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From gesture to Sign? An exploration of the effects of communicative pressure, interaction, and time on the process of conventionalisation

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Abstract: This study explored how non-signers exploit their gestural repertoire during a process of handshape conventionalisation. We examined how communicative context, interaction, and time affect the transition from iconically motivated representations to linguistically organised, generalised forms. One hundred non-signers undertook a silent gesture-elicitation task, describing pictures in one of four conditions: (A) in isolation; (B) with a passive recipient tasked with identifying the objects gestured; (C) with an interlocutor, sharing addressor/addressee roles; (D) with a confederate, sharing addressor/addressee roles, where the confederate restricted her handshapes to four. Analyses focused on whether participants used their hands productively (proportion of 'hand-as-object' responses), and whether they generalised handshapes to similarly shaped but different objects (handshape range). High communicative pressure and interaction (C, D) generated the highest proportion of hand-as-object representations. The condition lacking these, (A), generated the smallest handshape range. Results did not change over time. At this incipient stage, individuals exploit their gestural repertoire productively, intent on depicting object characteristics accurately. Communicative pressure and interaction spur this exploratory process. However, they do not yet generalise their handshapes, a development requiring a loosening of the iconic mapping between

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symbol and referent. This aspect of conventionalisation needs time and might be more likely to emerge in isolation.

Keywords: silent gesture; Sign Language; conventionalisation; production; handshapes

1 Introduction

1.1 Learning to depict objects in a Sign Language

A hearing person who is new to Sign Language may have caught glimpses of signed languages being used and might know that what appears at first glance to be a system based on transparent symbols is actually complex, and largely indecipherable to a non-signer (see Sehyr and Emmorey 2019). However, novices are unlikely to know that a visual-manual system is not restricted to a sequential ordering of words. Instead, meaning can be represented simultaneously, where so-called multiple meanings are fused onto one particular form. A typical example of this capacity is the classifier construction, where one form comprising a number of components (i.e., handshape, location, and movement) can simultaneously depict what something is, where it is, and what direction it is moving in. In contrast, a spoken language must order arguments, verbs, and adjuncts sequentially in accordance with its word-order restrictions.

A novice learner of Sign Language thus faces a number of challenges with respect to producing classifier constructions (see Boers-Visker 2020; Schönström and Mesch 2022). Foremost, they must learn to draw on their gestural repertoires and use their hands as communicative tools deliberately, and recognise that they can create multiple shapes with their hands which can, to a greater or lesser degree, iconically represent the physical characteristics of the object they are depicting. Second, they must select an appropriate handshape from their gesture inventory. Third, they must select these handshapes consistently so that one handshape always refers to the same class of object and produce them with sufficient precision since sloppy handshapes can equate to mispronunciations that are vulnerable to misinterpretation. A final challenge is to learn to extend the use of one particular handshape for an object to objects of a similar shape – a certain handshape (e.g., a B-handshape in British Sign Language [BSL]; see Figure 3) can refer not only to a certain book or to books but to a whole range of flat and broad objects (folders, DVDs, sheets of paper, etc.).[1]

1 Although our study focuses on adult second learners of Sign, it is interesting to note that when deaf children acquire classifiers, they also find the mastery of handshapes challenging (see Kantor 1980; Schick 1990).

In the present paper we examine how the process of conventionalisation starts by looking at non-signers' manual productions. We focus on the initial challenges facing a hearing second language (L2) learner of Sign when grappling with one set of linguistic constructions whose imagistic basis is clear – the classifier construction – but whose form is nevertheless conventionalised within the particular signed language being learnt. We ask what role interlocutors play in the development of a structurally complex system, and which of these developments are driven by the individual, that is, whether communicative pressure and interaction bolster the transition from largely iconically motivated representations to linguistically organised forms (see Boers-Visker 2020; Casey et al. 2012; Janke and Marshall 2017; Marshall and Morgan 2015; Ortega 2017; Ortega et al. 2019; Singleton et al. 1993). By examining the productions of non-signers during a silent gesture-elicitation task, we investigate whether different communicative conditions impact the way in which a participant explores their use of handshapes and progresses from handshapes mapped tightly to specific characteristics of individual objects to a reduced, generalised set of symbols that represent broader object categories.

In the next sub-sections, we provide some background on classifiers, motivating our focus on them, and highlight some of the main challenges accompanying their acquisition, drawing on literature from gesture and Sign Language studies. We then turn to ontogenetic and microgenetic studies that have examined the role of interlocutor input in Sign Language development and learning, drawing particularly on Singleton et al. (1993), one of the first studies to explore the conditions needed for the development of systematicity and complexity in Sign. With the relevant findings and implications clear, we turn to the elicitation task devised for the present study. This task aims to tap into whether and how different kinds of communicative pressure and interaction propel a non-signer to use their hands productively to represent objects, and whether these factors affect non-signers' progression away from gestural iconicity towards a linguistically organised system within a short time frame.

1.2 Classifiers: isolating handshapes from movement and location

Amongst other functions, classifiers are used across signed languages to specify the location and movement of objects or people in the linguistic or topographical environment. A signer can form a specific handshape, which represents a class of objects, and place it within her signing space to show where an object is relative to others and to illustrate whether it is moving in a particular direction. The addressee interprets this information in an analogue way so she can identify the precise position and trajectory of the item. For example, in BSL, if a signer wishes to convey a person walking up a hill, having first introduced the person, they can form a G handshape (i.e., a fist with the index finger extended) to represent that person. The hand would be placed in the signer's signing space; its orientation would be upwards, with the index finger extended vertically, and the signer would elevate their hand diagonally to depict the person's inclining path (see Figure 1). Thus, classifiers comprise three fundamental parameters: handshape, location, and movement (with orientation often being classed as a subsidiary to these [see Boers-Visker 2020]).

