $t(27) = -4.69$, $p < .001$, and higher than on the endpoints (M = .82, SD = .09), $t(27) = 5.40$, $p < .001$. Within category accuracy was higher than on the endpoints, $t(27) = 2.43$, $p < .05$. Hearing non-signers were also more accurate on the boundary (M = .86, SD = .09) than within categories (M = .84, SD = .07), $t(27) = -2.43$, $p < .05$ and more accurate on the boundary than on the endpoints (M = 78, SD = .09), $t(27) = 4.48$, $p < .001$. Within category accuracy was also better than accuracy displayed on the endpoints, $t(27) = 2.93$, $p < .05$. Overall, deaf signers were more accurate in discrimination (M = .87, SD = .07) than non-signers (M = .83, SD = .09). Mean accuracy in discrimination between handshapes within category, on the boundary and on the endpoints for both HH continua is provided in Figure 3.13. For individual continua, see Figure 3.14 a) and 3.14 b).

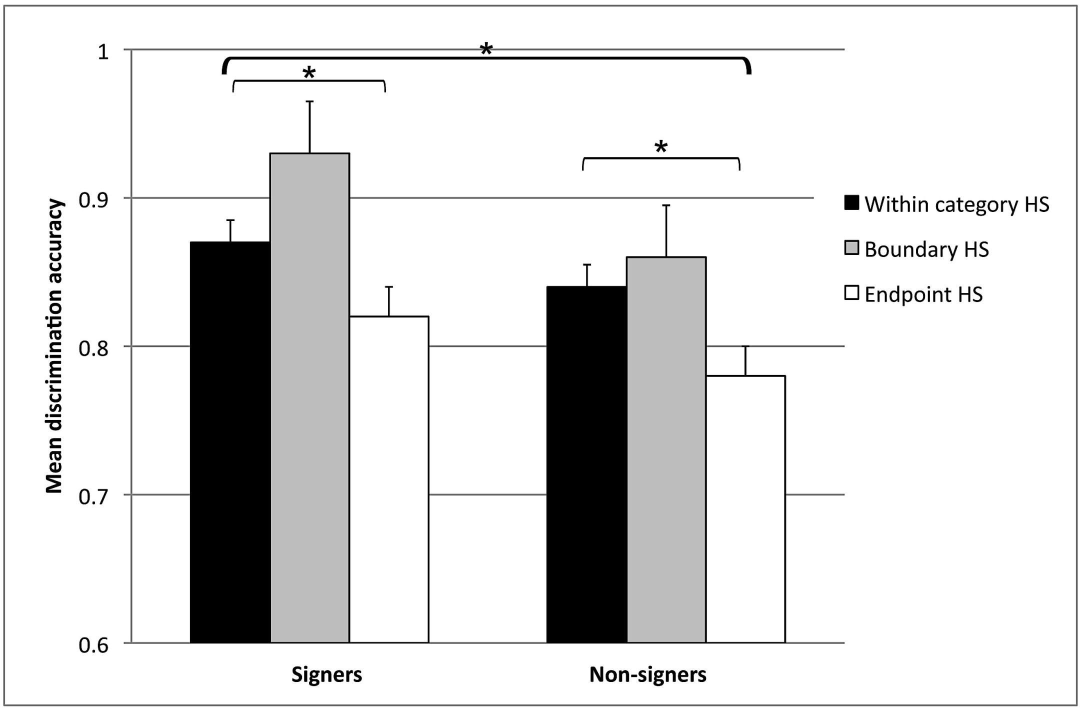


Figure 3.13. Mean accuracy in discrimination between handshapes within category, on the boundary and on the endpoints for the HH continua

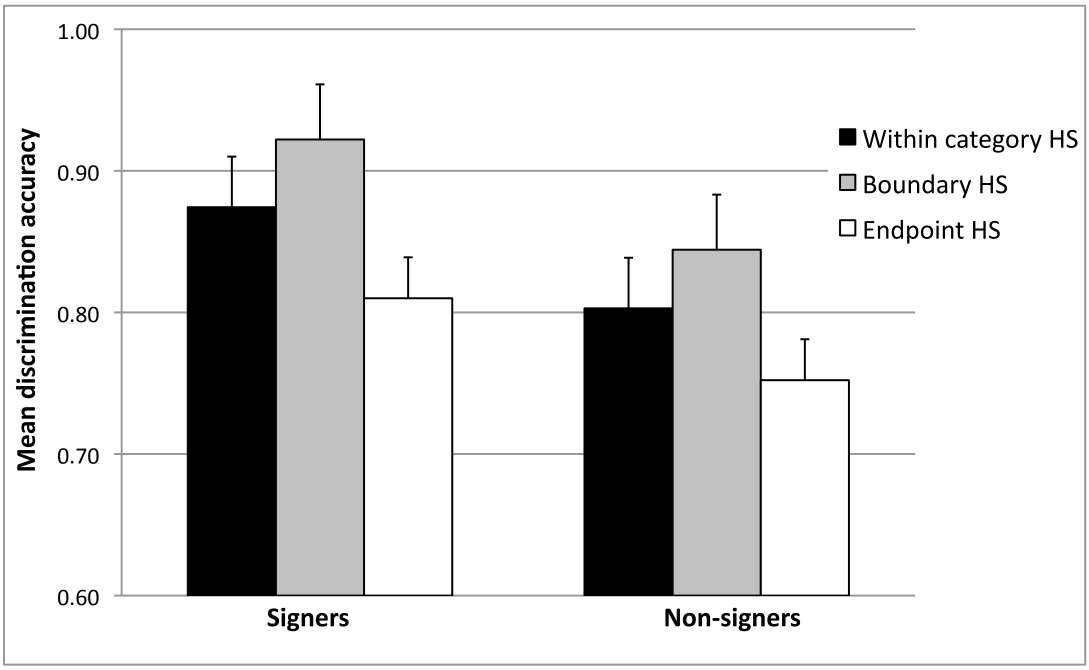


Figure 3.14 a) Mean accuracy in discrimination between handshapes within category, on the boundary and on the endpoints for the /flat-O/-/flat-C/ continuum

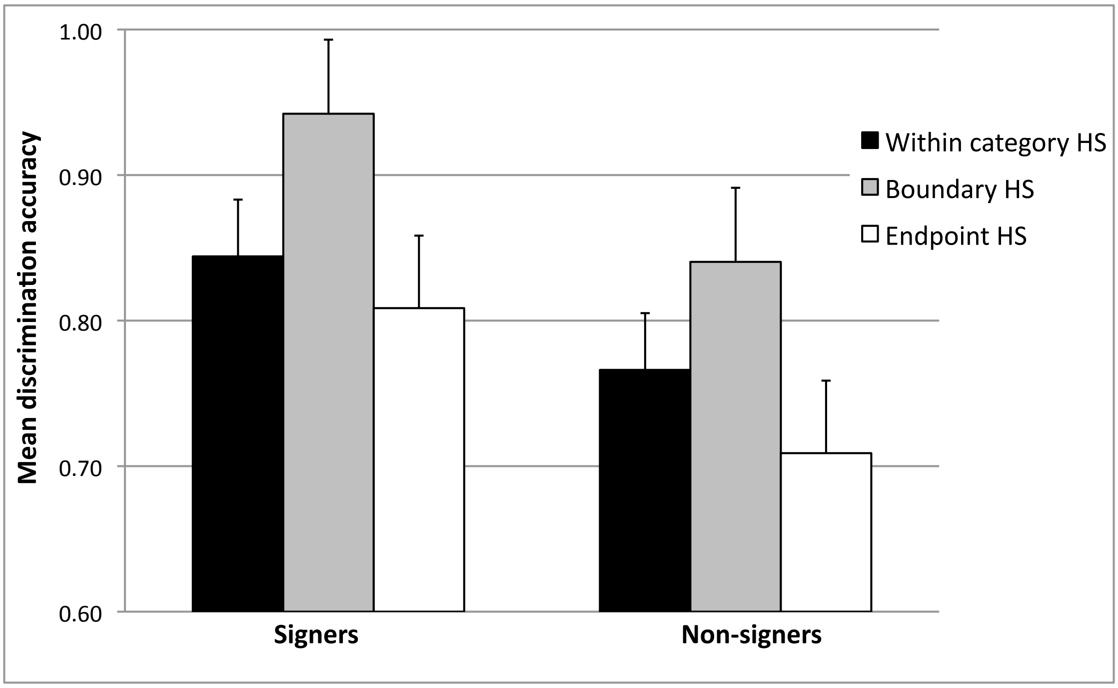


Figure 3.14 b) Mean accuracy in discrimination between handshapes within category, on the boundary and on the endpoints for the /S/-/C/ continuum

A psychophysical effect occurred on the /flat-O/-/flat-C/ continuum, where both deaf and hearing participants displayed high discrimination accuracy on the endpoint handshape pair where fingers were touching vs. minimally apart (specifically, item pair 1 and 3). This can be seen in Figure 3.15 a). Figures 3.15 a) and b) show average discrimination accuracy per handshape pair. Discrimination accuracy gradually declined towards more open endpoint where the fingers were most widely spread apart. Despite this visual comparison strategy observed for the /flat-O/-/flat-C/ continuum, the CP effect in accuracy was retained when discrimination accuracy on the boundary was compared with items on the endpoints and within categories. There was no such perceptual strategy for the /S/-/C/ handshape continuum, see Figure 3.15 b). In addition, category boundary did not coincide with discrimination peaks in either group for the /flat-O/-/flat-C/ continuum (Figure 3.15 a) and in the deaf BSL group on the /S/-/C/ continuum (Figure 3.15 b). The mean category boundary however did coincide with the highest discrimination in the non-signers group on the /S/-/C/ continuum (Figure 3.15 b)

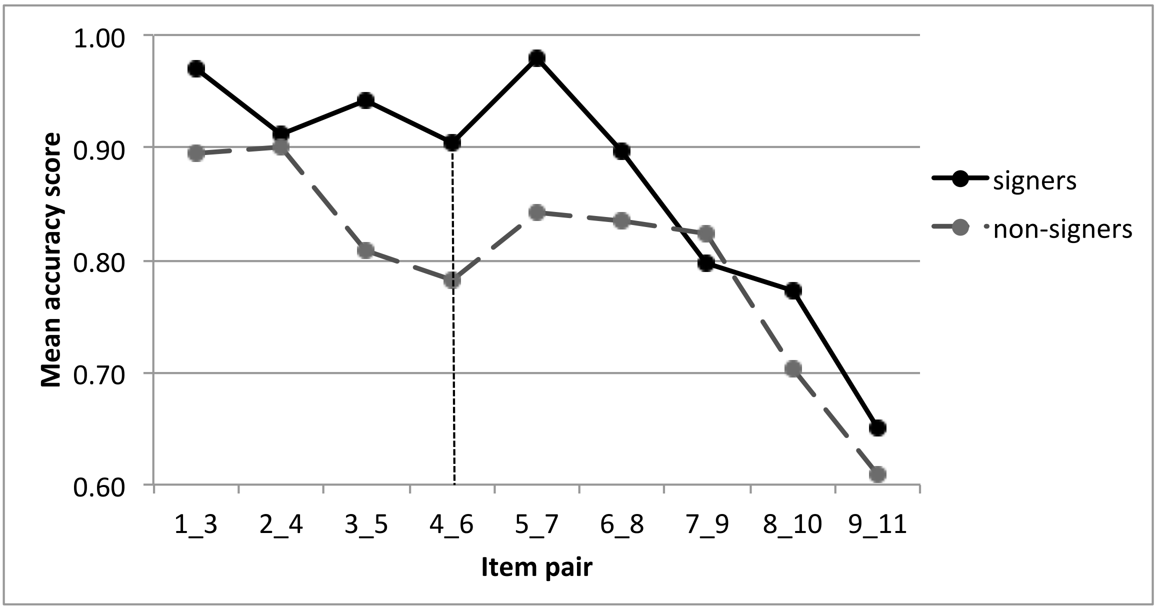


Figure 3.15 a) Discrimination between flattish rectangular handshape pairs on the /flat-O/-/flat-C/ continuum

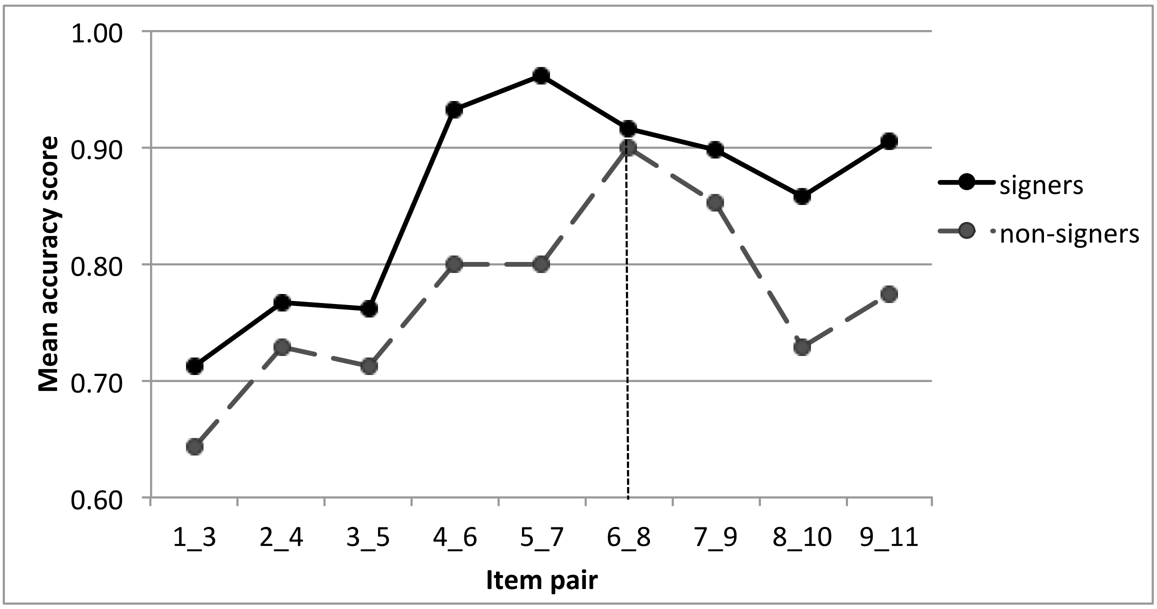


Figure 3.15 b) Discrimination between cylindrical handshape pairs on the /S/-/C/ continuum

Discrimination task RTs were analysed to examine patterns in handshape processing. The effect of language status with 2 levels (group: deaf signers vs. hearing non-signers), status of handshapes with three levels (category membership: within category; boundary items; endpoint items) and handshape type as covariate with two levels (flattish rectangular vs. cylindrical) on RTs in the discrimination task was examined using 2 x 3 x 2 repeated measures ANOVA. Outliers were eliminated using the 2 standard deviations rule. The main effect of group was non-significant $F(1, 37) = .82$, n.s. The main effect of category membership was also non-significant, $F(2, 74) = 1.94$, n.s. There was no interaction between the group and category membership, $F(2, 74) = 1.00$, n.s. and no interaction between category membership and handshape type, $F(2, 74) = 2.45$, n.s. Both signers and non-signers displayed similar RTs patterns for the handshape continua and no effect on processing was observed for boundary handshapes. Mean RTs for discrimination between handshapes within category, on the boundary and on the endpoints for the HH continua is provided in Figure 3.16.

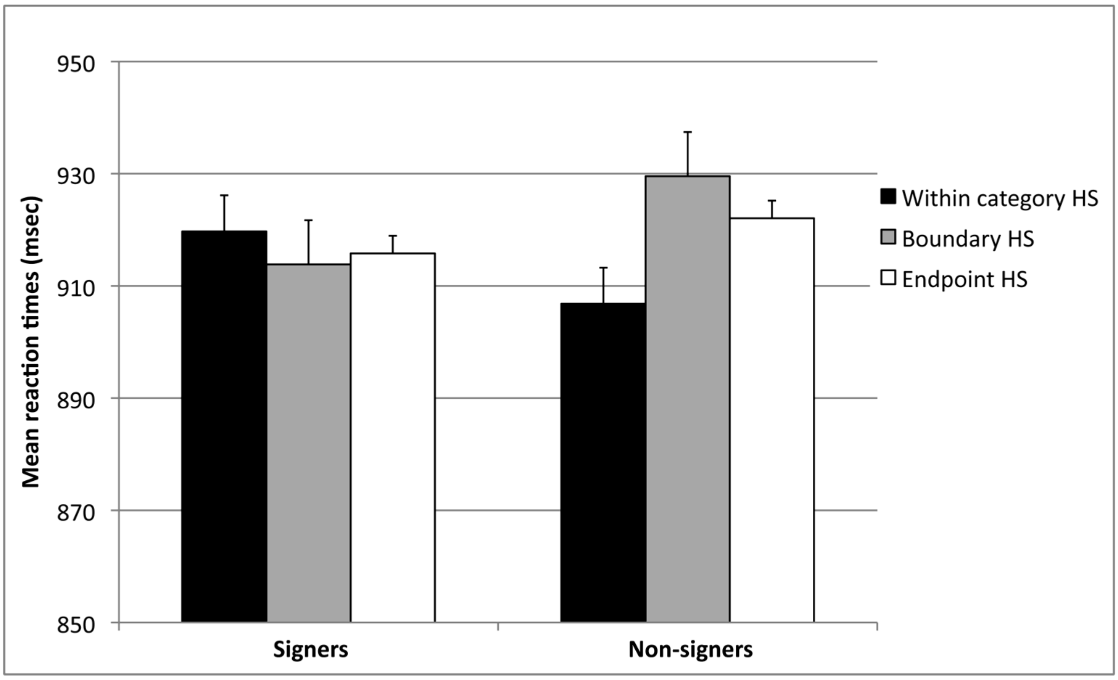


Figure 3.16. Mean RTs for discrimination between handshapes within category, on the boundary and on the endpoints for the HH continua

3.6 Discussion

To summarise the results, deaf signers and hearing non-signers both exhibited similar patterns in binary categorisation (identification) of both handshape continua. Both deaf and hearing participants were significantly slower when assigning handshapes straddling the boundary to endpoint categories than handshapes elsewhere on the continuum showing that categorisation of handshapes was most difficult at a boundary. Additionally, all participants labelled items to the left of the boundary (pre-boundary) more slowly than items to the right of the boundary (post-boundary). In handshape discrimination, signers and non-signers also displayed similar patterns. Both groups peaked in discrimination accuracy on the category boundary on both handshape continua thus displaying a CP effect. Deaf signers were significantly more accurate in discrimination overall than hearing non-signers. Both groups displayed comparatively similar RTs on both handshape continua, showing no significant processing advantage for items on the boundary versus elsewhere on the continuum. RTs distribution differed between the two continua. RTs coincided with the category boundary which for /flat-O/-/flat-C/ continuum was located closer to the closed side of the continuum than for /S/-/C/.

The results showed that deaf BSL signers and hearing non-signers displayed similar perceptual categorisation of handshape forms that appear in constructions depicting handling of objects in BSL. Regardless of the participants' language background, both groups perceptually sorted the HH variants into binary categories, displaying a clear sigmoidal shift between the categories. Thus the binary categorisation of HHs remained unaffected by sign language experience. Categorisation was at chance at the midpoints where assigning handshapes to the endpoint categories is most difficult. This suggests that both deaf and hearing participants employ visual perceptual strategies when assigning handshapes to binary categories, even though the extent to which participants could make purely visual comparisons between finger distances was controlled by presenting dynamic stimuli in different places on the screen.

The identification task results are consistent with findings from earlier studies (Baker et al., 2005; Emmorey et al., 2003; Lane, Boyes-Braem, & Bellugi, 1976) who found similar sigmoidal function in the identification task suggesting that linguistic experience does not influence the ability to identify visual features involved in identifying handshapes. The present finding is also consistent with the results of Emmorey et al. (2003), where all of the participants perceptually separated the handshape continua in similar positions along the continua. The findings confirm the assumption that visual perception of handshapes, rather than linguistic processing, guides the process of binary categorisation and extend this from handshapes in lexical signs and static size and shape specifier (SASS) constructions to handshapes in handling constructions.

The discrimination task revealed that deaf signers and hearing non-signers exhibited better discrimination (higher accuracy) across the category boundaries on both continua as compared with within-category discrimination which could be argued to demonstrate CP for both handshape continua. These CP effects were due to all of the within-category pairs being discriminated less well than the across-category pairs, despite the fact that accuracy within category was still relatively high for both groups. The finding that non-signers also displayed CP effects for these handshape contrasts indicates that the enhanced discrimination at the boundary may have been due to general properties of visual discrimination and perception. It is important to note that here, a strict CP definition is not adopted. According to the traditional CP principle, discrimination should be the sharpest and coincide with the category boundary, while discrimination within category should be at chance. However, such ideal CP function has rarely been observed especially in sign language studies and was not observed in the present study. Further, it was the hearing non-signer group whose discrimination peak was aligned with the boundary, not the deaf BSL signers. Therefore, it is argued that the discrimination ability was enhanced at midpoints due to sensitivity to a boundary. This boundary falls along natural perceptual boundaries for both deaf signers and hearing non-signers. The perceptual features of handshapes influenced their discriminability, suggesting that contact vs. no contact and spread vs. no spread are salient visual features that both deaf and hearing perceivers use to guide their discrimination. Curvature or the stacking of fingers, on the other hand, might be more difficult to judge. Future studies could look into investigating the perception of other handshape features besides aperture.

The discrimination patterns found in this study are not in line with findings in previous studies on CP although it should be noted that discrimination function across prior studies has not always been consistent. As discussed earlier, previous CP studies have mainly examined perception for handshapes in lexical signs or pseudo-signs, which are very different in nature from handshapes in less conventional constructions depicting object handling and manipulation. In addition, most CP studies have been conducted on ASL and it is unclear whether perceptual patterns observed for ASL signs can be extended to other languages. So, what can comparisons with previous studies tell us about the nature of HHs, with respect to what we already know about categorical perception?