The imagistic aspect of classifiers has raised questions about the most accurate way to categorise them (Engberg-Pedersen 1993; Goldin-Meadow and Brentari 2017; Liddell 2003). Some work relevant to this issue proposes a synchronic analysis that draws a distinction between gestural and linguistic components (Schembri et al. 2005). Analysing data from an elicited production task, these researchers found that handshapes used to depict the same objects often differed cross-linguistically between signed languages but that movement and location did not. This was true for signed languages that have developed within similar speech communities, such as American (ASL) and Australian Sign Language (Auslan), and those that have not, such as Taiwan Sign Language (TSL). Schembri et al. (2005) took this distinction to indicate that handshapes have evolved into categorical linguistic constructs but that movement and location, in their cross-linguistically shared representations, remain largely gestural. Independent support for this proposal came from the productions of non-signers during the same task. These productions differed little from those of native signers in terms of movement and location but contrasted markedly in terms of handshapes, a result that is expected if movement and location chiefly exploit universally available gestural abilities whereas handshapes incorporate language-specific knowledge too.

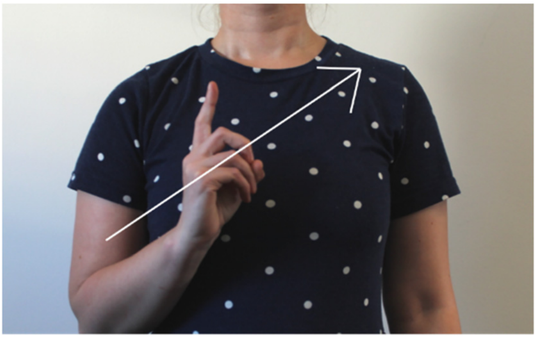


Figure 1: Illustration of the three major parameters of a classifier: handshape, location, movement.

The present study circumvents ongoing questions surrounding the classification of movement and location as it focuses on static objects placed in a particular spatial configuration. We restrict our focus to one dimension of classifiers, namely handshapes, whose gestural origins are clear but whose forms are stabilised and conform to rules – that is, they have become conventionalised. By focusing on handshapes, we can ask if non-signing participants progress towards systematicity because handshapes cannot simply be transferred from their gestural repertoire but exhibit a learning process during which they depart from strict iconicity. With this loosening of the mapping between form and concept, the evolution into linguistically regulated symbols becomes possible.

1.3 From gesture to Sign

It has long been recognised that a hearing novice of Sign Language brings a gestural inventory to the task of learning a Sign Language. Manual gestures are core to language use in spoken communication (see Kendon 1980, 2004; McNeill 1985, 1992, 2017), reflecting and affecting linguistic processes in child and adult language acquisition (Capirci et al. 2021; Gullberg 2006, 2022), disfluency (Graziano and Gullberg 2018; Seyfeddinipur 2006), and language processing (see Özyürek [2014, 2017] for overviews). Speakers mobilise manual movements in systematic culture- and language-specific ways as part of their speech production, and these so-called 'co-speech gestures' are processed by addressees during speech comprehension. In addition to co-speech gestures, language users typically have repertoires of conventionalised gestures, referred to as 'emblems' or 'quotable gestures' (e.g., Ekman and Friesen 1969; Payrató and Clemente 2020). A typical example would be the use of a flat hand held to the ear to mean (mobile) phone, which has largely replaced the earlier telephone gesture in which curled index, middle and ring fingers were surrounded by an outstretched thumb and pinkie. These gestures and the concepts they represent form fixed form-meaning pairs that have standards of well-formedness. A long-standing interest in the field of gesture studies is how and when certain gestures conventionalise and become more word- or even sign-like (e.g., Ekman and Friesen 1969; Kendon 1972, 1990, 2008; Micklos 2016; Payrató and Clemente 2020). Recently, much of this research has focused on so-called silent gestures (in the past often called pantomimes), in which people are required to restrict themselves to gesture only in order to convey meaning. The absence of speech has been shown to propel micro-standardisation of form-meaning mappings forward (e.g., Goldin-Meadow et al. 2008; Micklos 2016; Özçalışkan et al. 2016).

The gesture literature has intersected at various points with the study of the development of signs and the impact of hearing learners' underlying gestural skills (e.g., Ortega et al. 2020; Ortega and Özyürek 2020). To probe the impact of gestures in the development of signs, several studies have examined non-signers within a so-called 'microgenetic timespan' to assess the amount of time and the type of environment needed for indications of sign-like systematicity to emerge. Singleton et al. (1993) have been most informative in this respect, having created a method to explore this process. They looked at the properties of classifier productions across three timespans: historical (native ASL signers), ontogenetic (one homesigner's individual development), and microgenetic (non-signers' manual productions in an experimental setting). Examining classifiers elicited using Supalla's Verbs of Motion Production (VMP) test (Supalla 1982), the researchers searched for evidence of "internal standards of well-formedness" (1982: 685). Of particular relevance to the present study were the handshapes produced by the non-signers. Their productions relative to the native signers were markedly different: as a group, they selected ASL target handshapes only 20 % of the time, which is perhaps not surprising since only native signers would know these targets. However, the authors developed criteria, centred on the mean number of handshapes produced for each class of object, to ascertain whether the non-signers were developing internal consistency. A small mean would indicate that participants were using the same handshapes for classes of objects consistently whereas a larger one would indicate they were using a broad range of handshapes for classes of objects so not yet developing any systematic representation of object categories. The results indicated that the mean of the non-signers (3.2) was significantly higher than that of the ASL signers (1.9) and of the homesigner (2). On this basis, they concluded that non-signers chose handshapes according to how tightly they mapped iconically to the characteristics of the object and had not started to generate a system in which one handshape represented an object class. However, despite this result indicating that non-signers were not systematic in the way that signers were, it stopped short of being able to indicate whether the non-signers had started to develop a system at all. To approach this question, one could monitor their range of productions over the course of a more expansive task and compare their repertoire of responses at the beginning of it with that produced at the end.

Use of such a method does assume that one of the key tasks for a learner of Sign is to narrow down from a broad range of responses recruited from gestural resources to a more restricted and consistent set, as suggested by Janke and Marshall (2017). In this study, 30 non-signers took part in a gesture-elicitation task and the range of their productions was compared to that of fluent BSL signers and learners to ascertain if a novice would need to expand or restrict their gestural productions in order to approximate the range of handshapes appropriate in a particular signed language. They observed that non-signers produced gestures not used by signers or learners and that their set of handshapes was larger than the other groups. This pattern lent support to the hypothesis that a key task for a learner trying to express locative relations was to narrow down from a large set of gestural resources rather than supplement a restricted one.

Practice can provide a novice with the opportunity of deciphering a system, but other factors might accelerate this process. The role of interlocutors, for example, is also important (cf. Micklos 2016). In Singleton et al.'s (1993) study, participants conveyed their responses to an experimenter they knew to be well-versed with the materials. In Schembri et al.'s (2005) and Janke and Marshall's (2017) studies, there was no communicative aspect to the tasks as participants gestured to a camera. More recent studies have introduced various elements of communicative pressure to similar tasks. Motamedi et al.'s (2019) study, which examined factors contributing to systematicity in artificial signed systems, suggested that gesturing multi-word strings to an interactive communicative partner propelled convergence on a reduced set of sequences. But the difference between gesturing to no-one at all and taking it in turns to gesture with a communicative partner is vast. In the former scenario, a participant is not required to produce responses that need to be understood by an interlocutor, and nor do they receive any feedback that might cause them to alter or develop their productions. In the latter case, both participants need to convey something that must be understood by another person, and they also have the opportunity of revising and/or developing their productions in accordance with the gestures explored by their interlocutor. It is important to tease apart communicative factors further. Systematicity might be encouraged, for example, purely by having to gesture to another person, even if that person provides no feedback. This could be investigated by a scenario in which a participant gestures to someone they believe to be naïve to the task, where that person is confined to a passive addressee role. In this case, the participant would know if their gesture is understood, and on that basis, might be encouraged to repeat it. Alternatively, as Singleton et al. (1993) suggested, having an active communicative partner, where both participants are engaged in the same task, may result in a different pattern of responses. In this situation, each participant is exploring possibilities, whilst witnessing alternatives produced by their interlocutor. Expanding communicative possibilities still further, an active communicative partner who restricts their productions to a reduced set of symbols might have a different impact on an addressee than one who is also encountering the challenge for the first time. The varying types of interlocutor could affect the developmental path of productions quite differently – the latter situation might propel systematicity within this short timespan, but the former might lead to an initial increase as participants witness a variety of hand configurations that might not have occurred to them alone.

We examine these possibilities in the present article. Our aim is to build on Singleton et al.'s (1993) search for progression and systematicity by examining non-signing participants' productions during a more expansive task. We do not expect participants to create a system as restricted as that of fluent signers but are searching for evidence of change over the course of the task. Further, we examine whether communicative conditions impact the degree to which participants experiment with handshape options and start to arrange the handshapes they produce into something resembling categorical organisation.

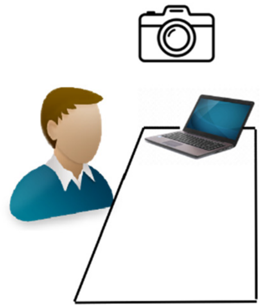
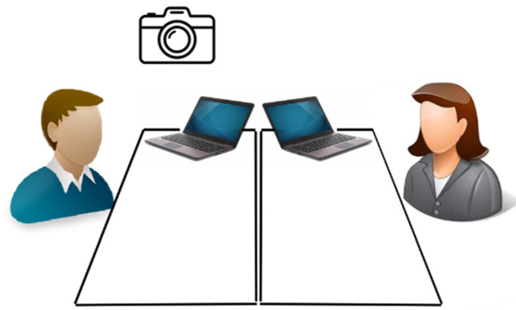
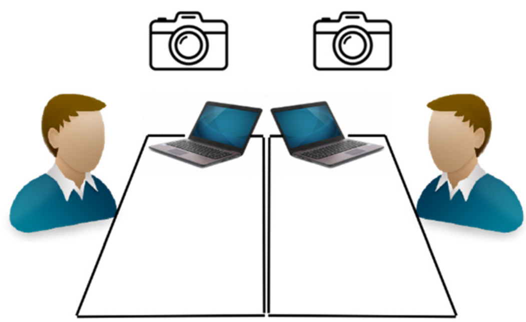
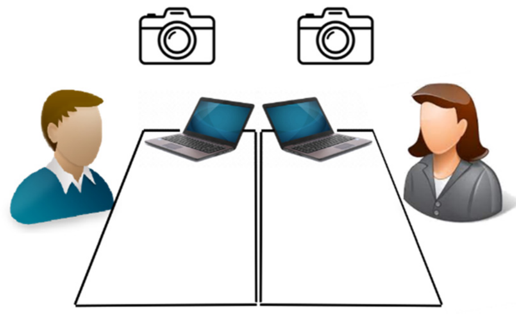
1.4 The present study

So-called silent gestures provide a communicative paradigm with which to explore what non-signers do when asked to label objects using only their hands in novel scenarios and what handshapes they produce. There is no practice run, aside from two starter trials using non-experimental stimuli, so responses are unrehearsed and impromptu. The fact that participants remain silent means that their hands carry the full communicative burden, which is markedly different from the type of gestures that accompany speech, namely co-speech gestures (see Goldin-Meadow and Brentari 2017). With this methodology, we can track if participants' productions differ in accordance with condition or change as the task progresses by comparing gestures in the first and second half of the experiment.

Table 1 illustrates the four experimental conditions: (A) completion of the task alone, (B) completion of it with a passive partner whose role is to identify what is being gestured, (C) completion with an active communicative partner, where both alternate between addressor and addressee roles, and each participant must identify what is being gestured to them, and (D) completion of the task with an active communicative partner (a confederate, limited to four handshape responses), where again, each partner alternates between addressor and addressee role, and the participant must identify what is being gestured to them. Collectively, these conditions enable us to explore whether non-signers' productions differ according to the communicative pressure and type of interaction attached to the task, and whether their productions alter over time.

The aim of this study is to identify what a novice learner of Sign brings to the learning task, so our first questions focused on the degree to which participants produced handshapes at all to represent objects. Participants would need to explore how to situate and configure their hands in the space in front of them. This

Table 1: Experimental conditions (where A has the lowest amount of interaction and D has the highest).

Condition	Communicative pressure/interaction	Illustration
A	No communicative partner: participant gestures to a camera	
B	Passive communicative partner: participant gestures to a confederate, who identifies the pictures being gestured	
C	Active communicative partner: two participants identify the pictures being gestured and alternate between addressor and addressee roles	
D	Active communicative partner: one participant and one confederate; both identify what is being gestured and alternate between addressor and addressee roles	

means that initial productions might span a range of possibilities, including, for example, tracing the outline of objects or using whole-body enactments, before reaching the point at which each hand deliberately depicts one item, namely a 'hand-as-object' response. These questions are addressed in Research Focus One.