Previous studies have presented convincing evidence that linguistic experience influences handshape perception because only deaf ASL signers displayed CP effect for phonemic hand configurations (Baker et al., 2005; Best et al., 2010; Emmorey et al., 2003). Baker et al. admit that the type of experience could be perceptual experience of using a language, both receptively and expressively. McCullough and Emmorey (2009) found perceptual discontinuity between furrowed brow and raised brow (these have been argued to be grammatical question markers in ASL) in both signers and non-signers. Perceivers naïve to sign language contrasts might re-interpret information on the face, such as facial adverbials or facial question markers, as categories of affect (Campbell et al., 1999; McCullough & Emmorey, 2009). Similarly, visual arrays of HHs represent familiar stimuli for both signers and non-signers, leading to similar processing mechanisms specialised for hand gesture processing. This provided another piece of evidence that sign language experience did not matter in the perception of sign language stimulus. Further, CP for semantic (meaningful) contrast has been reported in studies on perception of non-linguistic information about affect. Thus, in light of these studies (also introduced in 2.6.4), HHs in the present study could have been associated with meaningful categories of object sizes or magnitude. Furthermore, this is another example where the presentation context leads to categorical perception due to the meaning values associated with the stimuli, unlike spoken language phonemes (as discussed in 2.5.2).

Other studies that previously found effects of language experience in CP such as Morford et al. (2008) examined age of acquisition effects in lexical ASL signs used by deaf signers but did not compare CP in signers with non-signers. The findings in the current study suggest that Morford et al.'s (2008) claims (that experience with co-speech gesture is not sufficient to shape handshape perception in the same way that exposure to language does) may not extend beyond the lexicon to DCs. In the present study, participants displayed similar discontinuities in their ability to discriminate between HH variants regardless of linguistic experience. There are several possible reasons why such patterns occurred. One possible explanation is that linguistic (phonemic) contrast is not necessary for CP to occur for handshape stimuli when presented in a non-lexical (not fully lexical) context.

Another explanation is that when perceiving handshapes in non-lexical contexts (where increased variation of form is permitted), signers and non-signers become more attuned to subtle changes in handshape form because of the semantic values associated with each handshape token. The relatively high discrimination accuracy rates suggest that both groups were attuned to the fine gradation changes in handshape aperture, although hearing non-signers were less accurate overall than deaf signers; this is consistent with previous CP studies described earlier. In addition, the presence of the psychophysical function, i.e. the perceived relationship between handshape size and magnitude, suggests that both groups of participants employed similar visual strategies to discriminate between handshapes, rather than linguistic categorisation.

Thirdly, although manipulative gestures occur in face-to-face interaction, the extent to which multi-modal language experience shapes perception of (aspects of) gesture is not well understood. Thus the non-signers' visual experience with co-speech gestures might have influenced discrimination. Viewers regardless of their linguistic experience might be rehearsed in fast mapping between gestural or manipulative depictive forms and their meaning and such representations might be outside of the linguistic system. This is plausible because effects of similar general visual perceptual experience have been reported in other CP studies. For example, Baker et al. (2005) reported that in fact, the ASL group's performance was not significantly better than the English group's performance for all contrasts, even though the English group had no expertise in looking at the fine distinctions required for the handshapes that are contrastive in ASL. So even though experience with a language constitutes routine mapping between form and meaning, it may be that non-linguistic, cognitive categorisation and familiarity with visual stimuli (e.g. manipulative gestures) drive visual processes in deaf and hearing perceivers.

While the lack of a linguistic effect driving CP does not rule out the possibility of linguistic handshape categories, assumptions about HHs as categories specified in BSL (i.e. phonemic and/or morphemic) need to be made with caution. The CP patterns obtained in the current study are comparable with those observed in vowel perception, where reasonably good within category discrimination has also been observed (Macmillan, Kaplan, & Creelman, 1977; Massaro, 1987). Although sonorant vowels can be perceived categorically, CP effects for vowels are generally weaker than for obstruent consonants (Fujisaki & Kawashima, 1971; Repp, 1984) due to more robust variation in the articulation of vowels. Thus, CP can be assumed if more lenient criteria are used, such as those used for CP in vowels. The observed above-chance within-category performance led Massaro (1987) to argue that the term categorical ‘partition’ rather than ‘perception’ might be more appropriate to refer to such outcomes in vowel perception. The results from the experiment in this chapter categorical ‘partition’ may also be more appropriate to refer to handling handshape perception.

Additionally, other meaningful many-to-one mappings may have supported perceptual discrimination ability within categories causing perceivers to switch to a finer grained level of processing, which in turn may have broadened their processing capacity and weakened the CP effect. It is plausible that within-category discrimination accuracy was elevated due to the existence of other categories along the HH continua. In fact, Baker et al. (2005) argued that one of the handshape continua ranging from [5] to [S] contained a third phonemic handshape, [claw] handshape. In the identification task, the ASL group were at chance labelling items at the midpoint as they were aware of the third category and they displayed good discrimination along the continuum with no peak on the boundary. In the present study, the identification function revealed that participants were at chance on category boundaries (see individual identification plots in Figures 1 and 2 in Appendix D). However, if they were aware of a third category, increased discrimination on the boundaries would not be observed. This does not exclude the possibility of other handshape categories, e.g. [O] or [C] with a small gap, particularly as the discrimination accuracy was relatively high overall; this warrants further research. Chapter 4 will examine this possibility via handshape encoding / decoding.

However, not all handshape phonemes are perceived categorically. In certain ASL lexical signs, e.g. SAY-NO-TO, the handshape ranging from most close to most open did not yield a CP effect (Baker et al., 2005, Emmorey et al., 2003). The handshape continuum in this lexical sign is similar to the /flat-O/ handshape continuum examined in the present study which also varied in aperture from most open to most closed, the only difference is that in /flat-O/ handshape, four fingers are selected instead of two. The authors explain the lack of CP as evidence that aperture in this sign is allophonic; allophonic contrasts are not typically perceived categorically (Emmorey et al., 2003) because perceivers would treat all allophones as equally good variants of the phoneme leading poor discrimination. Lexical contexts can influence the discriminability of allophones (Whalen, Best, & Irwin, 1997)

This was not the case in the present study where the contrasts ranging from fingers touching to fingers most open were perceptually categorised. This contrast might have been due to the association of handshapes with graspable object sizes, in which case aperture may be a meaningful feature in HHs. Here, aperture has neither been perceived similarly to allophonic nor to phonemic contrasts. Therefore, even though handshapes used to depict handling of flattish rectangular or cylindrical objects might be discrete, based on the present findings, it is difficult to argue for any similarity to handshape phonemes in lexical signs. Handling constructions could be structurally more simplex than previously thought. An open question that remains is that if HHs in DCs are not phonemes / allophones, what are they and how are they stored and represented? In Chapter 5, a more general question of what CP reveals about handshape processing in general will be discussed.

In addition to accuracy, RTs shed important light on the processes involved in handshape perception and advance our knowledge of processing of HHs. RTs in categorisation and discrimination have yielded strong and reliable patterns of discrimination sensitivity in spoken languages. CP studies on sign language handshapes have rarely measured RTs. RT patterns in sign language investigations have been variable and provided weak support for categoricity of certain facial expressions in BSL (Campbell et al., 1999). Previous research on speech perception showed that stimuli from the same category were judged faster if participants were asked to respond whether the stimuli were 'same' than if they were asked to respond 'different' (Bornstein & Korda, 1984). Thus judging similarities between stimuli from the same category should be easier and faster than stimuli from different categories. It was expected that participants would be faster on within-category judgments than across-category judgments, given that they assessed handshapes on similarity. However, RT performance revealed no effects of category in either group and no linguistic advantage for deaf signers. Thus, categoricity of HHs was not supported by the RT data in this study, although it is possible that this was due to lack of power due to a small sample. The lack of linguistic effects would point to perceptually rather than linguistically driven categorisation and fits the accuracy findings. Regardless, the outcome is consistent with previous research on facial expressions, e.g. Campbell et al.'s (1999) observed similarities in RTs between deaf and hearing participants for facial expressions.

A possible reason for the lack of effects could be due to the relatively high variability in RTs, which was sustained even when outliers were excluded using the 2*SD rule. This, in turn, could have obscured potential group differences. However, it is equally plausible that higher RT variability in the perception tasks was due to the fact that visual perception is quite different in nature to auditory perception; very different processes are involved in perceiving and processing visual stimuli than when the auditory channel is concerned. Previous studies that measured RTs in categorisation and discrimination of auditory stimulus (speech sounds) observed small error rates (e.g. see Bornstein and Korda, 1984, p. 214). However, due to the differential nature of auditory and visual perception, it is difficult to make comparisons. Unfortunately, comparison with other studies in the sign language domain is not possible because to my knowledge, no study has previously measured RTs in categorical perception for sign language handshapes. McCullough and Emmorey (2009) and Campbell et al. (1999) measured RTs in CP of morphed facial expressions. The standard deviations of response rates obtained in identification tasks by Campbell et al. (1999) were considerably large. Although the signers were overall faster in responding than non-signers, the authors observed no additional effects of factors tested. Therefore, further studies with large samples are needed to determine whether RTs provide a measure sensitive enough to detect patterns of perceptual discrimination and categorisation of visual stimulus. Other measures, such as goodness-of-fit ratings or handshape monitoring tasks (e.g. Gosvald et al. 2012) could be used in future studies to further examine the extent or nature of perceptual and linguistic factors in the processing of HHs in BSL depicting signs.

3.7 Conclusions

In this experiment, HHs used to depict handling of flattish rectangular and cylindrical objects in BSL were perceived discontinuously regardless of the perceiver's linguistic experience. The elevated discrimination at midpoints on both continua suggests sensitivities to category boundaries but the CP effect was weakened by the fact that both deaf and hearing participants remained perceptive to the gradient changes in aperture. One could critique that the within vs. across-category differences, although significant, were not large enough to support claims of a clear CP effect. However, robust CP effects are rarely found in sign language research. It can be concluded that CP occurred as a result of perceived contrast between perceptually salient or meaningful contrasts, e.g. the deaf and hearing participants displayed perceptual or visual judgment strategy of discerning between smaller and larger HHs. Thus the processes involved in categorisation of HHs appear to be similar for signers and non-signers. CP has arisen due to categories in a shared general semiotic system rather than a linguistic system. HHs thus appear to have underlying meaningful contrasts outside the linguistic realm, suggesting that BSL HHs might be less linguistically complex in nature than previously assumed. This research has implications for category structure in sign language and for theories of DCs. The extent to which handshapes are discrete and conventional in BSL or how similar they are to depicting gestures remains to be determined. The question of whether handshapes in DCs are encoded and decoded categorically in discourse is examined in the experiments reported in the following chapter.

CHAPTER 4 Categorical and gradient encoding of object size in handling constructions in BSL, co-speech gesture and pantomime

4.1 Introduction

As discussed in Chapter 2, previous studies suggested that constructions depicting whole/part of entities, i.e. entity constructions in ASL and Auslan, contain a discrete set of handshapes which categorise the referent according to their shape, size or semantic properties (Brentari, 2011; Eccarius, 2008; Schembri et al., 2005). Similarly, handshapes depicting the size and shape of objects (SASS) are also discrete morphemes in ASL, according to Emmorey and Herzig (2003). Deaf signers appear to use handshapes depicting whole entities systematically when compared to hearing non-signers who use co-speech gesture (Schembri et al., 2005). Similar claims about structural properties of handling handshapes (HHs) have been made for ASL and other sign languages (e.g. Brentari & Eccarius, 2009; Eccarius & Brentari, 2008a, 2010; McDonald, 1982; Slobin et al., 2003; Zeshan, 2003; Zwitserlood, 2003). Despite the increasing focus on DCs, there is a lack of empirical evidence to support such claims. There is a lack of corresponding evidence from non-signers in particular.

Following on from the previous study, CP paradigm does not allow us to make a distinction between co-speech gesture and pantomime as it tests perception based on the perceivers' representations. The issue is that previous studies examining size encoding in DCs based their claims on comparison between ASL and gestures without speech; see e.g. Goldin-Meadown et al. (1995, 2007) and Emmorey & Herzig, (2003) (as reviewed in section 2.4 or 2.5.3). But Goldin-Meadow et al. (1996) have also demonstrated that there are differences between co-speech gesture and pantomime forms. Moreover, the finding that homesigners use conventional handshapes when describing objects and their handling suggested that that other factors, not linguistic categorisation, contribute to their conventionalisation. It is therefore a valid question to ask whether constructions depicting handling have underlying representations outside of the linguistic realm by examining how objects are described in natural discourse (speech / sign) in comparison with more strategic communication strategy (i.e. pantomime).

Further, in comparison with entity or SASS constructions, constructions depicting handling afford a more direct mapping of the signer's articulators onto the articulators of the depicted referent. Thus the signer uses their hands as articulators to enact the way in which the object was manipulated or how the referent's hand is shaped for handling on a large, real-life scale. Some researchers have suggested that handling constructions are forms of CA, a strategy frequently employed by deaf signers to re-enact actions, thoughts or dialogues of referents (Cormier, Smith, & Sevcikova, 2013) in a more or less conventionalised manner. There appears to be overlap between conventionalised properties of language and non-conventional gesture in handling constructions; however the nature of this overlap has not been carefully studied. In the current experiment, I begin to gather evidence about handling constructions in their own right, by looking at whether the continuous information about handled object sizes (and shapes) is discretely conveyed in sign languages in contrast with depictive gestures.

This chapter investigates whether depicting handshapes in BSL are used and subsequently interpreted discretely in BSL narrative. Chapter 3 examined CP for handshapes depicting handling of objects in BSL where CP as a tool was used to examine sensitivity to discrete contrasts in HHs in BSL. The experiment reported in Chapter 3 points to perceptual rather than linguistic categorisation of HHs because both signers and non-signers exhibited a CP effect. BSL HHs appear to have an underlying contrastive meaning outside the linguistic realm and as such, linguistic experience may not be necessary to perceive such contrasts. One explanation of the occurrence of CP for HHs is that it is the result of visually perceived contrast between the thumb and the fingers and is thus observed in perceivers regardless of their language experience. Another explanation is that that CP for HHs may occur as a result of the perceived contrast between categories associated with meaning of graspable object sizes (i.e. handshapes associated with grasping small vs. large objects) and is thus motivated by general semiotics associated with information on the hands rather than linguistic categories. The question as to whether HHs are specified for BSL remains open although results reported in the previous chapter suggest that they are not. It appears that HHs in DCs convey meaning as a whole, similar to gestures, and that they appear to be conventionalised across the communicative repertoire. However, their linguistic status is still unclear.

This study is the first to use an experimental basis to examine categorical encoding of object size via aperture of HHs in sign language and gesture. It builds on the findings from study 1 that BSL HHs are perceived categorically regardless whether the perceiver has experience with sign language. Previous findings have opened up interesting empirical questions as to whether HHs might be conventionalised and discrete in sign language and whether discrete handshapes might also occur in gestures articulated by hearing speakers. Handling constructions have been under researched and the amount of systematic comparisons between deaf signers and non-signers' handshape production or perception has been rather limited. Firstly, this study establishes whether constructions depicting handling and manipulation of objects in BSL are composed of discrete handshapes by examining encoding via decoding of graspable object sizes in HHs. This method assesses the perceivers' interpretation of naturally occurring handshapes. It is then discussed whether these categories mark semantic distinctions in BSL. Handling constructions used by BSL signers and handling gestures used by non-signers in co-speech gestures appear very similar. Experimental design, rather than observational methods, is therefore used to examine discreteness or gradience in HHs and gesture. The outcome of this study should inform descriptive accounts of the structural properties of handling constructions and DCs in general. It contributes to the debate about the tight relationship between language and gesture and provides support for theories that conceive of language as an embodied and amodal phenomenon.

4.2 Research questions

The main research question in this study is whether the increasing size of graspable objects is encoded and subsequently decoded discretely in handling constructions produced by deaf BSL signers, hearing non-signers in co-speech gesture and hearing non-signers in pantomime. Discrete encoding is assessed indirectly via handshape decoding as follows. HHs describing objects increasing continuously in size are elicited from three groups of producers. These handshapes are subsequently matched by another group of judges to examine for gradient or discrete encoding of graspable object sizes. This is determined by a regression analysis. If deaf BSL signers encode (in production) the gradient information about graspable object size by means of discrete HHs, another group of deaf judges naïve to the object continuum should be at chance matching the objects with handshapes but only within categories or certain distance on the continuum. There would be no systematic form-meaning mapping, and thus no correlation within a category. If gradient encoding occurs, there would be a correlation between the object size described and the object size chosen even within categories. Discrete encoding by BSL signers only would suggest that HHs are used categorically to depict handling of objects and that they are discrete morphemes in BSL. By comparing deaf BSL signers and hearing non-signers in natural spontaneous discourse it is assessed whether HHs are encoded / decoded differently due to sign language experience.

4.3 Study design

As explained above, encoding of graspable object size was assessed via handshape decoding. The procedure of assessing gradient vs. categorical sign language descriptions by measuring how those descriptions are interpreted (pioneered by Schwartz, 1979) was adapted from Emmorey and Herzig (2003) who assessed the categorical expression of static SASS handshapes by determining how they were interpreted by another group of judges (see section 2.4.1). A similar handshape decoding design was adapted for the current study in order to assess if systematic (categorical) handshape-to-object size mapping occurs in BSL handling constructions and gestures with speech (co-speech gesture) and without speech (pantomime). This decoding technique assesses the categorical expression of dynamic HHs by determining how other signers and non-signers decode them. The strength of this technique is that it does not assume categories a priori. Handshapes are first elicited to describe objects of a range of sizes, and then descriptions are used as stimuli for the decoding part of the study. However, to address some shortfalls, Emmorey and Herzig's design was adapted in the following ways.

Firstly, the HH stimuli were recorded in a more natural narrative context where participants described real life objects rather than a set of pictures which elicited a more standalone SASS constructions in the Emmorey and Herzig experiment. Secondly, in the decoding phase, each video clip was shown four times during the trial in random order and the presentation included distractor handshapes. This provided a larger set of decodings per stimulus item which allowed for statistical testing and increased statistical power and increased the reliability of findings.

Thirdly, Emmorey and Herzig did not systematically examine how hearing non-signers depict or interpret gradient object sizes. Therefore, this was addressed in the current study by asking two groups of hearing non-signers to describe handling of objects increasing in size during English narrative and during pantomime.

Nine deaf BSL signers and two groups of nine hearing non-signers (co-speech and pantomime groups) described handling of objects increasing continuously in size, items 1–9. Handling constructions were elicited in BSL and spoken English narratives and pantomime. There were two object continua, cylindrical and rectangular. Each producer only saw one target object from each continuum (thus avoiding comparisons). Narratives were recorded and the clearest examples of handling construction from each participant were edited into 3-second clips. The elicitation procedure is described in 4.4.2.2.

In the decoding phase, another group of seven deaf BSL signers and two groups of seven hearing judges watched the clips and matched the handshapes in each clip with the objects. Each judge was presented with the complete object sets (randomly arranged). Each clip was shown four times and each time the participant recorded an answer in an answer sheet (Appendix F). The presentation of clips was randomised and presentations included distractor clips (descriptions of objects of unrelated size / shape). There were total of 36 test trials. In total, 252 responses were recorded in each group. Responses outside the 95% confidence interval (less than 5%) were removed using a 2 SD rule.

To reiterate the hypothesis spelt out in 4.2, the assumption was that if gradient encoding occurs, there would be a positive correlation between object size described and object size chosen such that an increase in object size described corresponds to an increase in object size chosen. However, if encoding is categorical such a relation would not be present. Further, categorical encoding / decoding was tested by looking at the effect of hypothesised size categories on the size of object chosen by the judges across three language conditions.

4.4 Method

4.4.1 Participants

Nine deaf signers (BSL group; eight deaf signers age range 18-38, one deaf signer age 58; M=2, F=7), nine hearing non-signers, native speakers of English (co-speech gesture group; eight gesturers age range 18-38; one gesturer age 48; M=2; F=7), and nine hearing non-signers (pantomime group; age range 18-38; M=4, F=5) were recorded and their productions used as stimuli in the decoding phase of the experiment. In the second phase, a group of seven deaf BSL signers (BSL; six deaf signers age range 18-38, one deaf signer age 58; M=3, F=4), seven hearing non-signers (co-speech gesture; age range 18-38; M=3, F=4), and seven hearing non-signers (pantomime; six gesturers age range 18-38, one gesturer age 58; M=1, F=6) took part. All deaf and hearing participants were approximately matched on age, with only two deaf and two hearing participants outside of the 18-38 age range (shown in brackets in Table 4.1), making the deaf and hearing samples roughly matched in age overall. Some participants disclosed only the age range, not the exact date of birth. Thus it was not possible to match some of them precisely on age. Age ranges are reported instead as mean age could not be calculated. Table 4.1 summarises the participant details.

Table 4.1

Summary of participant details (study 2)

	Producers			Judges		
	N	Gender	Age	N	Gender	Age
BSL	9	M=2, F=7	18-38 (58)	7	M=3, F=4	18-38 (58)
Co-speech	9	M=2, F=7	18-38 (48)	7	M=3, F=4	18-38
Pantomime	9	M=4, F=5	18-38	7	M=1, F=6	18-38 (58)

Participants who took part in the second phase did not participate in the elicitation phase of the experiment. All deaf participants were either born deaf or became deaf before age two and acquired BSL before age six from a primary caregiver. Their preferred language of communication was BSL. All hearing non-signers were native English speakers and had no previous experience with sign language. Deaf participants were recruited through the online participation pool website administered by the Deafness Cognition and Language (DCAL) Research Centre (UCL) or through personal contacts in the deaf community. Hearing participants were recruited through the UCL Psychology online participation pool website and through personal contacts. The study took place in a computer laboratory at DCAL.