Research Focus One

(a) To what extent do non-signers produce hand-as-object responses and does the proportion of such responses differ according to communicative condition?
(b) Does the proportion of non-signers' hand-as-object responses increase between the first and second half of the experiment?

Having examined the degree to which participants give hand-as-object responses, our second focus is on whether they are consistent with the handshapes that they do use to represent objects, and whether there are any indications of conventionalisation occurring. First, we compare the range of non-signers' hand-as-object responses to that of fluent signers to illustrate the target set of handshapes that a learner of a signed language would need to narrow down to. For this comparison, we use the non-signing participants from Condition A, where all participants only gesture to a camera, as in Janke and Marshall (2017). With the target set of handshapes clear, we will search for any indications of emerging consistency in their fledgeling system, by seeing if the range of handshapes produced by non-signers is affected by communicative condition and whether this reduces over time. These questions are formulated in Research Focus Two.

Research Focus Two

(a) Do non-signers produce a broader range of handshapes than fluent signers overall, and at the level of the individual non-signer, as expected on the basis of Singleton et al. (1993) and Janke and Marshall (2017)?
(b) Does the number of handshapes produced by non-signers differ according to communicative condition?
(c) Does the number of handshapes produced by non-signers decrease between the first and second half of the experiment?

2 Method

We used an elicited production task to probe the effect of communicative pressure (the presence of an interlocutor), interaction (feedback from an interlocutor), and time (first vs. second half of the experiment) on responses. These three variables were instantiated in four conditions. In all of them, participants produced gestural descriptions of the location and orientation of static objects. In Condition A, the task included no communicative pressure and no interaction. In Condition B, communicative pressure was created by the presence of a confederate who had to identify the picture being described to them. In Condition C, both communicative pressure and interaction were present as the participants undertook the experiment in pairs, alternating between addressor and addressee roles. As addressors, they produced gestural descriptions of objects and as addresses, they identified which picture the gesturer was describing. The final Condition, D, also included communicative pressure and interaction. It replicated that of C but for this condition, one of the pair was a confederate who restricted their productions to four classifier handshapes. These are shown in Figure 3. The task used a between-subjects design. Drawing on established methodology (Janke and Marshall 2017; Marshall and Morgan 2015), the present elicitation task used a new set of materials and had a modified design to incorporate the communicative pressure and interaction components.

2.1 Participants

We used opportunity sampling, where participants were mainly undergraduate and postgraduate students from the University of Kent, UK. A total of 100 hearing participants took part (68 female), ranging in age from 18 to 40 years (mean age 21). Conditions A, B, and D each had 20 participants (A: mean age 23; 14 female, B: mean age 22; 15 female, D: mean age 20; 14 female; 1 non-binary), and Condition C, which was conducted with participant-pairs, had 40 (mean age 21; 25 female). They were native speakers of English, reported no neurocognitive impairments, and had no knowledge of Sign Language or manual communication systems such as Makaton. In return for their involvement, they received a £10 voucher. Five fluent signers of BSL (4 female; 4 Deaf, 1 hearing) undertook Condition A of the experiment. This confirmed the target classifiers for the materials, enabling us to record when non-signers' productions coincided with those preferred in BSL. They also received a £10 voucher.

2.2 Materials

Our materials are available on our Open Science Framework OSF site: https://osf.io/9dv8n/. Here, the reader will find all orders of the elicitation tasks,[2] participants'

2 These PowerPoint presentations can be viewed once downloaded.

instructions for the different conditions, three Excel data files containing the trials, anonymised results, coding schemes, and participant background information, a data dictionary accompanying the Excel files, and the R scripts used for analyses.

The task was presented on Microsoft PowerPoint slides and had 40 experimental trials. For each trial, a laptop screen showed four photographs of the same objects positioned and/or oriented slightly differently, as illustrated in Figure 2. The borders of two of the four photos were highlighted, indicating which two photos the participant should describe. Their task was to use silent gestures to first describe how the objects were situated in the blue-framed picture and then how their location and/or orientation had changed in the red-framed one. The use of four photos ensured that participants in conditions B, C, and D continued to pay attention to the gestures being produced. Had there only been two, once the first picture had been identified, there would have been no reason to maintain any focus on the details of the second picture.

All objects were selected to be represented by one of four handshapes from the BSL classifier inventory: G, B, C, and Claw 5 (Brennan et al. 1984), as illustrated in Figure 3.

These occurred throughout the trials with equal frequency so that there were four sets of trials, with each set targeting one of these handshapes. Several different

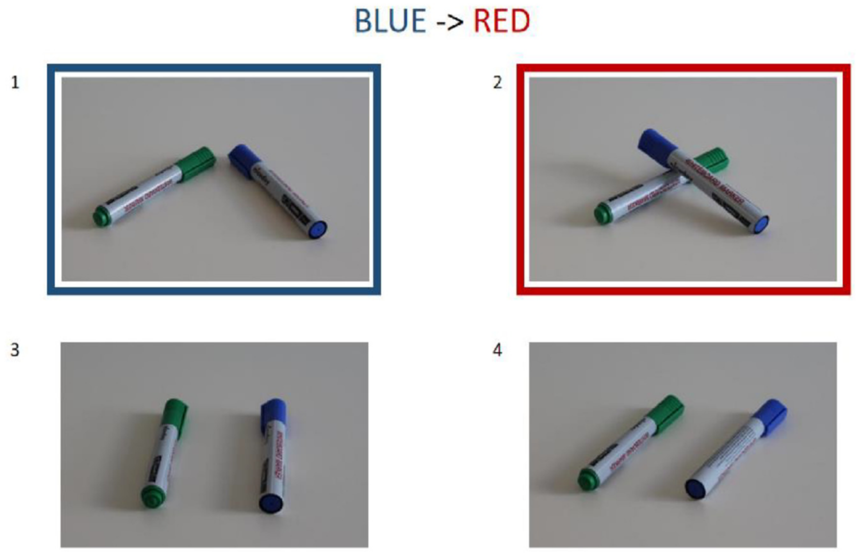


Figure 2: An example trial indicating the photo lay-out and how the two target pictures were highlighted.

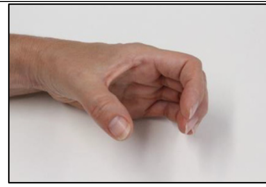
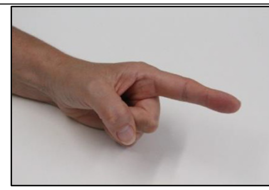
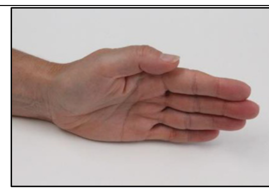
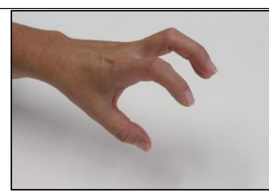
C-hand (*CURVED-1* in Handshape Inventory) Four curved fingers opposite a curved thumb.	
G-hand (*EXTENDED-1* in Handshape Inventory) Index finger extended straight from a closed fist.	
B-hand (*FLAT HAND-1* in Handshape Inventory) Straight, flat hand with fingers together.	
Claw-5 (*CURVED-12* in Handshape Inventory) All five fingers separated and bent.	

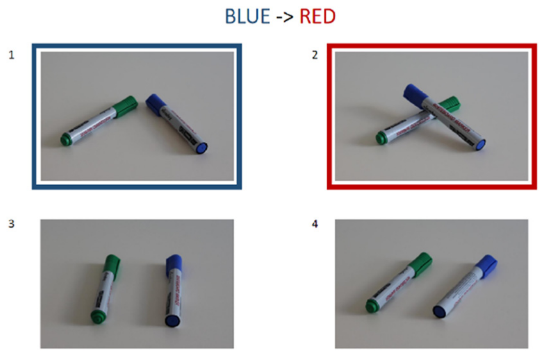
Figure 3: The four target handshapes.

objects were chosen for each hand shape and the classifier handshape for each of these objects had been checked with native signers of BSL.

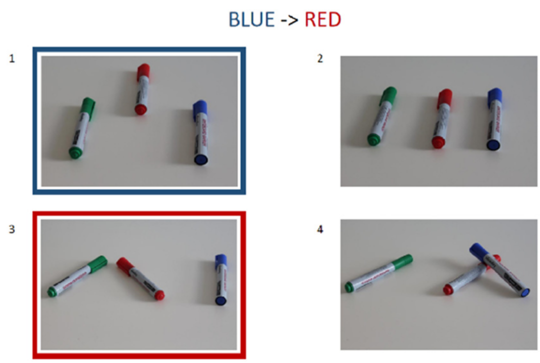
The present study's set of materials departed from Janke and Marshall's (2017) materials in a number of ways. Trials excluded toy people and toy cars to ensure objects were life-sized and all objects were photographed in the lab with the same plain white background to eliminate any unnecessary visual distraction. The trials in each set were divided according to how many objects of different types (i.e., that would elicit different handshapes) appeared in each trial. Another important addition was that the systematicity of the trials was increased in terms of item distribution. That is, the same number of trials was created for each expected classifier handshape and the same number of trials for each type of object. These are listed in (1) and illustrated in Table 2. The full list of objects is provided in Appendix 1.

Table 2: Illustration of the five different types of trial.

a.



b.



c.

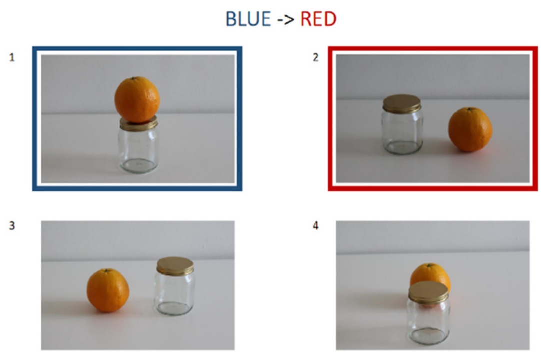
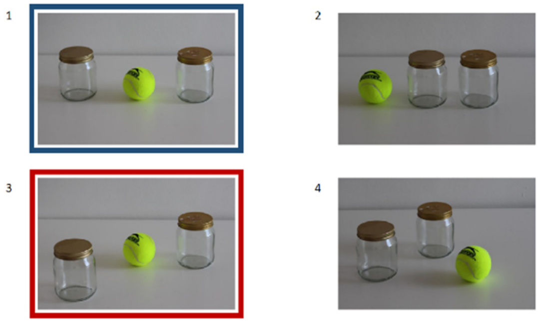


Table 2: (continued)

d. BLUE -> RED



e. BLUE -> RED

(1) a. 2 × locative trials with two tokens of an object
b. 2 × locative trials corresponding to (a) but with three tokens
c. 4 × locative trials with two objects of different shapes, each targeting a different handshape
d. 4 × locative trials corresponding to (c) but with three objects, where two are identical and the third is different
e. 2 × distributive trials with six or more tokens of the same object

The trials in (1a) created a simple way to elicit classifier-like handshapes as the two objects were the same and each could be depicted with one hand. The trials in (1b) built on (1a), using the same object but increasing the number of tokens by one. This meant that the three objects could not be depicted simultaneously so participants faced the problem of how to represent an array of objects where the number of objects exceeded the number of hands. Janke and Marshall (2017) noted that trials of this kind had proven challenging, resulting in several interesting innovations. The trials in (1c) further encouraged participants to adopt handshapes that reflected the objects' shape as the two objects used were of different shapes, potentially eliciting different handshapes. Moving to (1d), these trials included the same objects as the corresponding (1c) trials but increased the tokens by one so again there were more objects than hands. Lastly, the distributive trials in (1e) represented plural forms in BSL. These further probed the strategies used by participants when practical restrictions forced them to describe objects sequentially. Trials were pseudo-randomised with four different orders created and each participant was assigned to one of the orders created.

A camera was positioned directly above the participant to gain a bird's-eye view of their hands and the laptop screen. Faces were not filmed. It was clear to the participant that the recording area captured all the gestures produced so they did not need to be concerned about the locus of their gestures.

2.3 Procedure

The experiments were run in the Kent Linguistics lab. Participants first completed a brief questionnaire, which checked language background, level of education, and confirmed that they had no learning needs diagnosis. They sat at a desk in front of a laptop situated slightly to their left. Task instructions appeared on the screen, after which the experiment started. Participants had unlimited time to read the instruction slides and were encouraged to ask questions. Once confident that they understood the task, they proceeded to two practice trials. The experimenter stayed in the room for the duration of these in case further questions arose. Once these trials were completed, the participants continued to the experiment.