4.4.2 Materials

4.4.2.1 Materials for elicitation of handling handshapes

HHs were elicited from the deaf and hearing participants in response to two continua of objects: rectangular flattish and cylindrical objects, books (Figure 4.1) and jars (Figure 4.2) increasing in thickness and diameter respectively in approximately 1cm increments.

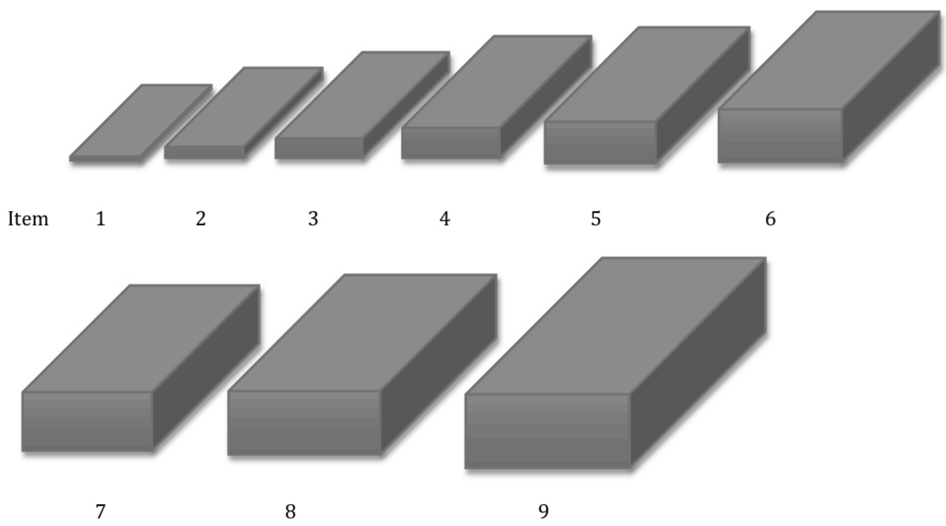


Figure 4.1. Schematic representation of the flattish, rectangular target object set

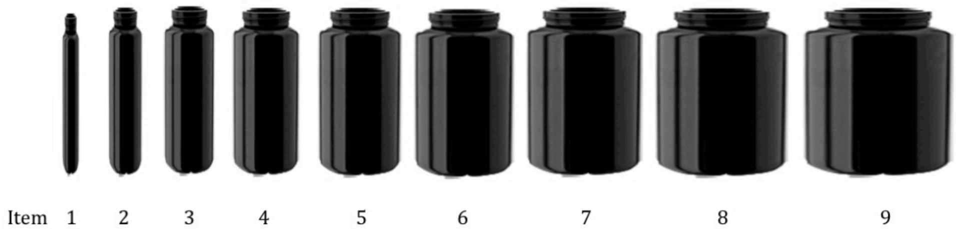


Figure 4.2. Schematic representation of the cylindrical target object set

The flattish rectangular target set consisted of nine flat, square objects (books) which continuously varied in thickness from 5mm (< 1in) to 90mm (> 3in) in approximately 10mm (0.4in) increments and varied in length only between 180-220mm (ca. 7-9in). The cylindrical set consisted of nine cylindrical objects (jars) which continuously varied in diameter from 15mm (<1in) to 90mm (> 3in) in about 10mm (0.4in) increments; the jars were approx. 150mm (5in) in length. 9 objects were used in this elicitation stage. The aim here was to examine size encoding and decoding by finger aperture in one-handed handling constructions only. The minimum and maximum size of endpoint target objects on both scales was constrained by the physical span of human hand when grasping objects. Objects larger than 10 cm in diameter are not easily graspable by one hand and would elicit two-handed constructions, while very small objects would likely elicit precision handshapes with different selected fingers and would thus be different from the rest of handshapes.

All rectangular target objects had the same plain white finish and all cylindrical objects had silver finish; this was to eliminate additional semantic or descriptive clues about the object (e.g. title of the book, colour etc.) and to direct the participants' attention on the size of the object instead. Each target set contained objects of the same kind (i.e. books and jars) to reduce variability in the types of HHs produced. There were three distracter items of unrelated size or object type to the target items (i.e. soft toy, mug, stapler). The distracter items were the same for all participants and all participants remained naïve to the contrast of the target object sizes. The rationale for using fillers with other characteristics and only one object from the continuum was to avoid forcing the participants to distinguish fine gradations of size or shape if they would not ordinarily do so.

The elicitation set for each participant consisted of the following: one item only from each target set of objects (i.e. one jar and one book) plus three distracters (distracters were same for all participants). Figure 4.3 shows an example of a test set presented to a participant (producer) who described handling of all five objects. In total, each participant produced five narratives that involved producing a handling description for one object from each set. The narratives involving handling constructions were elicited using a cartoon story, which was designed to elicit a number of handling constructions (see Appendix E).

Figure 4.3. An example of target object set presented to a participant

4.4.2.2 Procedure for elicitation of handling handshapes

Prior to the recording, deaf participants viewed pre-recorded BSL instructions by a deaf native BSL signer. Hearing participants received instructions in spoken English. Both deaf and hearing participants were provided with an English transcript of the instructions (see Appendix C).

During the recording session, the producers were seated opposite to another participant (a confederate). For the deaf BSL group, the confederate was a fluent deaf BSL signer who was a member of the Deaf community and acquired BSL before age 6. For the two hearing groups, the confederate was a hearing native English speaker. The producers were instructed to familiarise themselves with the cartoon. They were then presented with an object from the elicitation test and asked to describe the story to the confederate in front of them. Each recording session began with a practice trial and the first object presented was a distractor to warm up the participant. They were told that the object in front of them should feature as the object that was handled by the character in that story. Both the objects and the cartoon were hidden from the confederate's view. This was to stimulate a situation where the producer believes the addressee does not possess visual information about the object as the presence of the referents in the addressee's environment might lead to reduction or even omission of the referent and its attributes in the narrative. A pilot using a small number of non-signers had previously shown that this strategy was successful in eliciting high number of spontaneous co-speech gesture in the hearing non-signers group.

The deaf BSL participants described object handling using BSL. The hearing group non-signers described handling in English using co-speech gesture and the second group of hearing non-signers acted out object handling using their hands (or upper body) without using their voice. This way, automatic handling descriptions were elicited from the BSL signers and hearing co-speech group, and strategic gestures from the pantomime group for comparison. These handshape productions, including practice trials, were recorded on a digital camcorder fixed on a tripod. A fixed angle of 45 degrees was maintained for all participants. The same distance between the participants and the camera was also constant. Video recordings were imported into iMovie and digitised. Handling constructions were edited into short video clips (2-3 sec) and used as stimuli.

The confederates were trained prior to the task on the type of questions to be asked, such as to re-tell or re-enact parts of the story, particularly those which focused on handling without revealing what the focus was on. The confederates would only ask for clarification if the handling constructions were not clearly articulated, or if they were completely omitted from the narrative. The deaf confederate communicated with the participants in BSL and the hearing confederate communicated with the participants in English. The questions were open-ended, for example *Please sign / say that again?* or *What happened when he entered the shop?*

The participants were naïve to the purpose of the task. They were told that the study investigates the differences between deaf and hearing participants in spatial descriptions and object placement and that they will be recorded for the purpose of creating stimulus material for another group of signers and non-signers who will examine the videos. All participants were debriefed about the project after the filming had finished. The elicitation task took around 20 minutes to complete and participants could take regular breaks if they wished to.

4.4.3 Stimuli

The video recordings obtained in the elicitation procedure described above were imported into iMovie. The selected handling constructions were edited into short video clips (between 2-3 seconds long) and exported in QuickTime® at 24 key frame rate and clip dimensions 640 x 480. Each clip contained one of the producers articulating handling of a target (or a distractor) object. These clips were then randomised and two presentation orders were created as stimuli for the comprehension task. Handling descriptions of distractor items were used as fillers and included at random in the presentation set. The cylindrical and rectangular continua were tested separately.

Careful attention was paid to the selection of HH exemplars, e.g. hearing co-speech gestures were selected only when they occurred simultaneously with the spoken description and all clips were checked by another deaf signer or hearing non-signer for clarity and appropriateness. Only the handling units that overlapped with speech were chosen as stimuli for the co-speech gesture judges. This was to ensure that the handling co-speech gestures were produced during an automatic rather than strategic process and as such were comparable in nature with the signed productions. In the signed and co-speech gesture descriptions, I made sure that the selected clips did not contain any identifying lexical labels uttered by the producer prior to articulation of the handling construction, although this rarely happened. Occasionally, adverbial information or mouthing occurred during handling descriptions (e.g. puffed cheeks or pursed lips) however, I ensured that any cues indicative of the manipulated object size or the object type were either concealed or not present in the short stimulus clips. From all object size encodings, the clearest forms were selected as stimulus items. A native deaf BSL signer assessed the tokens for clarity. The clearest, rather than random, tokens were selected to prevent confusion due to articulatory handshape assimilation. It is possible but unlikely that this introduced a confound; this is further explained in section 5.8.

4.4.4 Procedure

Each participant (judge), none of whom took part in the elicitation phase, was seated in front of a desk with a laptop and the object set to the right of the monitor as shown in Figure 4.4. The objects were arranged randomly for each participant. All items were arbitrarily labelled as A, B, C, etc.

Figure 4.4. Production-object matching task set up with a cylindrical object set

The deaf participants received instructions in BSL. They were asked to decide which object the deaf signer was talking about in the clip. Both hearing groups of judges were instructed in English. The hearing judges viewing spoken descriptions with co-speech gestures were asked to decide on the basis of both spoken and visual information which object the speaker was talking about and note down their answer. They were asked to note down how confident on a scale 1-3 they were in their choice. The hearing judges viewing pantomime were asked to view the clips and decide which object was described as being handled by the gesturer in the clip. The participants were told that only the handshape, and not the speaker's identity, was important in determining the answer because the same model could appear several times, describing a different object on each occasion. This discouraged the judges from associating a model's identity with a particular handshape or size and reduced the confound caused by trial repetitions. Elicited handling constructions were relatively similar across the productions which further prompted the judges to pay closer attention to the handshape itself. The advantage of trial repetitions was that four tokens (responses) per handshape were collected from each judge, which increased power and reliability of the data.

Each test session was preceded by several practice trials to familiarise the participants with the task set up. Participants were allowed to ask clarification questions before the main test began but not during the main test. The test clips were presented randomly to each participant. Each clip disappeared immediately after it had been played, followed by a blank screen during which the participant noted down their answer and rate their confidence. They were encouraged to answer as quickly as possible. Once the participant noted down their answer, the experiment moved onto the next trial. The trials were controlled by the experimenter. Participants viewed each clip only once.

The presentation of clips was randomised, presentations included distractor clips (descriptions of objects of unrelated size & shape). The stimuli clips were separated into two blocks according to the object type, thus giving the participants a short break in the middle. There were total of 36 test trials. In total, 252 responses were recorded in each group. Responses outside the 95% of tolerance were removed to reduce the effect of outliers.

4.5 Results

The results pointed to a linear correlation between object size described and object size chosen indicating that all deaf and hearing participants reliably associated smaller objects with smaller apertures and larger objects with larger apertures and not the other way round. However, hearing participants in the co-speech gesture condition differed from the deaf BSL and hearing pantomime groups as they showed most clearly that the HHs were not interpreted as gradient variations. The hearing co-speech group appeared to make distinctions between smaller and larger object sizes but not between smaller and medium sizes. The judges of pantomime handshapes showed the most gradient encoding of graspable objet sizes as they showed stronger effect of size in comparison with the hearing co-speech gesture. The deaf judges of BSL handshapes did not significantly differ from the two hearing groups in terms of the effect of size category on the size of object chosen. In addition, deaf signers were significantly more confident in the handshape-object matching task than hearing non-signers in both conditions, suggesting a visual language advantage. Size encoding and decoding via aperture thus yielded similar results in signed and spoken discourse. The following sections report these results in more detail.

4.5.1 Graspable object size encoding: a relationship between object size expressed versus object size chosen

If gradient encoding occurs, there would be correlation between object size described and object size chosen. Lack of correlation (e.g. quadratic trend) would suggest categorical encoding. In other words, if signers encode (in production) gradient information about graspable object size discretely, another group of deaf judges naïve to increase in size should be at chance matching the objects with handshapes. Multiple regression analysis was carried out to find out if the size of object described by the producers using HHs significantly predicted the size of object chosen by the judges. The regression analysis was carried out for each continuum and group separately and included tests for both linear and quadratic functions. The quadratic term was added to the regression model by centering the predictor values on the x-axis and squaring them. For ease of presentation, the average size of object chosen by the judges and the size of object described (mm) are shown in Figure 4.5 a), b) and c) for flat rectangular continuum and Figure 4.6 a), b) and c) for cylindrical continuum.

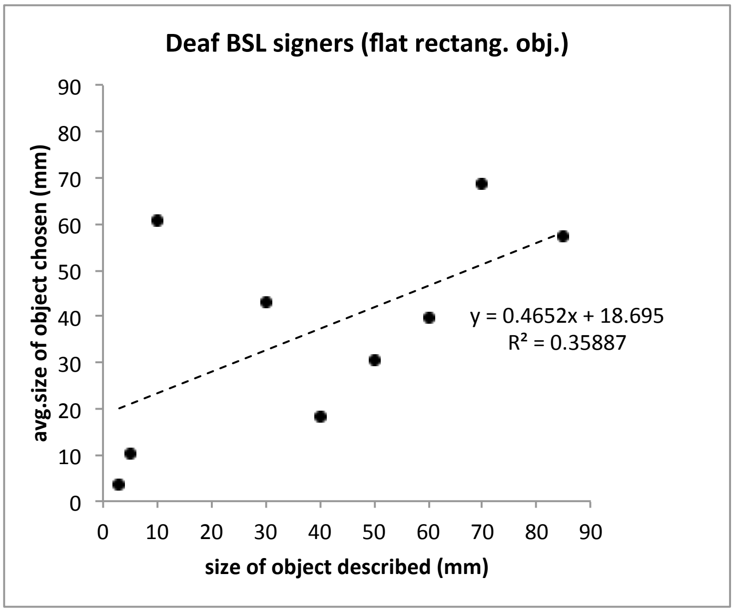


Figure 4.5 a) Average match between rectangular object size described by deaf BSL signers on the X-axis and rectangular object size chosen by deaf BSL signers on the Y-axis

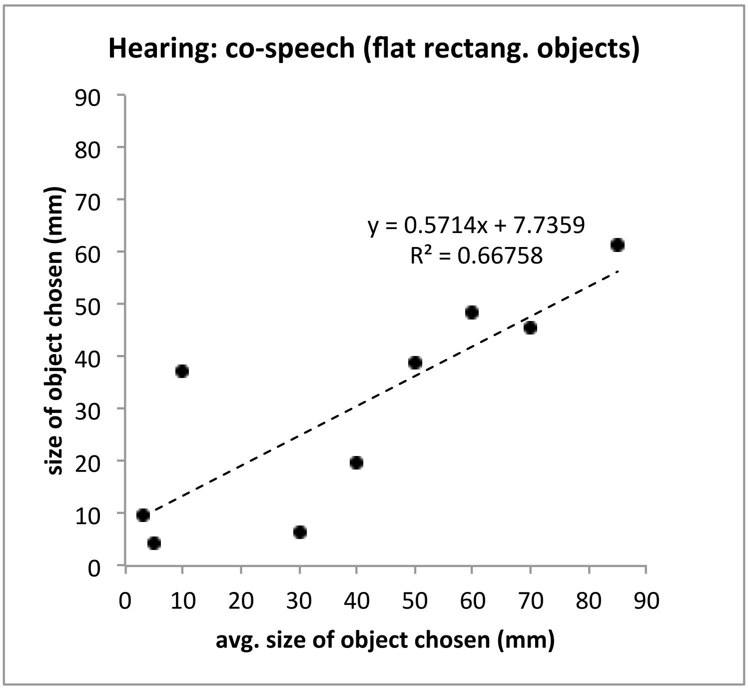


Figure 4.5 b) Average match between rectangular object size described by hearing non-signers (with speech) on the X-axis and rectangular object size chosen by hearing non-signers on the Y-axis

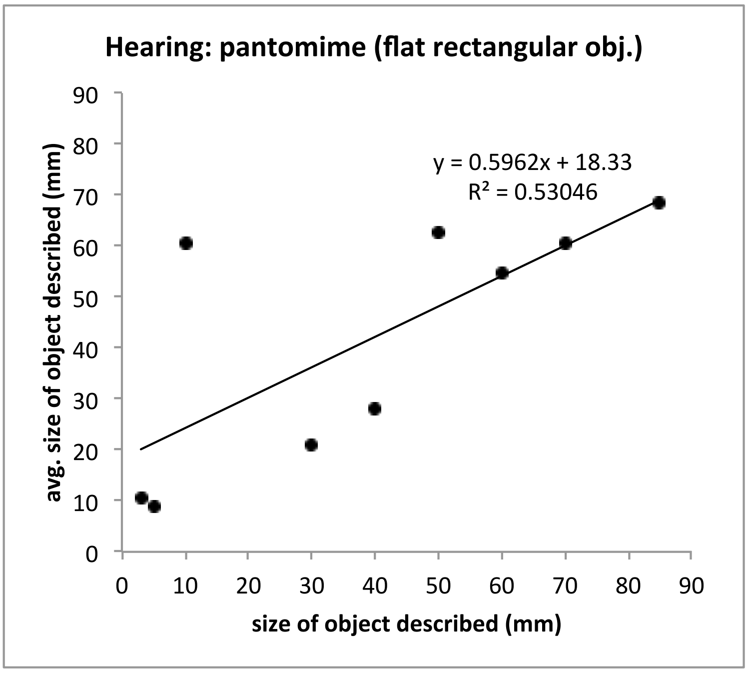


Figure 4.5 c) Average match between rectangular object size described by hearing non-signers (without speech) on the X-axis and rectangular object size chosen by hearing non-signers on the Y-axis

The results of regression reported in Table 4.2 indicated that the size of flattish rectangular objects described (using finger distance) overall significantly predicted the size of object chosen by deaf BSL judges in linear terms. Using the enter method, a significant model emerged, R^2 = .33, $F(2, 234)$ = 56.9, p < .001, accounting for 32% of the variance. Similarly in the hearing groups, the size of object described by hearing speakers in English narrative using co-speech gesture predicted the size of object chosen by hearing speakers, R^2 = .41, $F(2, 188)$ = 64.4, p < .001, accounting for 40% of the variance. In the pantomime group, the model, R^2 = .37, $F(2, 234)$ = 69.3, p < .001, also predicted the size of object chosen accounting for 37% of variance. Significant variables are reported in Table 4.2.

Table 4.2.