For Condition A, the experimenter left the room. This reduced self-consciousness and minimised the risk of attempts at communication with the experimenter. As the only person in the lab, the participant did not gesture to anyone or experience any interaction. For all 40 trials, participants saw four photographs on a screen, which showed the same objects in different spatial arrangements, labelled 1–4. Two of the pictures had a coloured border, one blue and one red. They were instructed to use just their hands to first depict the objects in the picture with the blue border, and then depict the objects in the picture with the red one, demonstrating what had changed between them. Once a participant had gestured both pictures, they pressed the space bar to progress to the next trial. They remained silent for the duration of the experiment.

For Condition B, participants gestured their responses to a confederate, whose sole role was to identify the pictures they were depicting. This introduced an element of communicative pressure to the procedure. The confederate sat opposite the participant in front of a different laptop. The participant knew that the confederate could see the same pictures but with one crucial difference: the confederate's pictures were not highlighted so they could not know in advance what pictures needed to be described. The difference between what the participant and confederate saw is shown in Figure 4. After the participant had silently gestured the two target pictures, the confederate wrote down the numbers of the two pictures. The confederate wrote down an answer uniformly each time the participant had finished gesturing and maintained a neutral face, giving no indication as to which pictures she had chosen. Both remained silent throughout the experiment. As with Condition A, participants completed 40 trials.

Condition C was conducted in pairs, with each participant sitting in front of a laptop and opposite one another. They did not know each other and were asked to remain silent. Throughout the experiment, they alternated between addressor and addressee roles. As addressors, they produced gestures describing the objects to their partner. Like Condition B, they knew their partner could see the same pictures as them but that none were highlighted. In the addressee role they had to identify and write down the picture being described. This condition included communicative pressure and an element of interaction because in the addressee role, they witnessed how the addressor depicted objects that they would need to depict come their turn. In this condition, two participants alternated between 40 trials, which meant that they produced gestures for 20 trials and interpreted them for the other 20.

Like Condition C, Condition D was conducted in pairs, with each participant sitting in front of a laptop and opposite one another. They also did not know each other and remained silent. Throughout the experiment, participants alternated between addressor and addressee roles. As addressors, they produced responses describing the objects to their partner, whose job was to identify the picture being

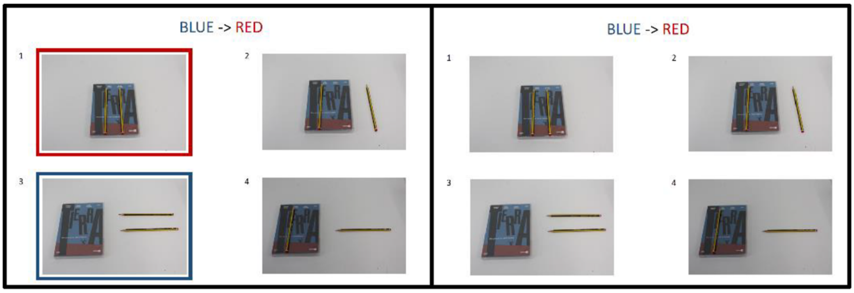


Figure 4: The trial on the left shows the participant's view and the one on the right shows the confederate's view.

described. However, in this condition, one participant was a confederate, who only produced the four target classifiers (B, G, C, Claw 5). Like C, this condition introduced communicative pressure and an element of feedback because in the addressee role, they witnessed how the addressor depicted objects that they would need to produce come their turn. Unlike C, the responses they witnessed were consistent and restricted. The participants alternated between 40 trials, which meant that they produced gestures for 20 trials and identified them for the other 20.

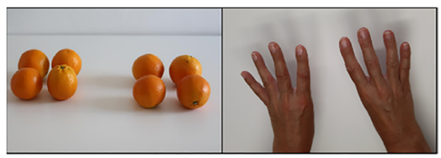
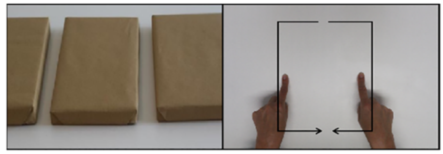
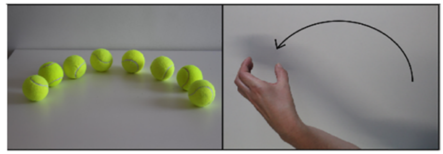
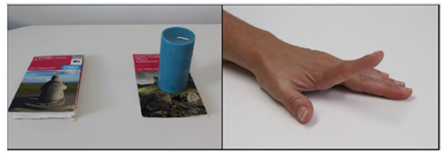
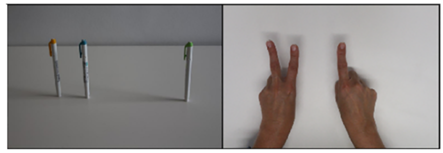
2.4 Coding

Janke and Marshall's (2017) coding scheme was used as a base to categorise handshape responses. This scheme had been created to capture those handshapes that formed part of the BSL inventory and those that did not. It was based on Brennan et al.'s (1984) classification scheme, which divides hand shapes into five groups: fully closed, curved or bent fingers, fingers together, fingers spread, and fingers extended from a closed fist. Within these groups, both BSL handshapes and non-BSL handshapes were included. The non-BSL handshapes were a mix of handshapes that might occur in other Sign Languages as well as those that would not. When participants used handshapes that Janke and Marshall's scheme could not capture, the inventory was expanded. This was anticipated since the materials in the present study were different. A full inventory of the handshapes produced by participants is provided in Appendix 3. Thus when a handshape was produced to represent each object, this was classified as 'hand as object'.

A participant's response was classified as 'Other' when they produced a response that did not use a hand to represent an object, such as pointing, tracing or producing whole-body enactments. These codings can be seen in Table 3. Most categories are transparent but the last two require some explanation. In all but one trial, these categories were used when the participant was faced with a trial consisting of three or more objects. In this instance, two strategies to represent the array simultaneously were exploited. One was when the participant created what we have termed an 'unanalysed whole', where they did not attempt to represent each object but instead used their hands to depict the overall shape of the complex of objects. The other occurred when the participant used digits on one hand to represent a plurality of objects. Notably, this 'short-cut' was not limited to long, thin objects but employed for objects of different shapes, too. Examples of these are discussed in the Results section.