Multiple regression: size of object described versus size of object chosen; flat rectangular objects

		B	*SE (B)*	*β*
BSL				
	constant	12.25	2.67	
	size described (LM)	.50	.05	.54*
	size described (QM)	.01	.00	.12*
CO-SPEECH				
	constant	4.04	2.99	
	size described (LM)	.60	.06	.60*
	size described (QM)	.01	.00	.13*
PANTOMIME				
	constant	18.37	2.78	
	size described (LM)	.59	.05	.61*
	size described (QM)	.00	.00	.03

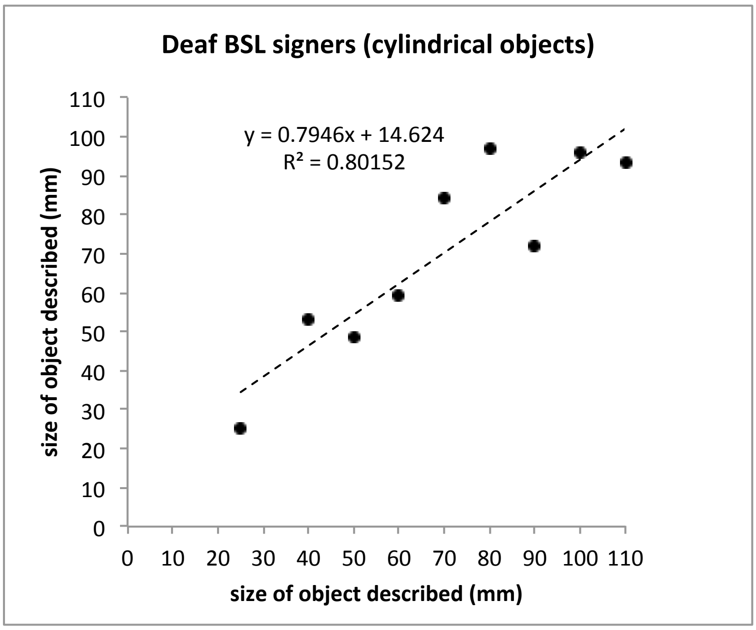


Figure 4.6 a) Average match between cylindrical object size described by deaf BSL signers on the X-axis and rectangular object size chosen by deaf BSL signers on the Y-axis

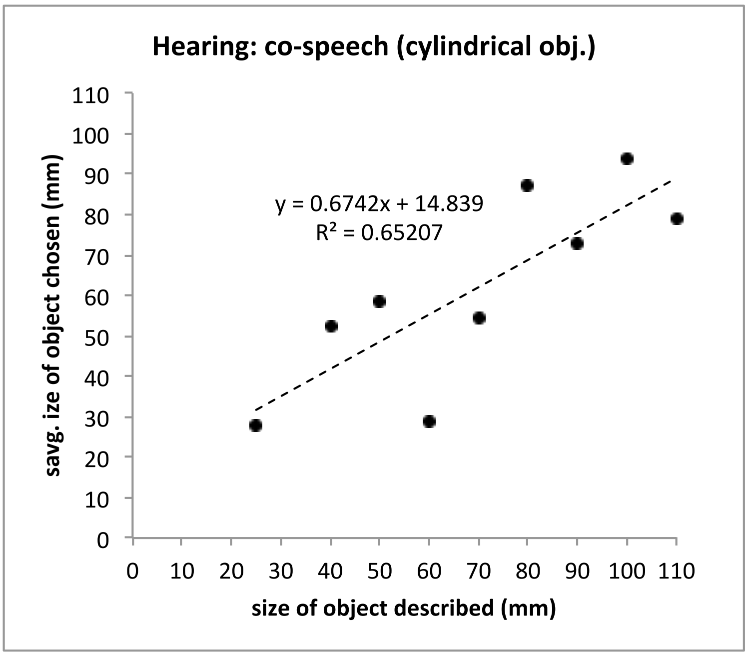


Figure 4.6 b) Average match between cylindrical object size described by hearing non-signers (with speech) on the X-axis and rectangular object size chosen by hearing non-signers on the Y-axis

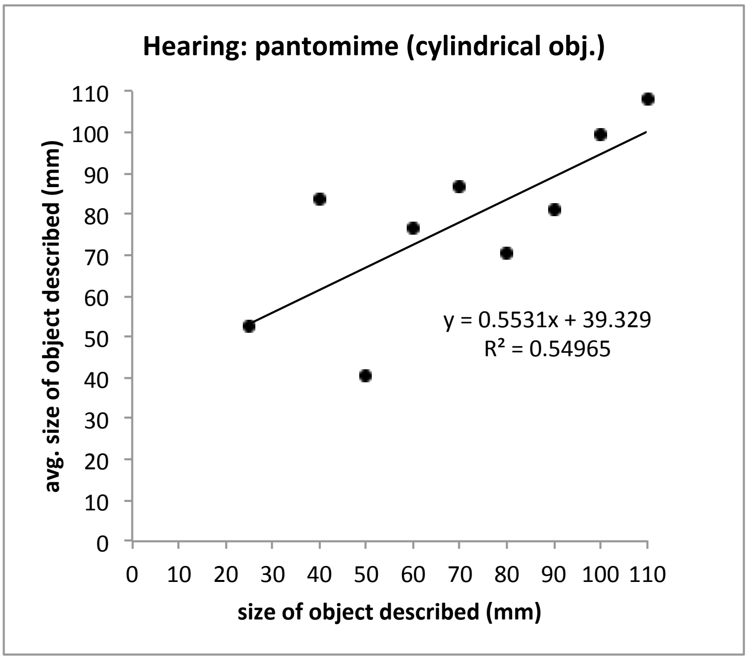


Figure 4.6 c) Average match between cylindrical object size described by hearing non-signers (without speech) on the X-axis and rectangular object size chosen by hearing non-signers on the Y-axis

The results of regression carried out for the cylindrical continuum are reported in Table 5.3. The results indicate that the size of cylindrical objects described (using finger distance) significantly predicted the object size chosen by the deaf BSL judges, $R^2 = .68$, $F(2, 233) = 274$, $p < .001$, accounting for 68% of the variance. In the co-speech group, the size of object described by hearing speakers in English narrative using co-speech gesture predicted the size of object chosen by hearing speakers, $R^2 = .57$, $F(2, 213) = 139.1$, $p < .001$, accounting for 57% of the variance. For the pantomime group, the model $R^2 = .36$, $F(2, 234) = 69.3$, $p < .001$ accounted for 36% of variance. Significant variables (the linear and quadratic models) are reported in Table 4.3.

Table 4.3.

Multiple regression: size of object described versus size of object chosen; cylindrical objects

		B	*SE (B)*	*β*
BSL				
	constant	20.913	2.904	
	size described (LM)	.79	.04	.80*
	size described (QM)	-.01	.00	-.21*
CO-SPEECH				
	constant	4.802	4.195	
	size described (LM)	.82	.05	.77*
	size described (QM)	.00	.00	.09
PANTOMIME				
	constant	35.35	3.99	
	size described (LM)	.56	.05	.60*
	size described (QM)	.01	.00	.14*

The relatively large standardized *β* coefficients for both continua indicate that size of objects described using finger distance has an effect on object size chosen in linear terms. The quadratic term was not a good predictor for size chosen, as can be seen from the relatively small *β* coefficients in Table 4.2 and Table 4.3. Despite the linear relationship, the *β* coefficient (slope between object described and object chosen) was less than 1. A slope of 1 would mean that the viewers accurately judged the size along the whole scale. A slope different from 1 indicates a reliable tendency to either under- or over-estimate the actual size. For example, in Figure 4.5 a), b) and c), the graphs show that deaf and hearing judges tended to over-estimate the size of objects 10 mm wide, while they under-estimated objects of sizes between 30-40 mm wide. Gradient production and interpretation of HHs would be marked by a clear one-to-one correspondence (an accurate estimate of match) between size described and size chosen. The slope that was smaller than 1 is perhaps telling us that the production and interpretation of these utterances is non-gradient and could be, to some extent, systematic.

4.5.2 Detecting categorical variation

The particular regression approach reported above does not allow us to distinguish between a linear and a categorical distinction among possible categories. This is illustrated in Figure 4.7 a) and 4.7 b) below.

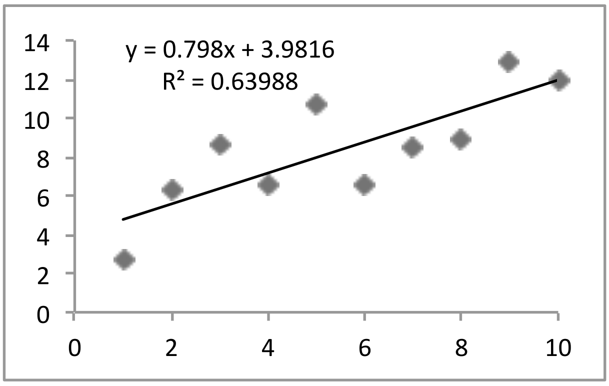


Figure 4.7 a) A schematised example of a mathematically linear dataset

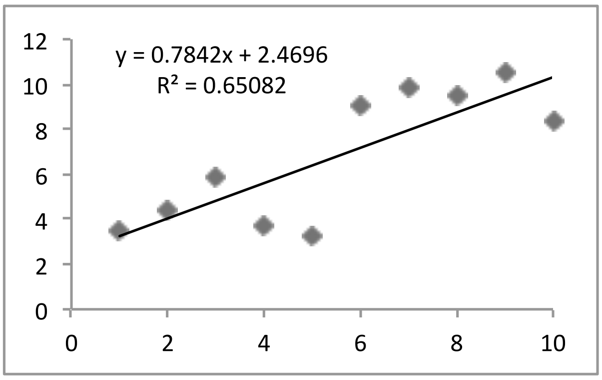


Figure 4.7 b) A schematised example of a categorical dataset

The first graph (4.7 a) shows an example of a mathematically linear dataset and the second (4.7 b) categorical. In both examples, the R statistic is approximately equal. The correlation turns out about the same even thought the scatterplots show clear differences in distribution. This similarity in the regression results is reflected in the best-fit lines overlaid on the two example scatterplots.[10] Even though the data fit

[10] Thanks to David Vinson for making this observation.

the linear function relatively well, the linear model explains only a small part of the total variance, especially for the flattish rectangular continuum.

Thus to probe the question whether the graspable object sizes may have been encoded and/or decoded categorically, the effect of size of described objects on object size chosen by the judges was examined. Three equidistant categories of object size were hypothesised. If there is an effect of the category of object size described on the size of object chosen, it will suggest gradient encoding / decoding. If the category does not account well for the variance in object size chosen, this will suggest a categorical encoding / decoding. If an effect of size is found for the hearing group but not for the BSL group, I can ask whether this is because the deaf BSL signers encoded and decoded object sizes categorically. In other words, the goal was to find out if the category of size predicts the size chosen in the three language conditions.

A mixed design, 3 x 2 x 3 ANOVA with one between subjects factor, language condition (BSL, English co-speech and pantomime) and two within subjects factors, continuum (rectangular vs. cylindrical) and size category described (small, medium, large) was carried out to reveal the effect of object size described on the size of object chosen for both object continua in three language conditions. These tests supplement the regression analysis. The relevant main effects and interactions are reported below and plotted in Figure 4.8.

There was a main effect of size category on the average size of object chosen by the judges, $F(2, 100) = 221.87$, $p < .001$, $\eta_p^2 = 0.816$, $\beta = 1$; 82% of the variance in object size chosen was due to category of size. Category of object size described was a powerful predictor of the object size chosen in all language conditions and on both continua. Contrasts revealed that the size object chosen for small category of size was significantly lower than for large category, $F(1, 50) = 481.27$, $p < .001$, $\eta_p^2 = 0.906$, $\beta = 1$ and the size of objects chosen for medium category was significantly lower than for large category across all participants, $F(1, 50) = 175.71$, $p < .001$, $\eta_p^2 = 0.778$, $\beta = 1$. The means of object size chosen were significantly different for small, medium and large categories of object size described as the average size ratings significantly increased with the size category when all three groups and continua are considered. This is consistent with the results from the regression analysis above which suggested that the size of objects described significantly predicts the size of object chosen overall.

There was a main effect of language condition, $F(2, 50) = 4.28$, $p < .05$, $\eta_p^2 = 0.146$, $\beta = 0.721$. Bonferroni comparisons revealed a significant difference between hearing participants in the co-speech and pantomime conditions, $p < .05$ but the difference between BSL and the gesture conditions remained non-significant, $p > .05$. This suggests that overall regardless of categories of size or continuum, the hearing judges of co-speech gesture and pantomime differed from each other in the average size of object chosen, but the BSL judges did not differ from the two hearing groups, as their average size ratings for all categories fell between co-speech and pantomime groups. There was also a main effect of continuum, $F(1, 50) = 11.53$, $p < .01$, $\eta_p^2 = 0{,}187$, $\beta = 0.92$; only 19% of the variance was due to handshape type.

The interaction between language condition and category of size was significant, $F(4, 100) = 5.58$, $p < .001$, $\eta_p^2 = 0.182$, $\beta = 0.973$. This indicates that the size of object chosen differed across the categories in all language conditions – BSL, co-speech and pantomime. These interactions for both continua together are plotted in Figure 4.8. To break down the interactions, contrasts were performed comparing each category with the large category across language conditions. When comparing the size ratings across groups, there was an interaction between the medium and large categories of size, $F(2, 50) = 10.11$, $p < .001$, $\eta_p^2 = 0.288$, $\beta = 0.981$ but no interaction was found when small and large categories were compared, $F(2, 50) < 1$, $p > .05$, $\eta_p^2 = 0.02$, $\beta = 0.128$. This means that all groups recorded a similar increase in average object size chosen as the size category of described objects increased from small to large; again this is consistent with the regression analysis above. However, the interaction between medium and large category is due to the fact that the co-speech group rated the size of objects in the middle of the continua differently from the BSL and pantomime groups. The average size chosen in the co-speech condition did not increase from small to medium category (the co-speech judges significantly underestimated the size of object described in the medium category) but recorded a dramatic increase between medium and large category. This suggests that the co-speech judges only made a distinction between smaller and larger object sizes, but not between smaller and medium object sizes. This resembles the scenario of a categorical data set sketched in Figure 4.7 b).

There was a significant interaction between category of object size described and continuum type, $F(2, 100) = 19.62$, $p < .001$, $\eta_p^2 = 0.282$, $\beta =1$. This suggests that the mean size of object described differed across the size categories on both continua. Performance on each continuum separately is plotted in Figure 4.9. This is in line with the regression analysis reported above as with the increasing object size described, the object size chosen also increased. The three-way interaction between language condition, continuum and category was not significant, $F(4, 100) = 1.90$, $p > .05$, $\eta_p^2 = 0.071$, $\beta = 0.557$, therefore, no post hoc tests were carried out.

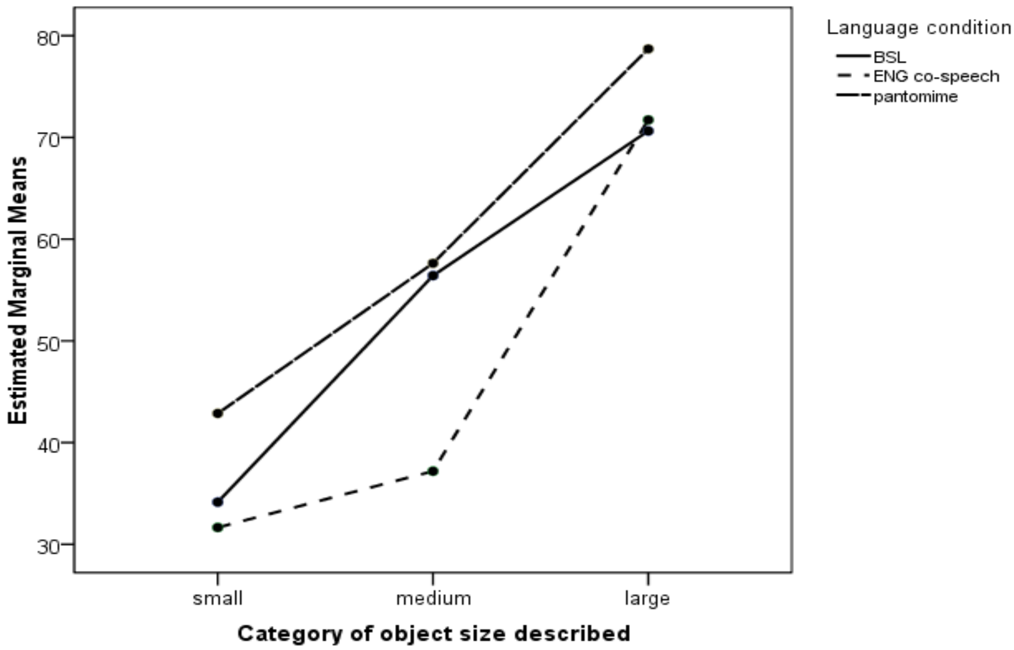
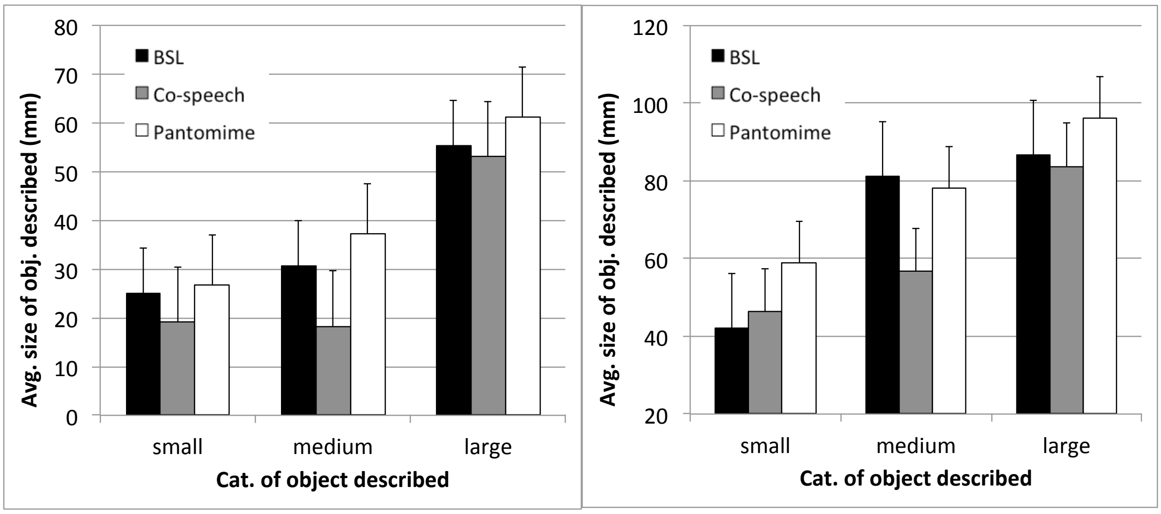


Figure 4.8. Interactions between categories of object size described by the producers and mean object size chosen by the judges in three language conditions, BSL, co-speech gesture and pantomime for rectangular and cylindrical object types.

Performances by group on each continuum were examined separately to examine the encoding / decoding patterns specific to each object type. On the rectangular continuum, plotted in Figure 4.9 a), there was main effect of size, $F(2, 106) = 60.20$, $p < .001$, $\eta_p^2 = 0.532$, $\beta = 1$. No effect of language condition was observed, $F(1, 53) = 2.37$, n.s. There was no interaction between language condition and category of size, $F(4,106) = 0.72$, n.s. suggesting a similar performance in all three language conditions. The difference between small and large category of size was significant when all groups are considered, $F(1, 53) = 83.91$, $p < .001$ and participants also differed on the medium and large category, $F(1, 53) = 100.09$, $p < .001$.

On the cylindrical continuum, plotted in Figure 4.9 b), there was main effect of size, $F(2, 112) = 122.70$, $p < .001$, $\eta_p^2 = 0.678$, $\beta = 1$. There was a main effect of group, $F(2, 56) = 5.77$, $p < .05$, $\eta_p^2 = 0.171$, $\beta = 0.85$. Participants differed in average object size chosen in small category, $F(2, 60) = 5.47$, $p < .001$, in medium category, $F(2, 61) = 6.68$, $p < .001$ and in large category of size, $F(2, 31) = 4.20$, $p < .001$. There was a significant interaction between language condition and category of size, $F(4, 112) = 5.88$, $p < .001$, $\eta_p^2 = 0.174$, $\beta = 0.98$. Contrasts showed a significant interaction when average size of object chosen was compared between medium and large categories, $F(2, 56) = 4.95$, $p < .05$, $\eta_p^2 = 0.14$, , $\beta = 0.75$.

Pairwise comparisons of mean size chosen across categories reported in Table 4.4 show that in BSL and co-speech gesture, handshapes were not completely interpreted as gradient variations. The mean size chosen for handshapes describing small rectangular objects did not differ from average size chosen for medium objects in the BSL and co-speech conditions. Similarly, for the cylindrical objects, the average size chosen for medium category was not significantly different from large category in the BSL condition and the difference between small and medium in the co-speech gesture was not significant. In the pantomime condition however, the effect of size was more apparent as the size of described objects yielded significantly different means of object size chosen for both handshape types. The results reported above are discussed further in section 4.6.



a) b)

Figure 4.9. Comparisons of average size chosen on the *y* axis and size category of *a)* flattish rectangular and b) cylindrical object size described on the *x* axis

Table 4.4.

Pairwise comparisons between small, medium and large categories of size of described objects within language conditions

	Cylindrical obj.		Rectangular obj.	
	S vs M	M vs L	S vs M	M vs L
BSL	*t*(20) = -11.56, *p* <.001*	*t*(19) = -1.98, *p* =.06	*t*(20) = -0.78, *p* =.45	*t*(20) = -4.61, *p* <.001*
Co-speech	*t*(17) = -2.56, *p* =.02	*t*(19) = -3.72, *p* =.001*	*t*(15) = 0.13, *p* >.90	*t*(15) = -6.94, *p* <.001*
Pantomime	*t*(20) = -4.83, *p* <.001*	*t*(20) = -4.70, *p* <.001*	*t*(20) = -2.84, *p* =.01*	*t*(20) = -6.54, *p* <.001*

**Reported as significant at 99% level*

4.5.3 Confidence rating in handshape-object matching task

For each trial, participants rated on a scale 1 to 3 indicating how confident they were in matching handshapes with objects (1 - very confident, 2 – more or less confident, 3 – not confident, just guessing). There were 36 test trials in total per participant. The aim was to find out whether participants with sign language experience displayed higher confidence in judging the handling productions in comparison with participants with no experience in sign language.

Repeated measures 3x2x3 ANOVA with two independent factors, stimulus type (BSL vs. co-speech gesture vs. pantomime) and object shape (rectangular vs. cylindrical) and one between-subjects factor, size category with three levels (small, medium and large) examined the effect of language experience, object shape and size category on the judges' confidence rating for their handshape-object match. There was a main effect of group on confidence ratings, $F(2, 12) = 49.14$, $p < .001$, $\eta_p^2 = 0.891$, $\beta = 1$. There were no other main effects; the effect of handshape type was not significant; $F(1, 12) = 2.31$, $p > .05$ and there was no effect of category of object size described on confidence rating, $F (1, 12) = 0.43$, $p > .05$. There were no significant interactions.

Planned comparisons revealed that deaf BSL judges were significantly more confident in matching handshapes with objects than hearing English speakers in both gesture conditions; $t(15) = 42.65$; $p < .001$. The difference in confidence rating between the two hearing groups, co-speech and pantomime was not significant, $p > .05$. Table 4.4 summarises the mean confidence rating and standard deviation in the decoding task. Thus, deaf BSL judges were more confident than both groups of hearing non-signing judges in matching objects to handshapes that described how they are handled. The average confidence ratings and significant interactions (*) are plotted in Figure 4.10.

Table 4.5.