The recordings of each experiment were clipped into 40 vignettes, each containing one trial. Responses were coded independently by two experimenters (the first and second authors) using the inventory outlined. Any disagreements were discussed and resolved by watching them again.

Table 3: Coding of responses: ‘Hand as Object’ and ‘Other’ (pass; enactment; point; count; index-finger trace; whole-hand trace; unanalysed whole; short-cut).

Responses		
Hand as Object	Handshape is produced to represent the object	
Pass	No response	
Enactment	Whole body used to act out scene	
Point	Index finger used to point at location of objects	
Count	Digits used to count number of objects	
Index-Finger Trace	Index finger used to trace outline of objects	
Whole-Hand Trace	Handshape produced but never settles, with a continuous tracing movement, representing object shape or object cluster	
Unanalysed Whole	One or two hands illustrate the overall shape of an object cluster	
Short-Cut	Digits on same hand used to represent individual objects	
		

2.5 Ethics

This study was carried out with the approval of the University of Kent's Central Research Ethics Advisory Group for Human Participants. All participants gave written, informed consent.

3 Results

As per our Methods section, our data, and the scripts used for the additional R analyses (see Note 3) are uploaded on our Open Science Framework OSF site: https://osf.io/9dv8n/. Starting with Research Focus One, our first questions centred on the extent to which non-signers produced hand-as-object responses, and whether the proportion of these responses differed according to communicative condition. Note that in conditions A, B, and D, 20 participants contributed data (the confederate's data in D were not analysed), but Condition C generated data from 40 participants, who had worked in pairs. To enable equal sample sizes and meaningful analyses between these four conditions, we used data from only the first participant in each pair of Condition C, which made the number of trials comparable to those in D. Table 4 illustrates the proportion of responses across the four conditions. It divides responses into the two main types: those coded as 'Hand-as-Object' and those coded as 'Other' as per Table 3. As illustrated in the second column of Table 4, the percentage of hand-as-object responses was above 80 % in all conditions. Condition A, with no communicative element, generated hand-as-object responses 81 % of the time. In B, where a participant gestured to a passive recipient, the figure increased to 86 %. In C, which comprised two naïve participants gesturing to each other, the percentage rose to 91 %. Finally in D, which

Table 4: Percentage of 'Hand-as-Object' and 'Other' responses according to condition (A, B, C, D) and experiment half.

Condition	TOTAL Hand as Object	TOTAL Other	Trials 1–20 Hand as Object	Trials 1–20 Other	Trials 21–40 Hand as Object	Trials 21–40 Other
A	81.5	18.5	80.6	19.4	82.0	18.0
B	86.5	13.5	84.9	15.1	88.0	12.0
C	91.2	8.8	91.8	8.2	90.5	9.5
D	94.3	5.7	93.8	6.2	94.8	5.2
All	88.3	11.7	87.8	12.2	89.9	11.1

coupled a naïve participant with a confederate producing a consistent set of responses, the percentage was highest, at 94 %.

The remaining columns demonstrate the extent to which hand-as-object responses increased over time by comparing their overall frequency in the first half of the experiment with that in the second. We compared the effects of experiment half and condition on the mean number of hand-as-object responses by conducting a two-way 2 × 4 mixed ANOVA, with experiment half as the within-subjects factor and communicative condition as the between-subjects factor.[3] There was a main effect of condition on hand-as-object responses (F (3, 76) = 5.89, $p = 0.001$, $\eta p^2 = 0.19$). A post hoc Tukey's HSD test for multiple comparisons showed that Condition A differed from C ($p = 0.02$, 95 %, CI = [–18.25, –1.12]), and from D ($p = 0.001$, 95 %, CI = [–21.38, –4.25]) but no other differences between conditions were significant. Despite there being a slight numerical increase in hand-as-object responses in the second experiment half, the effect of experiment half on hand-as-object responses was not significant (F (1, 76) = 0.953, $p = 0.332$, $\eta p^2 = 0.012$), and nor was there an interaction between experiment half and communicative condition (F (3, 76) = 0.587, $p = 0.625$, $\eta p^2 = 0.023$). This pattern can be seen in Figure 5.

We now turn briefly to what participants were doing when they were not producing hand-as-object responses (Table 5). These productions were categorised as 'Other' and comprised a heterogeneous set. Within this set, two categories stood out because, although for these responses participants did not use one hand per object, they did attempt to configure their hands to reflect the objects' characteristics. We termed these attempts short-cuts and unanalysed wholes. When used, they occurred when the number of objects in need of depiction superseded the number of hands. A participant would portray this plurality by using digits on just one hand to represent target objects (short-cuts) or by configuring one or both hands to capture the overall shape of a cluster of objects (unanalysed wholes). These strategies were different from the rest in this category, which included those where a participant's hands did not settle (e.g., traces) or where no attempt was made to capture the object's dimensions (e.g., pointing or enactment). We return to a discussion of these short-cuts later in light of Özyürek et al. (2010), who observed fluent signers of Türk İşaret Dili producing these forms.

Next, we move to Research Focus Two, which focused on what these hand-as-object responses looked like by examining the variety of handshapes produced.

3 One of our crucial predictor variables, Condition, had four levels (A, B, C, D). Because analyses that involve independent variables with more than two levels requiring multiple pair-wise comparisons are challenging in R (Winter 2020), we have presented the results generated in SPSS. We have, however, analysed the data in R, too, the results of which are in Appendix 1. In short, the analyses in R resulted in a significant effect of condition ($p < 0.01$) but not of experiment half ($p = 0.40$) on the mean number of hand-as-object responses.