Average group confidence rating and standard deviations across categories of size for both object types

	Small	SD	Medium	SD	Large	SD
BSL	1.41	.08	1.52	.20	1.52	.10
Co-speech	1.94	.14	1.88	.17	1.93	.14
Pantomime	2.02	.21	2.13	.18	2.02	.33

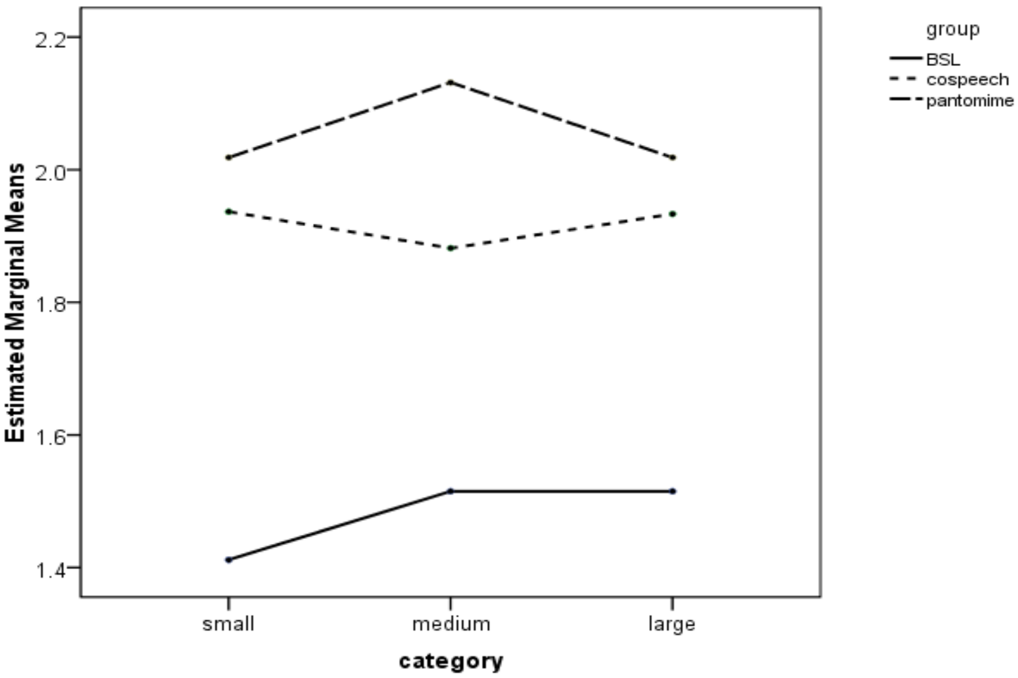


Figure 4.10. Average group confidence rating plotted on the *y*-axis and category of size plotted on the *x*-axis in handshape-object matching task

4.5.4 A description of handling handshapes in BSL and gesture

Handling constructions produced by all groups appeared similar; all three groups appeared to use similar movements and locations in handling constructions. An example in Figure 4.11 shows how constructions depicting opening a jar produced by a deaf BSL signer (a) and a hearing speaker (b) during pantomime displayed striking resemblance in the use of arm and body movements. Both participants produced similar short circular movements twisting the forearm to show how the referent unscrewed the lid.

a) b)

Figure 4.11. Handling constructions depicting opening a jar produced by a) a deaf BSL signer during a signed narrative; b) a hearing gesturer in pantomime

However, HHs produced with speech were less crisp, less defined and more varied in type than the handshapes produced by deaf BSL signers. Co-speech gesture handshapes resembled a generic 'grab' handshape (/fist/ or /C/ with spread fingers) and were also less defined than handshapes produced by hearing speakers without speech. Figure 4.12 shows HH choices by participants from each group in response to a) a book 5mm thick, b) a book 30mm thick and c) a book 85mm thick. Deaf BSL signers were more systematic in their handshape selection as they articulated variants of /C/ with fingers angled and extended, whereas the gesturers selected different handshapes for the same class of objects (books), such as /intl-T / or /claw/. The use of /intl-T/ was particularly prevalent in both gesture groups. Deaf signers were selecting HHs more systematically than the hearing gesturers in both co-speech and pantomime conditions.

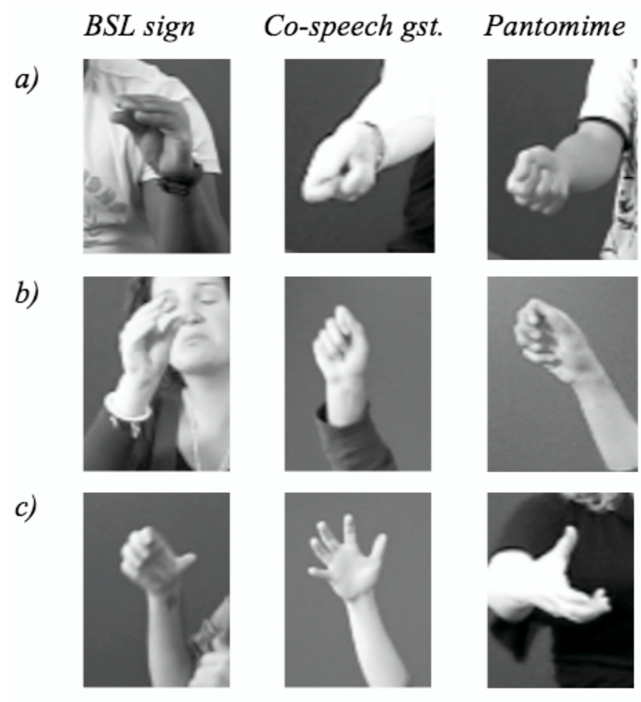


Figure 4.12. Comparison of HHs elicited for the same object types; a) HH elicited in response to a book 5mm thick, b) a book 30mm thick, and c) a book 85mm thick from a deaf signer, hearing co-speech gesturer and hearing pantomime

All participants produced 'power' handshapes for both object types due to the nature of handling actions depicted in the cartoon (taking objects off the shelves or placing them in a trolley does not require manipulative precision). 'Power' handshapes are used to manipulate objects with greater power exerted, while 'precision' handshapes are typically used for objects that require delicate handling (Napier, 1956). Thus, all deaf and hearing participants produced handshapes with the same selected primary fingers but of varying joint features complexity as shown in Figure 4.13.

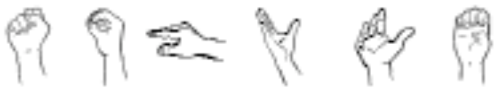


Figure 4.13. Examples of four-finger handshapes

Handshapes depicting handling of flattish rectangular entities contained four primary selected fingers, with the thumb opposed for all gradients and for both object types. The selected fingers specified for the feature [all] and the thumb for the [opposed] feature in the model. For the flattish rectangular objects, the signers tended to produce a /C/ type handshape with palmar joints angled rather than curved. Similarly, the hearing non-signers' handshapes tended to be more angled than curved for the flattish objects, although based on observations, the non-signers' handshapes were much more varied in handshape type and finger selection, see Figure 4.12.

In terms of object size and aperture mapping, the contrast between a thin rectangular object (3mm) and thicker objects (5 mm and wider) was marked by the [closed] and [open] feature. For all other objects on the scale, fingers were no longer touching. Items thicker than 3mm elicited handshapes with a small gap (< 1 inch) where the thumb and fingers are straight, unspread, angled and the gap is narrow (less than 1 inch). For objects wider than 40mm, deaf signers were producing HHs with a gap wider than 1 inch, fingers slightly angled and unspread.

Using existing notation systems, such as the Eccarius and Brentari code (2008b), which was introduced in section 2.1.2, to represent finger distance to object size mapping in depicting handshapes may be problematic. Their system is based on two handshape features: finger combinations (selected fingers and thumb opposition) and joint configurations (flexed, stacked, spread, etc.). One example is the handshape , transcribed as *BT< (* where *B* is the symbol for four selected finger handshape, *T* symbolises that the thumb is opposed, and < is the symbol for primary fingers [flexed]). The  handshape differs from  in the joint feature only; the former can be transcribed as *BTc* where *c* is the symbol is for primary fingers [bent] with the thumb opposed. More examples of HHs from the narratives, their codes and categorisations are provided in Appendix G (Figures 3 and 4). The handshape feature specification by Eccarius and Brentari (2008b) is also provided in Appendix G (Table 2).

The data in this thesis provide the possibility of mid category handshapes, which warrants further research. However, there is currently no symbol can be used for angled /C/ handshapes or for curved /C/ handshapes with a gap smaller than one inch to account for interim categories. To transcribe HHs for flattish rectangular objects, there are currently BT> (joints angled, four fingers selected and touching), BT< (joints angled, four fingers selected and apart). New symbols could be introduced, e.g. the symbol '=' could be used for HHs with angled joints and an intermediate (approx. 1 inch) gap. The lower case *c* symbol can be used for curved handshapes with a gap smaller than one inch, e.g. BTc, and for handshapes with a 1-3 inch gap, the *C* symbol can be used, e.g. BTC. For handshapes with aperture wider than 3 inches, the existing symbol *(* can be used.

While the notation by Eccarius and Brentari is useful in distinguishing between different handshape features (e.g. finger stacking, spreading), it does not effectively account for small gradation changes in aperture. It currently limits the number of possible HH categories to describe handling of cylindrical and rectangular objects to only two each. This research has pointed to a strong likelihood of a third, possibly fourth category, so this coding system may not be sufficient in accounting for such instances. The HHs elicited in the present study during the stimuli production phase are listed and annotated using Eccarius and Brentari (2008b) transcriptions in Appendix D (Table 2) for reference.

An alternative system that does take aperture systematically into account is the Goldin-Meadow and colleagues (Goldin-Meadow, 1998, 2007) categorisation system. Based on a small sample of HHs produced by homesigners, Goldin-Meadow and colleagues identified various size categories based on the systematic mapping between object sizes and the finger distance. The handshape categories are described in Table 2.1, section 2.4.2. Refer to Appendix G (Figures 3 and 4) for elicited exemplars organised into the categories of size for HHs by Goldin-Meadow and colleagues.

There is currently no evidence to suggest if the finger-thumb distance is phonologically specified. Evidence based on a small set of two types of HHs examined in this study suggests that aperture is mapped more or less systematically onto object sizes and is a meaningful feature, but it is unclear if this is a property unique to the BSL system. As handling constructions involve the use of several features/properties, e.g. internal movements / finger curvedness and can encode various elements of meaning including manner of handling, they deserve closer attention in future research before the morpho-phonology of handling constructions can be fully explained.

4.6 Discussion

Deaf and hearing judges, irrespective of sign language experience, reliably associated handshapes characteristic of smaller apertures to objects of smaller sizes and larger apertures to larger objects and never the other way round. The finding that there was a strong linear relationship between object sizes described and object sizes chosen across all groups is not surprising as perceivers visually associate smaller objects with smaller thumb-finger distance and larger objects with larger distance. However, closer examination revealed that the deaf and hearing judges under-estimated object sizes when viewing the HHs. Despite the linear relationship, the linear model explained only a small part of the total variance, especially for the flattish rectangular continuum. This suggests that although generally perceptive to the gradient changes in handshape form, the deaf and hearing judges were unable to accurately determine the object size seen and described based on the producers' handshapes.

The groups were then compared on average size of object matched to the HHs produced to find out if categories of object sizes described affected the average size of object chosen by the judges. If the category of size of described object is a factor in the average size of object chosen, there would be gradient encoding and decoding of size. If, however, there is no effect of size, this could be because the object sizes are encoded and decoded categorically.

Overall, all deaf and hearing participants differed in terms of the average size of objects they chose for the HHs seen in the videos for both object types as they recorded different average ratings for each category of size. However, it was only the two hearing groups in co-speech and pantomime conditions that differed statistically. The BSL group did not differ from either hearing group, suggesting that their average ratings of size were midway between the other two groups. When both continua were considered, the most pronounced differences between average ratings occurred in the medium category causing interactions which are discussed below.

Results suggest that the judges viewing HHs produced without speech (pantomime condition) interpreted the handling gestures as gradient interpretations of object sizes because the average size of object chosen increased in proportion to the size of object described. These judges differed significantly from judges of co-speech gesture handshapes who exhibited binary category bias – their average size ratings were not significantly different between small and medium categories. In other words, they associated HHs describing objects in the medium and small category with similar sizes on average. This is illustrated in Figures 4.9 where the dotted line corresponds with the co-speech condition group. This rather discrete encoding / decoding is also apparent when handshapes describing handling of flattish rectangular objects are considered; see Figure 4.9a where the average size rating for objects in the small and medium category were similar on average. Figure 3 in Appendix G shows the handshape exemplars produced by the English speakers. It can be seen that the co-speech handshapes describing handling objects that were around 40mm wide contained either a very small or no gap between the thumb and fingers. This, in turn, prevented the judges from accurately mapping the handshapes to the size of object they described. Thus when describing object handling in English narrative, speakers' HHs categorically differentiate between smaller and larger graspable objects (but not between small and medium sizes) and are decoded as such by hearing viewers.

Similarly, the effect of size of category disappeared in the BSL group for cylindrical objects where the differences in average size of objects chosen for medium and large objects described did not reach significance. Participants in the BSL condition did not make a categorical distinction between medium and large object sizes. This prevented the deaf judges from accurately matching the HHs with the original size of cylindrical object the producers described. Figure 4 in Appendix G shows that HHs produced by deaf BSL signers for medium and large categories of cylindrical object were characteristic of apertures ranging from one inch to more than three inches but these handshape variations were not decoded gradiently by the deaf judges. This finding that there were correspondences between smaller objects and smaller apertures and larger objects with larger apertures also reduces the possibility that size of objects was decoded (and encoded) completely randomly and non-systematically by the hearing non-signers.

However, these data also show that gradient expression is common in some BSL handling constructions. Specifically, in handling descriptions of flattish rectangular objects, deaf BSL judges appeared to interpret the handling constructions in a gradient manner. One plausible explanation is that the linear trend was due to the existence of three or more categories; that is, deaf BSL signers were making systematic distinctions between several categories of size of graspable objects but such discontinuities were not demonstrated in this experiment. This is conceivable given that a) Baker et al. (2005) found evidence of a third phoneme category on the [5]-[S] handshape continuum and b) deaf BSL signers maintained high discrimination accuracy across the handshape continua in the discrimination task reported in the previous chapter. Testing a larger number of object descriptions could provide more evidence for this. A second explanation is that BSL signers employed an enactment / CA strategy (Quinto-Pozos, 2007; Quinto-Pozos & Mehta, 2010) in which they introduced finer-grained distinctions in depictions of object handling. In fact, this strategy is also available to speakers though it seems that hearing speakers were not making gradient distinctions in co-speech gestures on this occasion.

So, if the descriptions of object handling were indeed gradient, could one observe a more gradient encoding in BSL and co-speech gesture? This question has been probed by Emmorey and Herzig (2003) who, in an additional experiment, asked one native ASL signer to articulate gradient descriptions of medallion sizes and showed these handshapes to another group of deaf ASL signers and hearing non-signers (they did not include a co-speech gesture group in their study). The deaf ASL judges were sensitive to the gradation changes and displayed gradient decoding, while the hearing judges randomly assigned the handshapes to the medallion sizes. The authors attributed this to the deaf signers' knowledge of handshape categories (in SASS constructions) and what aspects of the handshape can be gradiently manipulated to depict object size. Thus, it could be argued that the BSL signers in the present study might have been aware that the flattish /O/ is lexically specified to mean "very thin" rectangular object, or that the flattish /C/ is specified to mean "relatively thick" rectangular object and made their object choices accordingly. The hearing non-signers could have interpreted the handshapes as merely indicating the shape of the object and arbitrarily selected from a range of smaller and a range of larger object sizes to match those descriptions. Thus although the deaf BSL and hearing co-speech groups could have perceived the small changes in aperture, these changes were not completely discounted when the handshapes were presented randomly as the overall linear trend indicates. Thus, linguistic knowledge is not necessary to interpret iconic mappings between form and meaning in DCs because iconicity is available to perceivers regardless of their linguistic knowledge.

The above raises a question of the extent to which the decoding patterns give clues to the encoding of size in handling constructions. I thus allow for the possibility that object sizes were described using analogic HHs, especially for the flattish rectangular objects (also, in the CP study, the categorisation was weaker for the /flat-O/-/C/ continuum than for /S/-/C/). A possible explanation is that size descriptions using SASS and HHs are expressed differently; although HHs and SASS handshapes can both be used to depict the size and shape of objects (either directly as in SASS, or indirectly as in the case of handling), the SASS constructions typically refer to two-dimensional objects whereas handling depict 3D objects. Further, in ASL SASS constructions, categorical encoding of medallion sizes may have been determined by the change in finger selection. This was not observed in our exemplars, which only varied in aperture (see also section 2.4.1). To conclude, although HHs may have been used systematically to refer to the size of handled object in BSL and English, the lack of linguistic categorisation calls into question whether the findings based on SASS handshapes from Emmorey & Herzig (2003) can be extended to HHs. As they did not assess how hearing non-signers would interpret the depicting productions, further comparisons with the current study are problematic.

One aspect where the effects of BSL experience were observed was in the judges' confidence ratings for object-to-handshape matching. Category of size did not make a difference to confidence ratings but the language condition did. The BSL group were significantly more confident in their choices overall than the two hearing groups. This could be attributed to a visual processing experience advantage for experienced sign language users. This is in line with previous research on confidence rating in relation to the length of exposure to faces showed that a longer exposure to stimuli increases confidence in judgment of those stimuli (Memon, Hope, & Bull, 2003).

Only a handful of studies have examined categorical encoding of object sizes in DCs in sign languages and to our knowledge, studies investigating this phenomenon in hearing speakers' gestures have also been limited to encoding of actions (movements) or locations in co-speech gestures and not handshapes or size encoding specifically. So, how do these results fit with the small number of studies on categorical encoding of object sizes? The analogue depiction of size of manipulated objects without spoken language input (pantomime) was expected and is consistent with Emmorey and Herzig (2003) who found that hearing non-signers who were not using speech during the descriptions of medallion sizes were producing gradient descriptions of the medallions. It appears that when language is involved in the task, more discrete distinctions are introduced in descriptions of object handling and these distinctions are, in turn, interpreted as analogue variations by hearing speakers.

Interestingly, when the handling gestures were articulated with English narrative and shown to the hearing judges, the judges did not interpret the handshapes as gradient variations of size, which suggests that hearing speakers introduce categorical distinctions when linguistic processes are involved. When speech was suppressed and the use of gesture became more strategic and improvised in pantomime, hearing speakers introduced more finely-grained distinctions of size in their descriptions and used handshapes that mapped the object size on the handshape form analogically. In the absence of linguistic output, the speaker must use all but conventional means to ensure sufficient information is conveyed. The pantomime handshapes appeared to be more true to an individual way of handling of described objects. This is in line with Brentari et al. (2012) who found that the hearing gesturers describing objects and their handling without speech remained faithful to the handling they witnessed in the videos while sign language HHs obeyed the handshape inventories of a sign language.

During an automatic (language) task, gradient information about object sizes in handling is not articulated gradiently in gestures with speech, except perhaps when used for emphasis or demonstration (as explained in section 1.3). Discrete encoding of object sizes may be a universal tendency that is not unique to linguistic encoding and manifests itself when other cognitive processes including language are in play. McNeill (1985) suggests that co-speech gestures, like conventional linguistic symbols, share commonalities among speakers. He argues that speakers produce individual manual symbols, e.g. a gesture for referring to upward movement, which have semantic parallels with the concurrent speech. Thus it is possible that speakers also use conventional symbols to convey the idea of a graspable object size in an iconic, rather than arbitrary way. The extent of such conventionalisation across large groups of hearing English speakers remains to be determined. It can be concluded that general perceptual and cognitive factors contribute to conventionalisation rather than linguistic.

It is important to note that Emmorey and Herzig's (2003) study on encoding and decoding DCs in signers did not test for the possibility of discrete encoding in gestures with speech, which makes comparisons with the current study difficult.

Further, they argued that the differences in size encoding between deaf ASL signers and hearing non-signers are due to discrete SASS morphemes in ASL. The present results however suggest that despite discontinuities in encoding, the handshapes need not be of linguistic character. Although the deaf BSL judges appeared to encode and subsequently decode the gradient size of the cylindrical objects categorically, it is not clear from this data whether such distinctions are morphologically specified in BSL. Thus claims about morphemic status of SASS handshapes in ASL depicting signs cannot be easily extended to HHs in BSL depicting signs.

The use of discrete handshapes to express handling of graspable objects of various sizes in handling constructions has also been observed in a small sample of deaf children using a homesign system (Goldin-Meadow et al., 1995). Such categorical encoding was not present in the hearing mothers' gestures. Goldin-Meadow et al. (1995) used this evidence to argue that children develop morphology from gestures despite the lack of conventional linguistic input available to them and that this ability is fundamental to language. In the light of the present findings, it is possible that Goldin-Meadow et al. described a set of discrete HHs that are somewhat conventionalised rather than fully-fledged morphemes such as those in lexical signs in sign languages. Goldin-Meadow et al. (1995) argued that the hearing mothers did not use categorical handshapes with their deaf children because their gestures were strategic in nature as they were trying to communicate with their deaf children but did not know a sign language. Thus it appears that the mothers in the Goldin-Meadow study and the pantomime group in the current study both relied on the visual means to communicate object properties, resulting in analogue, one-to-one form-meaning mapping and a highly strategic use of HHs.

It could be argued that any discontinuities in handshape encoding or decoding in the current study might have been due to conventionalised depicting handshapes that form part of the general communicative repertoire for signers and non-signers. In the presence of linguistic labels, visible gestures may assume a complementary role to language or reflect prototypical categories or affordances associated with the objects and events described. Visual examination of handling constructions produced by all groups appear to be formationally similar, at least in terms of movements and locations. This is consistent with Schembri et al. (2005) who found similarities in locations and movements of entity constructions produced by signers and non-signers. Despite these apparent similarities, deaf BSL signers used handshape types more consistently for the same object classes (books or jars) than hearing gesturers (Appendix G, Figures 3 and 4).

Some qualitative differences were apparent between BSL handshapes and the gesture handshapes. For example, all BSL HHs contained the same number of selected fingers and were all variations of either flattish /C/ handshapes with angled fingers unspread or variations of curved /C/ hanshapes, whereas the handshape choices in terms of selected fingers varied in the gesture groups. The increased use of the /intl-T/ handshape in both gesture groups is particularly interesting; both groups assigned the /intl-T/ handshape to items of smaller as well as medium sizes (Appendix G, Figures 3 and 4, and also Figure 4.12). BSL signers did not use this handshape at all for either object type in the current study. Although a larger sample would needed to examine the typical usage of this HH in BSL in detail, descriptions such as Brennan (1992) suggest that /intl-T/ is used to describe handling of small flattish objects (credit card, bank notes), large flattish objects (newspapers, certificates) and also long stick-like objects (tennis racket, pan handles). Brennan notes that it is not directly linked to a particular object size or shape but to how the hand shapes when grasping (part of) the objects. Thus it could be argued that the use of /intl-T/ is emblematic. Emblems are socially learnt and are highly conventionalised (Efron, 1968; Kendon, 1980). The occurrence of /intl-T/ in the co-speech gesture data suggests that this handshape is somewhat conventionalised and emblematic across individual gesturers. This handshape could also be polysemous when accompanying speech as it can refer to handling of different object types.

4.7 Conclusions

This chapter has provided novel experimental evidence based on an assessment of categorical encoding of object size via decoding in HHs in BSL, co-speech gesture and pantomime. Using a method pioneered by Emmorey and Herzig (2003), this study has revealed interesting similarities in object size encoding between BSL and hearing co-speech gesturers. Generally, all perceivers were sensitive to gradient increase in size of described objects, which highlighted an important role of gradience in depiction of handling. However, the size of graspable objects was described by means of discrete rather than analogue handshapes in spontaneous natural signing and speaking. In contrast, hearing speakers switched to more gradient encoding when speech was suppressed. To conclude, HHs appear to be used conventionally both in BSL DCs and in co-speech gesture but speakers or signers might introduce more gradient demonstration into their descriptions for the purpose of specificity or emphasis, for example. The extent to which the visual modality impacts on sign language category representation and organisation is still unclear but it appears that in the visual modality, gradient representations are harder to discount than variability in the auditory signal. Such evidence bears important implications for theories of visual cognition and language processing.

CHAPTER 5 General discussion

5.1 Summary of experimental findings

The two experimental studies reported in this thesis investigated whether sign language experience influences the perception and comprehension of handshapes depicting handling and manipulation of objects. In these studies it was questioned whether handling handshapes (HHs) are discrete and conventionalised in BSL, co-speech gestures and pantomime. Let us first briefly summarise the main outcomes and consider the two studies together before discussing the results in light of existing theoretical and empirical accounts from sections 5.2 onwards.

The first study suggested that visual rather than linguistic knowledge guide categorisation. It was argued that the lack of processing advantage in deaf signers might be due to the rather different nature and status of depicting handshapes in comparison with lexical signs. The gradation changes in handling handshape aperture were salient for the deaf and hearing perceivers, unlike in handshapes in lexical signs, thus suggesting that gradience is an essential aspect of HHs. It appears that perceivers regardless of their language possess a mechanism for sorting relevant visual information (which in the case of co-speech gesture occurs simultaneously with speech). The finding that both deaf and hearing perceivers categorise HHs in ways not significantly different from each other suggests that they might be conventionalised through regular manual (communicative and/or functional) behaviour. It is possible that the degree of conventionalisation of handling constructions varies between BSL and co-speech gestures in ways not revealed in the CP study in this thesis and more evidence needs to be obtained to find out if HHs in DCs are indeed governed by linguistic principles.

Therefore, the second experiment examined if meaningful information about graspable object sizes is manually encoded and decoded in conventional ways in natural signed and spoken discourse in addition to pantomime, where the participants rely on mostly visual-perceptual strategies. Although generally attentive to the linear increase in gradient object sizes, deaf and hearing participants in natural BSL / English discourse referred to graspable object sizes in a conventional manner, because the deaf and hearing judges were less able to detect the exact size of described object when the handling constructions were articulated in BSL and English discourse, in contrast with pantomime. When speech was suppressed, hearing speakers used more gradient and analogic mapping between object sizes described and handshapes perceived. This suggests that HHs might be used in a conventional manner when speech and gesture are taken together as a package rather than when gesture is produced without speech, highlighting the multi-modal character of face-to-face communication.

The two studies reported in this thesis bridge the gap between handshape representation and perception / comprehension and together have provided novel evidence about conventional and less conventional use of handling constructions in BSL and gesture. More specifically, they bring together evidence from perception of well-controlled synthetic handshape exemplars and comprehension of naturalistic handshape exemplars produced in discourse. Firstly, the discontinuities in perception of handling handshape forms and then again in the interpretation of handshape meaning displayed by both deaf and hearing participants point to a lack linguistic categorisation and suggest that knowledge of a sign language is not necessary for HHs to be parsed discretely. But the studies also showed that gradience is pertinent to handling constructions, especially in more strategic face-to-face interaction (e.g. providing emphasis or showing). Both experiments suggested that such complex structures appear to be managed by general perceptual or cognitive rather than purely linguistic processes.

Considering Studies 1 and 2 together, they have not supported previous claims that HHs are overt morphemes (see discussion in section 2.3.1) because their linguistic status could not be ascertained in the study. Instead, evidence from both experiments suggests that HHs are categorised due to common cognitive abilities in signers and non-signers when using language. The cognitive processes might relate to imagery of handling and object manipulation generated during processing of HHs, although what such specific underlying cognitive processes involved in categorisation of HHs are remains unclear. For example, it is not clear whether participants categorised handshape form on the basis of magnitude associated with the perceived finger distance, or whether handshapes were understood as holistic symbols or units of meaning. Taken together, the outcome of Study 1 and 2 converge to provide support for the cognitive-functional approach to language.

The experiments together overcome some of the limitations handling handshapes pose for a linguistic analysis due to their strong true-to-life mapping between the act of object handling and the way the articulators are shaped to depict the act. The apparent similarity between handling handshapes in BSL and handling handshapes in gesture means that claims based on observational evidence may be inaccurate. The two experiments together have thus provided valuable insights into the perceptual and conceptual organisation of handling handshapes drawing on data from perception of handshape form and comprehension of handshape meaning in handling constructions. These two psycholinguistic methods provide important insights into the workings of the mind and expose handling constructions in ways they have not been examined before.

So how do these findings advance the knowledge of processing of HHs? What do the findings reveal about the role of sign language experience in HH processing? What do the discrete perceptual and encoding patterns tell us about the nature and representation of DCs and their relationship to gesture? Further, HHs in DCs do not appear to be readily decomposable, at least not to the same extent as in lexical signs. What are the implications of this for theories of DCs in sign languages and for theories of language in general? In the following sections such implications are considered with regards to existing theoretical arguments concerning the nature of depicting handshapes and their processing.

5.2 Does sign language experience influence perception of handling handshapes?

It has been demonstrated in the literature that although it is not linguistic processing alone that gives rise to CP, effects of language experience on categorisation and discrimination patterns have been found for some auditory and visual stimulus (Baker et al., 2005; Best et al., 2010; Emmorey et al., 2003; Jusczyk et al., 1977; Liberman et al., 1957; Roberson & Davidoff, 2000; Whalen et al., 1997). In sign language studies, native-like experience with sign language (as opposed to spoken language) was found to mediate the CP effect but only for handshapes in phonemic opposition (Baker et al., 2005; Best et al., 2010; Emmorey et al., 2003). Best et al. (2010) used the CP method to show that the degree of sensitivity to categories also varies with the length of exposure to sign language (age of acquisition, AoA). Despite the failure to obtain a CP effect, Best et al. illustrated that AoA of ASL influences perception of minimal contrasts in pseudosigns, as deaf native signers were the least attuned to within category differences than late learners of ASL. Language experience (and probably the length of exposure to it) plays an important role in the discrimination of handshapes that occur in phonemic opposition (Baker et al., 2005; Emmorey et al., 2003), although a true minimal contrast in sign language is rare (see also Brentari and Eccarius, 2009). Thus language experience constitutes the routine mapping between form and meaning. It is important to note that such distinctions need not be linguistic in nature as signers could simply have categories for the visual perceptual input of signs whereas non-signers do not (Baker et al., 2005).

However, an important finding in sign language studies was that deaf and hearing perceivers employ visual comparison strategies when perceiving handshapes even if standard CP paradigm was employed (Best et al., 2010; Boutora & Karypidis, 2007) (see section 2.5.3). Such findings are in line with the current study, where deaf and hearing perceivers were highly perceptive to the change between the fingers touching (as opposed to when they were slightly spread apart) and displayed good within-category discrimination abilities. Visual strategies were also observed when handshapes were presented within discourse. In Study 2, hearing judges utilised a finer-grained visual feature detection strategy when matching pantomime handshapes with object sizes, likely due to the lack of lexicalised linguistic material.

CP for semantic (meaningful) contrast has been reported in studies of both sign and spoken language, bringing to light important evidence about the importance of visual and cognitive processing in communication. Recall a study by McCullough and Emmorey (2009) who found that facial expressions commonly used by ASL signers were categorically perceived by hearing speakers with no sign language experience (see section 2.5.4). Perceivers without sign language experience in the current experiment displayed similar categorisation patterns to the non-signers in the McCullough and Emmorey (2009) study. HHs might thus be categorised on the basis of other cognitive categories that may have representations outside of the linguistic system. This suggests the possibility that HHs could have been perceived as meaningful gestures which have become more conventionalised through regular use. Linguistic experience is thus not necessary in order to perceive such stimuli categorically.

So, what does CP add to our understanding of HH representations and linguistic processing in general? CP is a function affected by task demands as much previous literature suggests. Recall studies on CP for sign language elements reviewed in section 2.5.3, which yielded varying patterns and strength of a CP effect. For example, the linguistic context influences not only perceptual but also comprehension patterns (as explained in 3.1.1). The context influences perception of vowels (Repp, Healy, & Crowder, 1979) although CP effects for vowels have been generally weaker than for obstruent consonants (Fujisaki & Kawashima, 1971; Repp, 1984). This may be due to more robust variation in the articulatory properties of vowels. Healy and Repp (1982) also emphasise the importance of context and suggest that consonants varying along a continuum are perceived categorically only when presented in syllables with certain vowels.

Previous CP studies with sign languages presented handshapes typically in the context of other more gradient elements (movements or locations) which has resulted in diverse CP patterns. Further, speech phonemes are not commonly presented in the context of a whole word (lexical context) which differs from the monosyllabic context of signs and where some handshapes alone can carry meaning unlike speech phonemes (see sections 2.5.2 and 2.5.3 for further discussion). Outcomes from previous studies in speech perception thus may not be directly comparable with studies on sign perception because the semantic context and other cognitive processes could have shaped perceptual categorisation differently.

Further to this, in section 3.6, it was argued that the CP patterns obtained in the current study on BSL can be compared with those observed in vowel perception in spoken languages. Such cross-linguistic and cross-modal comparisons are much needed across CP studies but should be made with caution, as similar patterns do not necessarily imply that HHs have a similar linguistic status to English vowels. Indeed there is debate generally about whether the handshape parameter in sign languages can be compared to the spoken language phoneme, given the simultaneous versus sequential nature of phonological systems in sign versus speech (e.g. Sandler & Lillo-Martin, 2006). Given that outcomes of CP studies in sign and speech have been inconsistent, it might be premature to make assumptions about the linguistic status of HHs. Rather, I use such comparisons to argue that CP is an outcome of modality-free cognitive classification that can be realised for some sign language stimuli, including HHs.

Other techniques, such as phoneme monitoring tasks, have been used to examine the effects of sign language experience on perceivers' ability to identify sign language components. Grosvald, Lachaud and Corina (2012) explained the lack of linguistic effect on handshape markedness as "something other than a purely abstract linguistic formalism" (p. 134). Their findings suggest that handshape markedness is a linguistic manifestation of more general perceptual constraints. The ability to perceive handshape complexity has a perceptual basis. Their findings align with the argument presented in this thesis that the object size to handshape mapping in DCs should not be considered as a purely linguistic property of signs. The perceptual features of the handshape continuum influence discriminability of handshapes regardless of linguistic categorisation: handshape tokens that differed in contact (+contact, –contact) showed high discrimination accuracy similarly to previous studies (Best et al., 2010), but for handshapes varying in the amount of curvature of the fingers the discrimination ability were poorer, as indicated by lower accuracy in discrimination between handshapes with wider aperture.

The ability to categorise visual stimuli also develops with experience of gesture as could be seen in deaf children with limited language input who introduce discrete handshape systems into their homesign communication (Goldin-Meadow et al., 1995). Goldin-Meadow et al. systematically mapped the hand breadth and finger curvature onto the features of referenced objects. For example, /fist/ and /O/ handshapes referred to wider objects, while /C/ and /palm/ were used for the widest objects. All four children used a large /C/ to represent handling an object greater than 2 inches/5 cm in width. The authors concluded that such categories develop over time within the children's inventory of homesigns and that these categories are morphemic. There appear to be some similarities in size encoding between the current study and the Goldin-Meadow et al. studies (1995, 2007) although arguments about the morphemic status are not extended to HHs in this study.

To summarise, linguistic categorisation is not necessary for HHs to be perceived categorically. Instead, categorisation of handshapes appears to be driven by the perceivers' experience with familiar visual stimuli, such as depicting gestures that occur in face-to-face interaction. Furthermore, given that context, stimulus type and perceptual experience influence the degree of CP with HHs, the term 'categorical partition' (Massaro, 1987) might be more appropriate. These findings advance our understanding of processing of HHs and their categorical properties. This is discussed in the following sections and the question of what the categorical partition can reveal about the nature of HHs is explored.

5.3 Cognitive processes in handling handshape categorisation

The studies reported in this thesis have demonstrated that sign language experience is not necessary to categorise HHs that convey meaningful information about graspable object sizes. HH categorisation however does not appear to be merely supported by low-level perception, which is involved in processing of colour, for example. Higher level cognitive processing, such as knowledge of affordances and functional knowledge how objects are manipulated appears to mediate processing of HHs as well. These mechanisms are similar to those involved in perceiving meaningful and familiar stimuli, such as human faces. Furthermore, these mechanisms appear to be independent of linguistic processing as sign language knowledge appeared to have little effect on perception (Study 1) and production/comprehension (Study 2) of HHs. Thus general cognitive processes underpin perception and comprehension of HHs.

This thesis provides insights into whether the processes involved in perception and comprehension of depicting handshape forms are due to visual object or action recognition in general or require specialised linguistic processing, via comparisons between signers and non-signers' perceptual and comprehension patterns. Constructions depicting handling appear to consist of conventional and non-conventional features to convey complex meanings and this holds true for language irrespective of the modality. Conventionality is important because constructions depicting handling of rectangular and cylindrical objects are different from analogue demonstrations of handling actions (mime), as they contain part conventionalised and symbolic handshapes. Such handshapes might become entrenched and decomposable in BSL overtime. HHs represent concepts that correspond with information about graspable object sizes. These forms are only partially conventional because the corresponding form to meaning mapping via aperture permits gradience which was is readily discarded by the perceivers, unlike in discrete parsing. The conventionalisation also does not appear to be exclusive to sign language users.

Both studies taken together provide evidence that HHs are partly conventionalised in DCs. Despite the fact the handshapes produced in speech and sign were perceived and interpreted in a discrete manner, deaf and hearing perceivers regardless of their linguistic experience remained well-attuned to the gradient finger-thumb distance and when linguistic descriptions were not available (i.e. in the pantomime condition), perceivers became highly reliant on gradient meanings. A question that warrants further research is whether and how such partly conventionalised forms are stored and represented in the BSL lexicon (cf. Johnston & Schembri, 1999; Brentari & Padden, 2001).

Together the results suggest that higher-level cognition mediates processing of depicting handshapes. Representations of object grasping and object sizes mediate perception and production. Representations of graspable object sizes or shapes are a part of the functional knowledge that is mutual to deaf signers and hearing speakers. Functional knowledge has been regarded as conceptual in nature and consists of knowledge about the intended or typical use or the purpose of an object (Myung et al., 2006), see section 2.4. Manipulation knowledge of words (e.g. how one plays the piano or types on a typewriter) assists the retrieval and constitutes a part of the lexical-semantic representation of objects. Similarly, certain manipulation features associated with HHs could form a part of the conceptual (semiotic) representations of objects and handshapes used to manipulate them. But if the studies cannot show that these abstractions are linguistic then what is the nature of such abstractions?

Lower-level processing advantage in RTs was not observed in the current studies for deaf BSL signers despite the fact that BSL signers were more accurate than hearing non-signers in discrimination. This outcome is in line with previous studies that found no differences in RTs between deaf and hearing participants on a cognitive tasks involving mental manipulation (Emmorey, Kosslyn, & Bellugi, 1993; Tomlinson-Keasey & Smith-Winberry, 1990). In addition to the similarities in visual acuity and categorisation patterns between signers and non-signers, this suggests that processing of HHs recruits a similar processing system for deaf and hearing perceivers. However, whether this is the visual-motor or visual-conceptual processing stream is unclear. This reasoning is in line with advocates of embodied language as a cross modal phenomenon (Gallese & Lakoff, 2005; Vigliocco, Vinson, Lewis, & Garrett, 2004) who have recognised the link between language and sensory-motor processing. It however contrasts with more traditional theories that have argued that the linguistic system is modular (e.g. (Fodor, 1975; Jackendoff, 2002). The fact that the processing of HHs as meaningful elements appears to be grounded in embodied, sensory-motor experience thus supports theories of language promoting a strong link between language and other cognitive/behavioural processes rather than formalist/nativist theories of language that assume a sharp division between language and other cognitive processes.

5.4 Handling handshapes and graded category organisation

The data from the studies reported in this thesis are important for an understanding of how variability in the linguistic signal is managed during perception and comprehension of signs. These studies lend some support to arguments for graded category architecture. Specifically, the finding that gradient variations in handshape form were not ignored by deaf BSL signers at perceptual and discourse levels is in line with theories of grounded cognition. As previously discussed (e.g. see section 2.1.1), a general cognitive approach assumes that natural categories are graded and the status of category members is inconsistent. The present research provides evidence in favour of arguments for graded organisation of categories.

Handshapes in phonemic opposition yield different perceptual effects than handshapes that are not contrastive (different degrees of contrast were discussed in section 2.1.2). All perceivers possess special perceptual mechanisms for recognising the human hand that allow for categorisation (Emmorey et al., 2003). In handling constructions, perceivers must take into account many aspects of the described event, such as the size and shape of the grasped object, its consistency, weight and the goal to be performed with the object. In comprehension, prototypical representations are activated in order to interpret the depicted event. Because handling constructions, and in fact most DCs, do not have a conventionally associated semantic value (Ferrara, 2012) their meaning is determined upon the context. Handshapes in DCs typically permit a larger number of permissible variants and one-to-one mappings than in lexical signs (Liddell, 2003a). Some variants might be more prototypical than others (see section 2.3). Boyes-Braem (1981) stated that signers tend to use the "best example" of manipulation of the object and that modification of handshape at a conversational level depends on the signer's personal style and adeptness at sign language. So although deaf signers develop a special faculty for perceiving distinctions that are relevant to a sign language, general cognitive and perceptual factors continue to monitor the extent to which a change in form is associated with a change in meaning in less conventional depicting contexts. The processes are similar to non-signers, which may explain the similarities between signers and co-speech gesturers. Thus, as mentioned above, such distinctions need not be linguistic in nature (Baker et al., 2005).

The idea that prototype categories may influence the perception and comprehension of gesture is related to a perceptual view of language comprehension. Previous studies found that people activate perceptual symbols of referents during spoken language comprehension (Barsalou, 1999; Kaschak & Glenberg, 2000; Stanfield & Zwaan, 2001). For example, listeners activate the object's implied orientation (Stanfield & Zwaan 2001) or its shape (Zwaan et al., 2002) even if the perceptual characteristics are not explicitly stated. This raises the issue of the extent to which perceptual symbols influence hand shaping in co-speech gesture. Previously, it has been unclear whether activation of perceptual symbols competes or overlaps with activation of linguistic symbols in signed and spoken communication. The finding that categorical encoding occurred in co-speech gesture and BSL, but not in pantomime, can be taken as evidence for such an overlap. Furthermore, representations containing detailed visual information might be more difficult (Solomon & Barsalou, 2001) and cognitively costly to verify. This could explain why hearing speakers introduced less gradient information about object sizes in English narratives.

In summary, this research has provided support for theories of graded category architecture, suggesting that handling constructions combine conventional and non-conventional elements to convey complex meanings about object sizes and their manipulation. The differences in cognitive mechanisms supporting sign versus speech appear to be modality free. So what does this tell us about the nature of language and gesture in general?

5.5 Conventional handshapes in handling constructions and gesture

Visual imagery is not unique to sign language but can occur in spoken language in co-speech gesture. Here it is argued that the shape and aperture of the hand corresponds with the size of object being handled in a partially conventional manner. Such conventional mapping occurs in spoken and signed discourse in interplay between imagistic and linguistic processes, supporting models of integrated speech and gesture production (Hadar & Butterworth, 1997; Kita & Özyürek, 2003). As Vigliocco et al. (2005, p. 1863) state: "[…] the modality in which languages are expressed modulates the degree of cross-talk between language and imagery, traditionally considered to be separate cognitive modules". Speech and gesture work as an inseparable unit, reflecting different semiotic facets of the underlying cognitive structure (McNeill, (2000). Together, these findings support the idea that language structure is dynamic because the representation of meaning from linguistic input includes flexible perceptual representations rather than just rigid, mechanical combinations of discrete components of meaning (Barsalou, 1999; Glenberg, 1997; Langacker, 1987).

The current studies suggest that there are close similarities between handling constructions produced by deaf signers and iconic character viewpoint gestures (McNeill, 1992) (see section 2.2.5). This argument that has also been put forward by Cormier et al. (2012). The sign language literature suggests that HHs are not expected to differ considerably across sign languages, which could further strengthen the claims in support of gestural nature of handling constructions. In line with Cormier et al. (2012), it is argued that the observed similarities between sign language DCs and depicting gestures call for the need to distinguish between lexicalised handling, e.g. the BSL sign NEWSPAPER from non-lexicalised depiction of handling. Components of generalised non-linguistic gesturing, including representations of handling, can be certainly found in the phonetic inventory of sign languages (Johnston & Schembri, 1999; Liddell & Johnson, 1989). Johnston and Schembri (1999) suggest that fully grammaticalised or lexicalised uses of HHs may exist synchronically alongside other gestural elements within a sign language (e.g. signs depicting handling vs. fixed lexicalised signs with a HH). Although there are lexicalised signs that clearly include HHs – e.g. the BSL sign COOK – there does not appear to be phonemic contrast in any pair or set of lexical signs that include HHs, i.e. where handling is the source of iconicity in each sign. It may be that iconicity blocks the possibility for such phonemic contrast with HHs. Therefore, it is essential to distinguish between instances of lexical signs of handling and non-lexicalised constructions depicting handling. Furthermore, based on the discrete patterning of HHs, the HHs have become abstracted from handling gestures through repetition and ritualised processes. It remains unclear to what degree HHs are conventionalised in sign languages, or to what extent are conventional HHs used in depictive / descriptive contexts. Cormier et al. (2012) suggest that a given token of handling within a sign language may be more or less lexicalised and that studies into the conventional nature of handling constructions must take this into account.

Similarly others have argued that the problem with adopting the 'degree of conventionalisation' is that distinctions based on conventionality are not categorical – they are matters of degree (e.g., Ferrara, 2012). In the Auslan Corpus, Ferrara observed that many depicting signs did not seem to be conventionalised and were not fully lexical and used within the deaf community. Zeshan (2003, p. 134) also suggests that in IPSL, handling constructions are rather improvised. As a handling gesture becomes conventionalised through repeated use, it can achieve a discrete unit status. Conventionalisation is however not a straightforward and one-directional process as gestures can become only partly lexicalised. Ferrara provides an example of the Auslan lexical sign TAP where the enactment of a person turning a small object with one hand conventionalises into a lexical sign over time. This could be said about the BSL sign JAR which originates from the enactment of a person holding a cylindrical object and performing a circular motion as in turning the lid shown in Figure 4.11. However, in the small collection of handling constructions in Study 2, such constructions appeared similar to those produced by non-signers, as they tended to contain varying degrees of enactment. Handling constructions can be produced as more conventional in one context and as non-conventional in another. This ability of signers to produce fully conventional signs together with novel depiction highlights the fluid relationship between language and gesture (Ferrara, 2012).

The role of embodiment and other articulators commonly involved in handling, such as the arms and torso, has also received limited attention in formal descriptions of handling. Similar to character viewpoint gestures is the use of CA by deaf signers in which the signer uses (parts of) their hands, arms or torso to depict actions of characters (see section 2.2.6). Despite visual similarities, some consider CA to be completely different from gesture. This is reflected in terminology such as 'body classifiers' (1982, 1986), although many do recognise gestural elements within CA (Liddell & Metzger, 1998; Quinto-Pozos, 2007; Quinto-Pozos & Mehta, 2010). The findings in the current studies suggest that some elements of CA might be more conventionalised than others.

5.6 Handling constructions as grounded blends

In section 2.3.2, I laid out an argument that depicting constructions can be conceived of as grounded blends, developed by Liddell (1998) based on Fauconnier and Turner (1996). According to Liddell (1998), the construction of grounded blends is independent of language modality and is relevant for both signed and spoken languages. In spoken language, grounded blends may contain discrete, grammatical elements and a variety of gradient gesture providing extra auditory or visual information, e.g. pitch, loudness, facial features or hand gestures. In sign language, grounded blends also contain discrete and continuous information, which may be fully linguistic (i.e. lexical signs) or non-linguistic (e.g., enactment or imitation).

The results in these studies seem to support the notion that both discrete and gradient elements are projected into the blend. Despite the strong potential for many one-to-one form-meaning mapping in handling constructions, information about manipulated object size was not depicted analogously in BSL and in gestures accompanying English descriptions of object handling, suggesting that HHs are used conventionally but are not exclusive to BSL. One speculation that can be made based on the data from the current studies is that handling constructions blend conventionalised elements (e.g. handshape via finger configuration of four selected fingers touching refers to a paper-thin flattish object) and non-conventional enactment of manipulation or handling, e.g. via degrees of finger opening / spreading or hand internal or arm movements but that such distinctions are not specified in BSL. It is unclear, for example, if HHs are linguistically (phonologically and/or morphologically) specified for joint configuration or aperture. Thus, a more suitable definition of grounded blends for handling constructions would be: DCs as 'grounded blends' consist of conventionalised elements, which are blended with a variety of gradient forms in order to convey richly grounded meaning. The notion of grounded blends is not compatible with the analysis of DCs as holistic, visual representations proposed by Cogill-Koez (2000). Instead it appears that handling constructions in sign languages contain handshapes that are partly conventional and can combine with locations and movements that are more gradient in nature. This could be related to the notion of componentiality in gestures by Sweetser (2009) explained in 2.2.2, who proposed that elements of metaphorical gesture can become conventionalised. Similarly, elements of handling can become fossilised in spoken and signed discourse to represent universal concepts of graspable object size, prototypical shape or manner of use.

The degree of conventionalisation of handling constructions might be different for signers and non-signers as non-signers' articulations might be more individualistic and not governed by a linguistic system. Handling constructions are thus more appropriately analysed as forms within a heterogeneous communication system of natural sign languages (Macken, Perry, & Haas, 1993), incorporating more than one way of representing meaning, using arbitrary conventional meaning and richly grounded meaning. The current findings challenge the traditional view of DCs (discussed in section 2.3.1) and support the idea that handling constructions are structurally different from lexical signs and entity constructions. These studies have revealed similarities between HH forms in BSL and gestures and provided an insight into what aspects of HHs might be conventionalised. Further investigation into the degree of conventionalisation of other HHs beyond those studied in this thesis would help shed further light on the nature of HHs used by signers and non-signers. Other aspects of handling beyond representation of object size via hand aperture, such as finger spreading, curvature or finger selection, should be examined to reveal discrete or analogue patterning across other HHs.

5.7 Implications for analysis of DCs

The traditional view that sign language DCs are composed of discrete linguistic units and are comparable in structure to lexical signs has dominated the work of many sign language researchers (e.g.Sandler, 1989; Sandler & Lillo-Martin, 2006; Supalla, 1982; Supalla, 1990). Experimental studies in the early 2000s further supported the argument that handshape in lexical signs or in constructions depicting size (SASS) are discrete and linguistic. Such arguments about the discrete nature of sign language handshapes, mostly based on entity and/or SASS handshapes, have largely been assumed to apply equally to HHs, even though analyses of depicting handshape data have been based predominantly on entity constructions (Schembri et al., 2005; Supalla, 1982, 1986). The few studies comparing both entity and handling constructions used by signers with those used by non-signers focused on finger selection features and have suggested that signers draw on a more conventionalised inventory of depicting handshapes compared to non-signers (Brentari et al., 2012; Schembri et al., 2005), thus leaving questions about the conventional use of aperture open to debate.

An important implication of the current studies for analyses of handling constructions is that apparently handshapes that occur as part of constructions depicting handling in narrative contexts cannot be ascribed the same morphemic status as handshapes that occur as part of more lexicalised handling signs. This is consistent with models of the sign language lexicon and other analyses that recognise that DCs share some but not all of the properties of lexical signs (e.g. Johnston & Schembri, 1999; Brentari & Padden, 2001; Zwitserlood, 2004). Despite the same operating linguistic principles for signed and spoken morphology / phonology, sign language morphemes do not behave like spoken language morphemes because their form can be manipulated to convey gradient distinctions in meaning. For example, the English word *drink* cannot vary gradiently to describe drinks of different size or shape, although it could be argued that this kind of information can be manifested via visible gesture on the hands, as mentioned in section 2.2.1. In a sign language such as Auslan or BSL, the handling handshape /C/ firstly represents itself (the hand) which is the literal meaning of the utterance (Johnston, 1991) and how it shapes around the object. It also represents semantic meaning, i.e. a small, vertical, cylindrical and graspable object. In most cases, the /C/ handshape conjures up a type of object that is typically handled in such a way. The meaning inferred is context-dependent and non-literal. In order for HHs to be morphemic, they must also be phonemic and discrete and exclusive to sign language.

To summarise, with its aim and scope, the first study makes a contribution to the field of CP with novel empirical data with stimuli not previously examined; this is the first time CP has been examined for HHs in any sign language. The similarity in the way HHs in DCs are perceived and interpreted regardless of language experience (i.e. with sign or speech) calls into question the linguistic status of HH in BSL and also the role of CP in processing of sign language stimuli. It was found that familiarity with stimuli drives categorisation of HHs, not linguistic experience per se.

Furthermore, the systematic comparison between gestures and signs provides valuable evidence for theories about language and gesture. The discontinuous patterning of some HHs lends some support to the argument that the size of graspable objects in encoded by means of conventionalised HHs. Furthermore, the fact that such discontinuous patterning was not different for signers and co-speech gesturers suggests that handling constructions are pervasive in face-to-face interaction, and the fact that those in the pantomime condition in Study 2 patterned differently from signers and co-speech gesturers points to the importance of both language and gesture together in allowing such discontinuous patterns emerge.

5.8 Limitations of the studies

It is inevitable that due to the modality differences between sign and speech, methodological adjustments may be necessary to investigate the patterns distinctive to sign language processing. In sign language, CP and its underlying mechanisms have been less clearly demonstrated than for speech or other auditory or visual stimuli. This is partly because the examination of CP for sign language stimuli is relatively recent, but mainly because there is potentially more competing information at the visual input level than there is through the audio channel. Firstly, visually presented information is differentially processed compared to acoustic stimuli. Secondly, the visual field is restricted to an area in front of the signer within the signing space in comparison to the 360 degrees environment for sounds of language. Whilst the standard procedure for testing CP has proved to be a reliable assessment of perception of some speech sounds, CP studies in the sign language domain have yielded considerably more varied results.

The advantage of the CP method is that it tests perception of two values through two intersecting tasks, identification and discrimination, and provides an indication of whether these values are minimally contrastive and determines the boundaries between these contrasts, should such boundaries exist. However, in handling constructions, findings from Study 1 suggest that CP was not restricted to linguistic categorisation and may have been mediated by other cognitive processes (e.g. object size representations, motor representations associated with handling of objects of various shapes or sizes etc.). For this reason, an additional method assessing the signers' and non-signers' interpretation of handshape productions was employed in Study 2 to help further determine whether there are handshape categories in BSL and what these categories might be. As this method involved elicitation of naturally produced handling constructions, it additionally enabled a small-scale qualitative analysis of handshape features.

The design in Study 2, in which categorical encoding was assessed via decoding, allowed us to examine how participants interpreted the naturally occurring exemplars of handling productions without categories a priory and enabled comparisons between handshape productions across gesture types, a distinction that has been rarely systematically made in previous studies. The fact that HHs articulated by deaf BSL signers were encoded in a similar manner to handshapes articulated by non-signers when gesture accompanied speech compared to when gesture was used without speech highlights the importance of considering the multimodal nature of face-to-face communication. Despite the strengths, there were aspects of the design that could be improved upon. From all object size encodings in Study 2, the clearest forms were selected as stimulus items to prevent confusion due to articulatory assimilation. A native deaf BSL signer assessed the tokens for clarity. The fact that clearest rather than random tokens were selected could have introduced a confound, however should not be a cause for concern because, similarly to Emmorey and Herzig (2003), the gradient / categorical expressions were assessed by determining how the handshapes are interpreted by another group of signers or non-signers. So, irrespective of what token was selected, it is still expected that in gradient encoding, all handshape tokens would be reliably matched with the objects used to elicit them. In future studies, a larger sample of articulations from the same signer could be included in the presentation of stimuli.

One could also object about the fact that not all signers were truly native signers, given Baker et al.'s (2006) claim that perception of handshape changes between 4 and 14 months of age due to sign exposure. However, the fact that hearing non-signers perform similarly to deaf signers on the task suggests that this concern may not be germane to the HHs under investigation.

In study 2, it was unclear to what extent additional cues articulated on the face or body, e.g. lip patterns, such as puffed lips to indicate the effort, contributed to the comprehension of HHs. Mouth gestures accompany handling constructions in BSL and can provide additional (adjectival or adverbial) information about the object properties but they do not appear to be obligatory. The stimuli in Study 1 thus intentionally excluded non-manual information testing handshapes in a more synthetic and carefully controlled context while in the second study, handling exemplars occurred in naturalistic discourse where other spontaneously produced information on the body or face was preserved, except lexical cues, which were edited out.[11] The use of both synthetic, carefully controlled exemplars and naturalistic production and comprehension data positively contributed to research on handling constructions and gesture. Future studies could control for the amount of additional non-manual information provided during articulation of handling to reveal whether it yields differences in stimulus interpretation.

5.9 Future studies

The overall similarities between handling constructions in signers and gesturers as found in this thesis suggest that there is a shared, conventionalised set of handling handshapes that emerges from our embodied experience of day-to-day manual interaction with objects. The lack of linguistic effect found in these studies may be due to iconicity blocking the possibility for phonemic contrast with HHs. Future studies could employ designs where the linguistic effects can be demonstrated, for example, by manipulating the context in which HHs are comprehended or perceived, ranging from fixed lexical signs and productive constructions depicting handling to CA and full body gesture/mime.

To further systematically study the relationship between linguistic and gestural components of depicting signs, other techniques such as neuroimaging could be used in similar experiments as in this thesis to identify the underlying neural networks for handshapes and other parameters in depicting constructions and gestures. If certain elements of handling constructions are treated as discrete linguistic units, increased activation in the left inferior cortices (i.e. regions responsible for phonological/lexical processing) might be observed in deaf signers in comprehension or production of handling. If certain handshape features are treated as gesture/analogue (e.g. aperture), cortical activity in deaf signers during processing might resemble that of hearing non-

[11] It is noteworthy that there were no instances where deaf signers mouthed an English word during the handling construction.

signers. While previous research on DCs might have concluded that such comparisons were not needed based on assumptions about the linguistic status of DCs, the findings from the current studies importantly suggest that such comparisons are needed.

An area for improvement relates to a practice effect. For example, in Study 1, despite randomisation of stimulus presentation, it is possible that practice effects might have occurred. The data were not originally coded for block, but it would be interesting if future analyses explored the extent to which a practice effect influences CP patterns by including block as a nuisance variable in the analysis.

Other areas for future research may involve sign language acquisition and learning. Slobin et al. (2003) have argued that handling constructions are produced earlier by deaf native signing children compared to other types of DCs due to their strongly embodied nature. Likewise, Taub (2001) has claimed that it is often easier to produce and recognise body movements associated with an object than an analogue of the object itself. These claims have been made on the basis of very little data. In future, large scale studies looking at acquisition of DCs in both children and hearing learners could test these hypotheses, partly on the basis of the studies in this thesis showing similarities between signers and co-speech gesturers.

CHAPTER 6 Summary and conclusions

DCs in sign languages have been widely studied but despite this extensive research, the componential structure of constructions depicting handling and the role of gradient versus categorical patterning in these constructions has not been clear. This thesis has provided evidence about the compositional properties of handling constructions based on findings from CP experiments (see Chapter 3) and from a handshape comprehension study (see Chapter 4). The experiments were designed to test the assumption of whether sign language experience mediates the perception and interpretation of HHs in BSL to reveal the extent to which they are categorical. Firstly, the CP paradigm was used to determine if HHs are categorically perceived if an aspect of the handshape, e.g. aperture, continuously varies. Secondly, a handshape comprehension task was carried out to examine if HHs in BSL, co-speech gesture and pantomime were used to describe gradient variation in object size categorically and if these HHs were subsequently interpreted categorically. One of the main aims was to tease apart the analogue and discrete aspects of HHs at the level of perception and comprehension.

The main finding of similarities in perception for handshapes between signers and speakers in the CP task was not surprising. Recent research on spoken and sign languages has shown that CP is a general mechanism that is not solely limited to linguistic categories. CP here was helpful in describing the patterns and mechanisms involved in the general processing of HHs. This thesis suggests that the (perceptual / semantic) processes underlying categorisation of HHs are a result of processing mechanisms that are independent of language modality and relate to a general perceptual or cognitive systems. Thus the perception and comprehension of HHs is driven by an embodied experience relating to perceiving and performing actions with objects rather than a specialised linguistic module. In the light of these conclusions, existing analyses of handling constructions as purely linguistic constructs should be revised.

Previous studies on DCs have been pre-occupied mainly with theoretical concerns that have involved limited natural data and/or limited samples. This thesis advances these previous accounts of DCs to an experimental study that tests the theoretical hypotheses. The findings presented here challenge existing claims about the linguistic properties of handling constructions, which were largely made under the assumption that entity and handling constructions are similar in nature.

This thesis is novel for two main reasons. This is the first study to date that experimentally examines handling constructions in BSL. Much early sign language research aimed to show that all constructions used by deaf signers are solely composed of discrete and combinatorial elements despite the analogue appearance of some aspects of their production. However, it is apparent that signers capitalise on the visual-gestural modality and some sign language linguists now accept that certain sign language forms (including DCs) blend both discrete linguistic and non-linguistic elements. For example, in highly embodied and partially lexicalised forms, such as handling constructions, the signer's hand can analogically depict the size of manipulated objects or the way and manner in which the objects are handled. The study is also novel because it systematically compares co-speech gestures, pantomime and a sign language. This allows for in-depth scrutiny of elements specified for BSL and elements that are available to both signers and non-signers.

The present findings have emphasised the need to distinguish between entity handshapes and HHs; these might be different in nature and thus should not be conflated in descriptions of DCs. Secondly, the finding of similarities between signers and co-speech gesturers (but not pantomimers) further underpins the need for considering language as a multimodal phenomenon. There are crucial differences between spontaneous gestures articulated with speech versus strategic gestures articulated in the absence of speech. The evidence that has come to light here is that co-speech gestures and pantomime encode gradient visual information differently. CP for BSL HHs is shaped by embodied or perceptual experience and not solely by sign language experience which stimulates a debate about cognitive and perceptual mechanisms involved in language processing. Such processes provide support for a cognitive-functional approach to language but is difficult to reconcile under a formal approach.

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Appendices

Appendix A List of sign language abbreviations

Auslan – Australian Sign Language

AdaSL – Adamorobe Sign Language

ASL – American Sign Language

BSL – British Sign Language

IPSL – Indo-Pakistani Sign Language

ISL – Israeli Sign Language

ISN – Nicaraguan Sign Language (Idioma de Señas de Nicaragua)

LSF – French Sign Language (Langue des Signes Française)

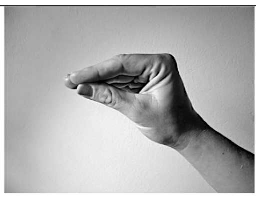
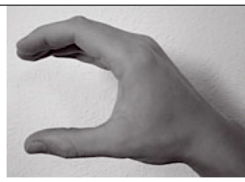
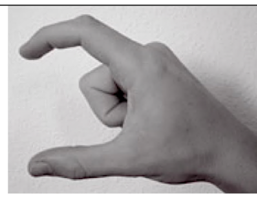
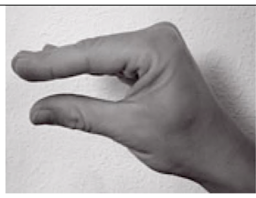
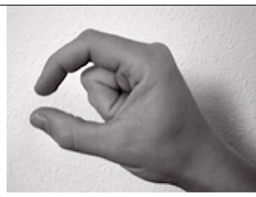
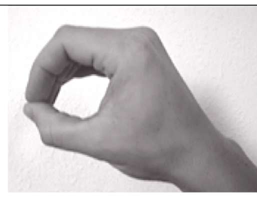
LIS – Italian Sign Language (Lingua dei Segni Italiana)

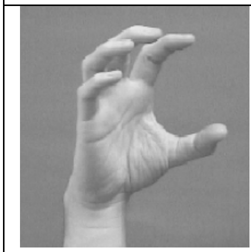
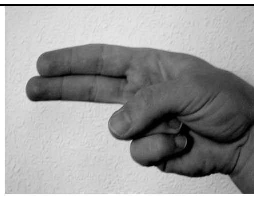
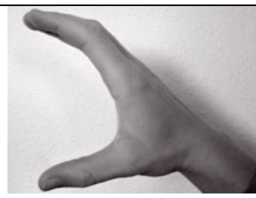
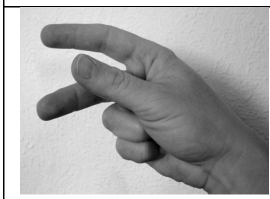
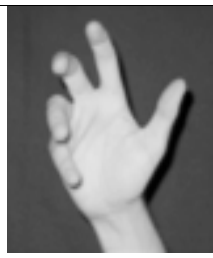
NGT - Sign Language of the Netherlands (Nederlandse Gebarentaal)

STS - Swedish Sign Language (Svenskt teckenspråk)

Appendix B List of handling handshapes and glosses

Appendix B Figure 1. List of handshapes and codes. First line contains handshape glosses according to Eccarius & Brentari (2008). The second line in the table contains glosses based on ASL fingerspelling. *signifies a variant and that there is no conventional gloss. The last seven images have been reproduced from Eccarius & Brentari (2008).

			
J;#	BT-	1@;T-;#	1;T;#
/pinky/	/flat/	/intl-T/	/index/
			
BT>	B^T-	U^;#	Uk;T;#
/flat-O/	/5/	/V/	/V/
			
U^[;#	U^c;T-;#	UT-^;#	BT@
/bent-V/ or /X/	/bent-3/	/3/	/fist/ or /S/
			
1To;/	1To;#	BTc	1T(;#
/F/	/baby-O/	/C/	/baby-C/*
			
JT-;#	BT<	1Tc;#	BTo

/Y/	/flat-C/*	/baby-C/	/O/
			
BT^c	U;#	B@;/	BT(
/claw/	/U/	/A/	/C/*
			
Uk;T;#	B@;T-	BT^(	Bk@;/
/stacked-3/	/B/		
			
AT(;/	1@;T;#	BTkc	Bkc;/
			
BT-k@			

Appendix C Instructions for participants

INSTRUCTIONS FOR PARTICIPANTS – STUDY 1

This experiment looks at similarities of handshapes in BSL

The handshapes we are comparing are used in BSL to describe handling and manipulation of:

- small flat square objects (practice handshapes)
- larger flat-ish, square objects
- round, cylindrical objects

There are two tasks, TASK 1 and TASK 2 – each TASK is preceded by practice session

You can ask questions during or after the practice session but <u>not</u> during the main test

TASK 1 is repeated 3 times, then a break and repeated again 3 times with other handshapes.

TASK 2 is repeated twice, then a break and repeated again twice with other handshapes.

Please press response key as soon as possible

Don't worry if you think you made a mistake ☺ just carry on

Any questions?

TASK 1:

Two handshapes will appear on the top of the screen. First one will be in the top left corner, second one in the top right corner.

Don't do anything. Look carefully at them. They will disappear quickly.

Then handshapes will start to appear in the middle of the screen at the bottom one by one.

If you think the handshape in the middle is more similar to the handshape in the left corner, press ⮌ key.

If you think the handshape in the middle is more similar to the handshape in the right corner, press ➲ key.

Press **<u>spacebar</u> to start** the practice. When you finish practice ask questions or **start the main test.**

Any questions?

TASK 2:

A handshape will appear in the left corner of the screen and then disappear.

Another handshape will then appear in the right corner of the screen and then disappear. Look carefully at them.

A handshape will then appear in the middle of the screen and then disappear.

If you think the handshape in the middle is like the handshape on the left press the ⮌ button.

If you think the handshape in the middle is like the handshape on the right, press the ➲ button.

Press **<u>spacebar</u> to start** the practice. When you finish practice, ask questions or **start the main test.**

Any questions?

INSTRUCTIONS FOR PARTICIPANTS – STUDY 2 HANDSHAPE ELICITATION TASK

Instructions to deaf and hearing participants

Hello and welcome. Thank you for taking part in this study
What do we investigate? Descriptions of objects and space and object placement in BSL
You will sit at a table opposite another deaf BSL signer
The researcher will show you a cartoon. Think about the story, it's about a birthday present
The researcher will now show you several objects
The deaf signer opposite you doesn't know what the cartoon is and can't see the objects
You will now explain the story the deaf signer in BSL
Please describe it in detail! Be imaginative! The deaf signer will have to answer some questions about the object and story later so be very specific
You will be videotaped
We will show your video later to another group of participants who will answer some question about the story and objects you described

INSTRUCTIONS FOR PARTICIPANTS – STUDY 2 HANDSHAPE-OBJECT MATCHING TASK

Instructions to deaf participants (transcript)

In this study, we investigate comprehension of handling handshapes in BSL

Look at the objects in front of you carefully
You will see many very short video clips on the computer screen
Pay attention to the HANDSHAPE
In each clip, a person describes an object being handled or manipulated
Pick the one you think the person describes from the objects in front of you and write the object's letter into first column
Circle – how confident are you about your choice? 1 – very confident, 2 – fairly confident, 3 – not confident at all
Now pick other object the person could describe – 2nd choice
You must answer quickly
Some clips might appear once and some several times
One person might describe several different objects
Some of the objects might not be described at all
There are two parts: Part A and Part B

Each part has 3 sections
You may take a break after each section
Whole experiment lasts about 30 minutes.
You will practice first
Any questions?

Instructions to hearing participants

In this study, we investigate people's comprehension of hand actions

Look at the objects in front of you carefully
You will see many very short video clips on the computer screen
Pay attention to the HANDSHAPE
In each clip, a person describes an object being handled or manipulated
From the objects in front of you, pick the one you think the person describes
Circle – how confident are you about your choice? 1 – very confident, 2 – fairly confident, 3 – not confident at all
Now pick other object the person could describe
Some clips might appear once and some several times
Some of the objects might not be described at all
You must answer as quickly as possible
There are two parts: Part A and Part B
Each part has 3 sections
You may take a break after each section
Whole experiment lasts about 30 minutes.
You will practice first
Any questions?

Appendix D Individual identification task performance

Appendix D Table 1.

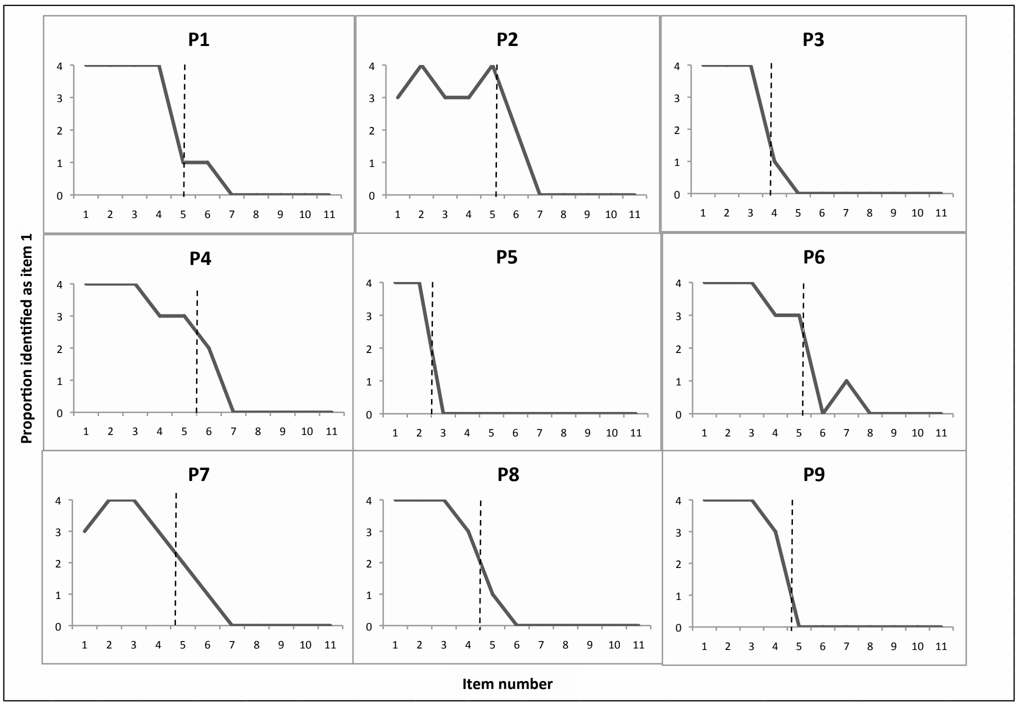
Individual boundaries and boundary pairs, /flat-O/-/flat-C/ continuum:

/flat-O/-/flat-C/	Participant	Boundary	Cat.boundary item pair
Deaf signers	1	5.00	4_6 5_7
	2	5.24	4_6 5_7
	3	3.94	3_5 4_6
	4	5.50	4_6 5_7
	5	2.22	1_3 2_4
	6	2.50	1_3 2_4
	7	4.50	3_5 4_6
	8	5.25	4_6 5_7
	9	4.74	3_5 4_6
	10	4.50	3_5 4_6
	11	3.50	2_4 3_5
	12	4.06	3_5 4_5
	13	4.00	3_5 4_6
	14	4.25	3_5 4_6
M cat. boundary		4.23	
Hearing non-signers	1	4.25	3_5 4_6
	2	2.50	1_3 2_4
	3	6.92	5_7 6_8
	4	5.25	4_6 5_7
	5	7.50	6_8 7_9
	6	4.50	3_5 4_6
	7	4.24	3_5 4_6
	8	4.50	3_5 4_6
	9	4.25	3_5 4_6
	10	5.00	3_5 4_6
	11	3.06	2_4 3_5
	12	5.25	4_6 5_7
	13	5.00	4_6 5_7
	14	3.50	2_4 3_5
M cat. boundary		4.69	

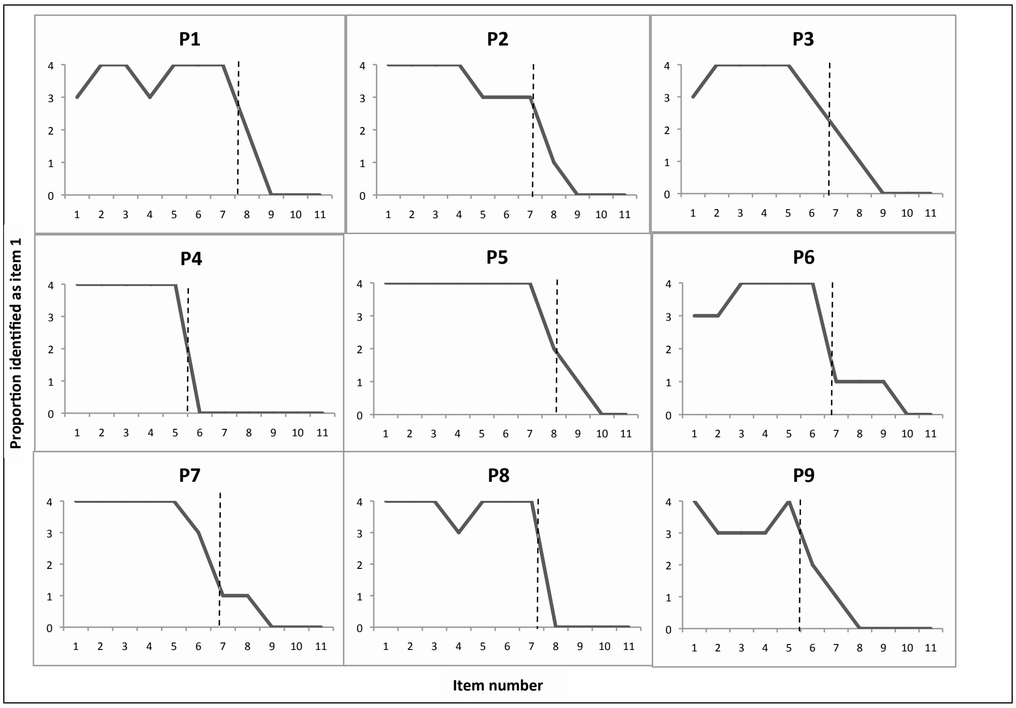
Appendix D Table 2.

Individual boundaries and boundary pairs, /S/-/C/ continuum

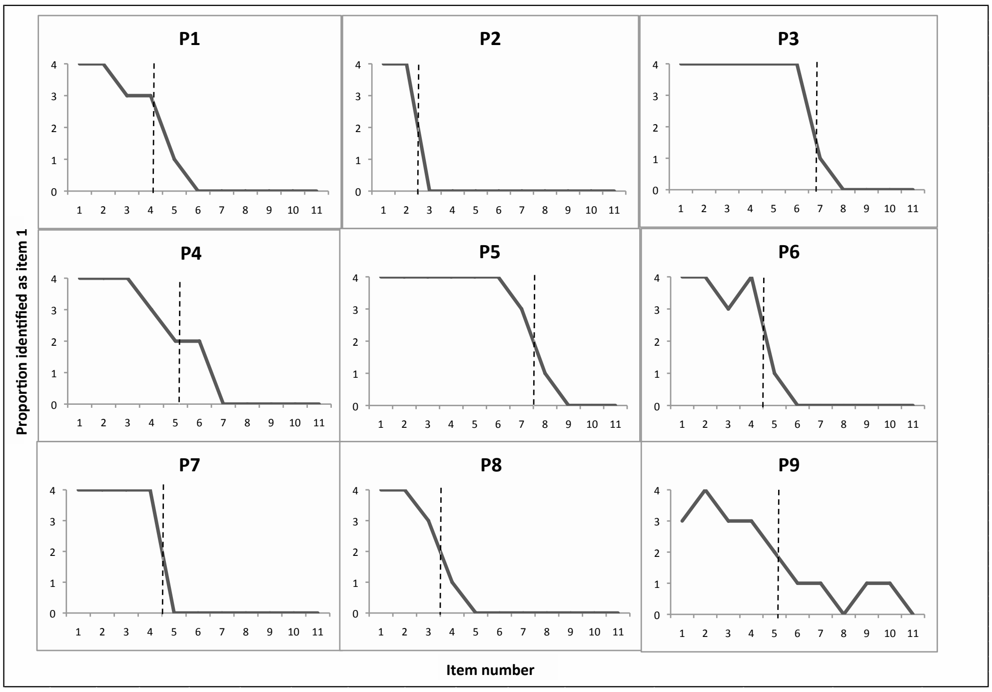
/S/-/C/	Participant	Boundary	Cat.boundary item pair
Deaf signers	1	7.57	6_8 7_9
	2	7.01	6_8 7_9
	3	6.76	5_7 6_8
	4	5.48	4_6 5_7
	5	5.50	4_6 5_7
	6	8.25	7_9 8_10
	7	6.50	5_7 6_8
	8	6.81	5_7 6_8
	9	6.75	5_7 6_8
	10	7.25	6_8 7_9
	11	5.49	4_6 5_7
	13	7.75	6_8 7_9
	14	6.50	5_7 6_8
M cat.boundary		6.74	
Hearing non-signers	1	7.48	6_8 7_9
	2	5.92	5_7 6_8
	3	8.24	7_9 8_10
	4	5.50	4_6 5_7
	5	6.75	5_7 6_8
	6	6.54	5_7 6_8
	7	5.50	4_6 5_7
	8	5.50	4_6 5_7
	9	6.25	5_7 6_8
	10	7.62	6_8 7_9
	11	5.94	5_7 6_8
	12	8.75	7_9 8_10
	13	6.75	5_7 6_8
	14	6.50	5_7 6_8
M cat.boundary		6.66	



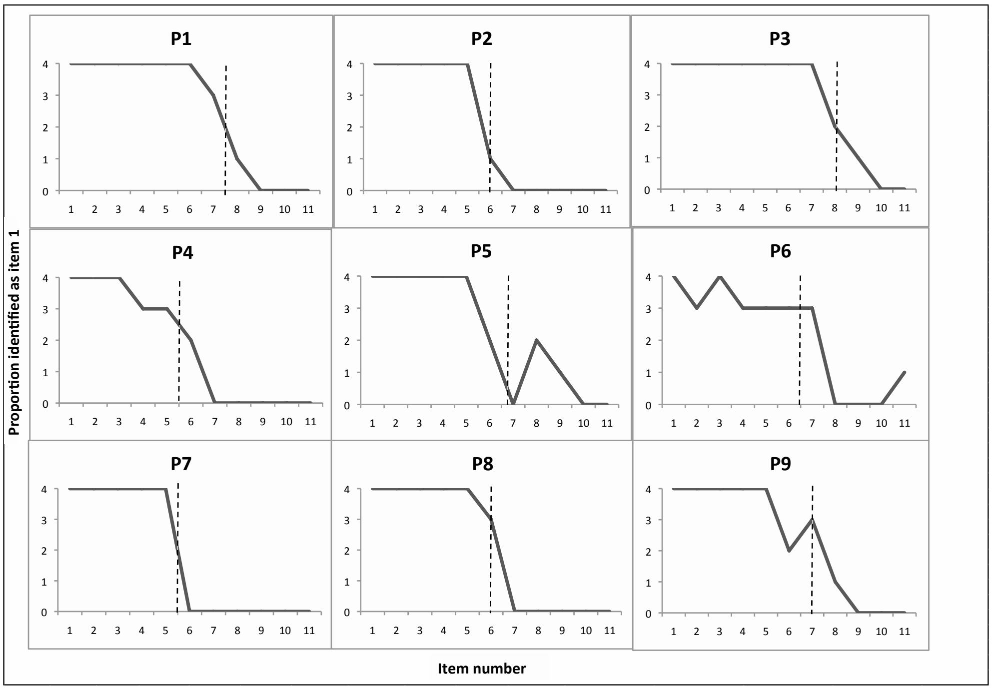
Appendix D figure 1 a) Sample of individual deaf BSL participants' identification of items as item 1; /flat-O/-/flat-C/*



Appendix D figure 1 b) Sample of individual deaf participants' identification of items as item 1; /S/-/C/



Appendix D figure 2 a) Sample of individual hearing participants' identification of items as item 1; /flat-O/-/flat-C/



Appendix D figure 2 b) Sample of individual hearing participants' identification of items as item 1 on the /S/-/C/ continuum

* The dotted lines indicate where the category boundary was identified for each participant based on 50% of their responses in identification of items as item 1. Items were assumed to be on an equal interval scale.

Appendix E Cartoon story used to elicit handling handshapes

Appendix E Figure 2. Cartoon story used in the stimulus production phase to elicit handling constructions

Appendix F Answer sheet sample for handshape-object matching task

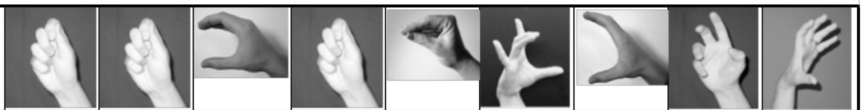
Study name: **BSL HANDLING HANDSHAPE & OBJECT MATCHING**

Participant code/name: ________________ Date: ________________

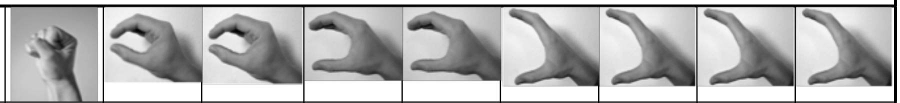
Clip no:	1st object choice	Confidence (1–very confident; 2–confident; 3–not confident)	2nd object choice
PRACTICE			
Clip 1		1 2 3	
Clip 2		1 2 3	
Clip 3		1 2 3	
BLOCK A1			
Clip 1		1 2 3	
Clip 2		1 2 3	
Clip 3		1 2 3	
Clip 4		1 2 3	

Appendix G A table of elicited handling handshape exemplars and codes

Appendix G Figure 3. A table of elicited HHs from the narratives in three language conditions (BSL, English with speech and pantomime) during the stimulus production phase for flattish rectangular objects, including their codes and categorisations.

		Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9
		3mm/0-1in	5mm/0-1in	10mm/0-1in	30mm/1-2in	40mm/1-2in	50mm/2-3in	60mm/2-3in	70mm/2-3in	85mm/>3in
	Flattish-rectangular object size									
Deaf BSL signers	HS type elicited									
	HS form	BT>	BT=	BT<	BT=	BT=	BT<	BT<	BT(	BT(
	Finger-thumb distance in elicited HHS (inches)	0	<1	>3*	<1	<1	1 to 3	1 to 3	>3	>3
	Hypothesised category	Touch (T)	Small (S)				Medium (M)		Large (L)	
	Actual production									
Hearing co-speech gesture	HS type elicited									
	HS form	Bk@;/	Bk@;/	BTc	Bk@;/	BT>	AT(;/	BT(	BTkc	BT^(
	Finger-thumb distance in elicited HHS (inches)	0	0	1 to 3	0	0	>3	>3	>3	>3
	Hypothesised category	Touch (T)		Medium (M)	Touch (T)		Large (L)			
	Actual production									
Hearing pantomime	HS type elicited									
	HS form	BT>	Bk@;/	BT=	BT-k@	BTc	BTc	BT<	BT(	Bkc;/
	Finger-thumb distance in elicited HHS (inches)	0	0	1 to 3	<1	1 to 3	1 to 3	<3	<3	<3
	Hypothesised category	Touch (T)		Medium (M)	Small (S)	Medium (M)		Large (L)		
	Actual production									

Appendix G Figure 4. A table of elicited HHs from the narratives in three language conditions (BSL, English with speech and pantomime) during the stimulus production phase for cylindrical objects, including their codes and categorisations.

		Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9
		30mm/touch	40mm/1-2in	50mm/1-2in	60mm/2-3in	70mm/2-3in	80mm/3-4in	90mm/3-4in	100mm/3-4i	110/>4in
	Cylindrical obj. size (diameter)									
Deaf BSL signers	HS type elicited									
	HS form	BT@	BTc	BTc	BTc	BTc	BT^(	BT(	BT(	BT(
	Finger-thumb distance in elicited HHS (inches)	0 in	<1	<1	1 to 3	1 to 3	>3	>3	>3	>3
	Hypothesised category	Fist (F)	Small (S)		Medium (M)		Large (L)			
	Actual production									
Hearing co-speech gesture	HS type elicited									
	HS form	Bk@;/	BT^c	BT^c	1@;T;#	BT^c	AT(;/	BT^(	BT^(	BTc
	Finger-thumb distance in elicited HHS (inches)	0	1 to 3	1 to 3	0	1 to 3	>3	>3	>3	>3
	Hypothesised category	Fist (F)	Medium (M)		Fist (F)	Medium (M)	Large (L)			
	Actual production									
Hearing pantomime	HS type elicited									
	HS form	B@;T-	BTc	BTo	BTc	BT^c	BTc	BT^(	BT^(	BT^(
	Finger-thumb distance in elicited HHS (inches)	0	1 to 3	0	1 to 3	1 to 3	1 to 3	>3	>3	>3
	Hypothesised category	Fist (F)	Medium (M)	Fist (F)	Medium (M)			Large (L)		
	Actual production									

Appendix G Table 3.

Handshape feature specifications (Eccarius & Brentari, 2008)

Selected Fingers	Joint Configuration	Symbols representing joint configuration of selected fingers
Primary selected fingers (PSF)	[flexed] [bent]	< > @ *[(o c*
	[spread]	^
	[stacked]	*k*
	[crossed]	*x*
Secondary selected fingers (SSF)	[loop] curved-closed	*o*
	[flexed] closed	@
Non-selected fingers (NSF)	[extended]	/
	[flexed] closed	#
Thumb	[opposed]	*T*
	[unopposed]	