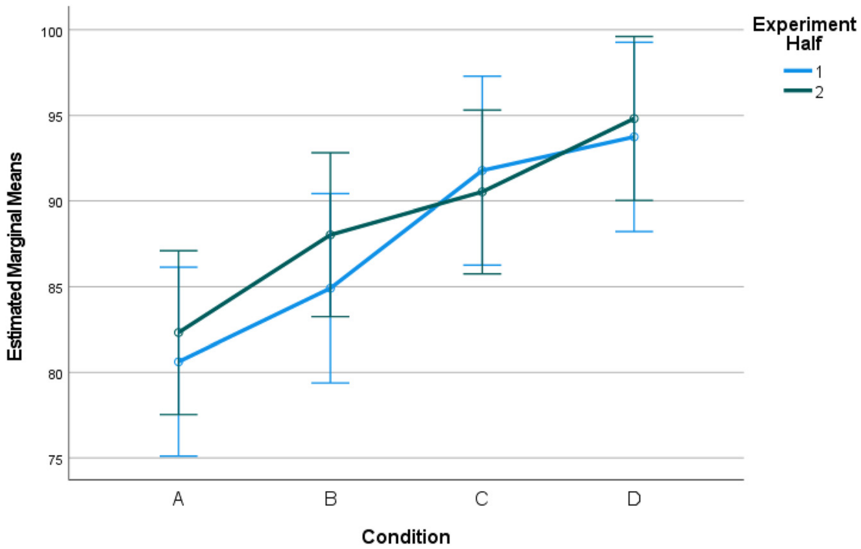


Figure 5: Mean percentage of hand-as-object responses by experiment half and communicative condition (Error Bars: 95 % CI).

Table 5: Percentage of 'Other' responses across conditions.

Condition	Responses categorised as Other								
	Total	Short-Cut	Unanalysed Wholes	Index-Finger Trace	Whole-Hand Trace	Point	Count	Enact	Pass
A	18.5	5.4	3.7	4.6	2.7	0.6	0.2	1.0	0.6
B	13.5	6.7	2.5	0.8	2.5	0.2	0.1	0.6	0.1
C	8.8	3.1	2.0	1.7	1.1	0.4	0.0	0.4	0.2
D	5.7	1.7	0.4	1.8	1.0	0.5	0.1	0.2	0.0

First, we compared the range of handshapes produced by non-signers in Condition A with that of five fluent BSL signers. We expected the non-signers to produce a substantially broader range of handshapes than the fluent signers and our first comparison checked that this was so. Table 6 shows that non-signers did indeed produce a much larger number of different handshapes overall, and in Table 7, we see that this was the case for all four key handshapes (i.e., B, G, C, and Claw 5). The table also shows that the variability of non-signers' handshapes was much greater for their representations of C and Claw 5 objects than it was for B and G objects, an issue to which we return in the discussion.

Table 6: Total, mean, median, and range of handshapes used by non-signers and fluent signers in Condition A.

OVERALL	Total number of handshapes	Mean	Median	Range
Non-signers (20)	30	7.65	7	4–11
Signers (5)	7	5.2	5	4–6

Table 7: Total, mean, median and range of handshapes used by non-signers and fluent signers in Condition A according to each target: G, B, C, Claw 5.

TOTAL		Total number of handshapes	Mean	Median	Range
G (3.01)	Non-signers	7	2	2	1–3
	Signers	1	1	1	1
B (2.01)	Non-signers	7	1.9	2	1–4
	Signers	2	1.8	2	1–2
C (4.01)	Non-signers	19	4.2	4	3–7
	Signers	4	2	2	1–3
Claw-5 (4.12)	Non-signers	16	3.4	3	1–7
	Signers	4	2	2	1–3

Moving on to focus exclusively on the non-signers, the next comparison examined the range of handshapes produced by non-signers, and whether this differed according to communicative condition. Note again that there is a discrepancy in the amount of data being produced in the four conditions, which has repercussions for our analyses of frequencies. In conditions A and B, participants responded to the full 40 trials whereas in C and D, they responded to only 20 trials (because they alternated with another person); in principle, this meant that participants in conditions A and B could have produced twice as many different handshapes as those in C and D. For this reason, the analyses on these raw frequencies were conducted on an equal number of trials. This was achieved by comparing the first 20 trials produced by participants in A and B with the entire 20 trials produced by those in C and D.[4]

4 Analysing the data in this way does raise a different issue: C and D participants receive input from their communicative partner, who might alert them to handshapes they would not have produced otherwise. This gives C and D participants an opportunity to produce a larger number of handshapes than A and B. In Appendix 2, we include an additional analysis based on all trials gestured, which translates as 40 trials for A and B and 20 trials for C and D. Here we summarise them in brief: the

Table 8: Non-signers' total, mean, median, and range of handshapes in conditions A, B, C, and D.

Condition	Number of participants	Total number of handshapes	Mean number of handshapes	Median	Range
A: Trials 1–20	20	23	5.8	6	3–8
B: Trials 1–20	20	28	7.6	7	4–13
C: Trials 1–40 (odd trials only)	20	27	7.85	8	5–10
D: Trials 1–40 (odd trials only)	20	27	8.15	8	6–12

Table 9: Non-signers' handshapes according to condition in the first and second half of experiment.

Condition	Trial numbers	Total number of handshapes	Mean	Median	Range
A	1–10	20	4.8	5	2–7
	11–20	18	4.75	4	3–7
B	1–10	25	6.05	6	4–10
	11–20	22	6.05	6	3–8
C	1–20 (odd trials only = 10)	22	6.4	6.5	4–9
	21–40 (odd trials only = 10)	21	5.95	6	4–8
D	1–20 (odd trials only = 10)	25	6.9	7	4–11
	21–40 (odd trials only = 10)	18	5.9	6	4–8

Bearing in mind that the trials have been equalised, we can turn to Table 8, which shows that participants in Condition A produced the smallest total number of handshapes, namely 23. Those in Conditions C and D produced 27, whereas the participants in B produced 28. Considered in conjunction with the means, this indicates that, as a group, participants in A worked from a smaller handshape inventory. Individually, these participants also produced a slightly smaller range of handshapes than those in the other conditions.

We then considered experiment halves and asked if the range of handshapes was more consistent in the second half of the experiment than in the first. Once again, we equalised the number of trials for participants, which meant that for A and B, the 20 trials we partitioned into halves were taken from the first half of their set of gestures, whereas for C and D, the 20 trials partitioned into halves came from their complete set of gestures. The means in Table 9 and depicted in Figure 6 suggest

effect of condition on number of handshapes was significant ($p < 0.001$) and the effect of experiment half on number of handshapes was significant ($p = 0.016$). There was no significant interaction between condition and experiment half ($p = 0.476$). Crucially, the differences between conditions A and B persist whether half or all of the data are considered.

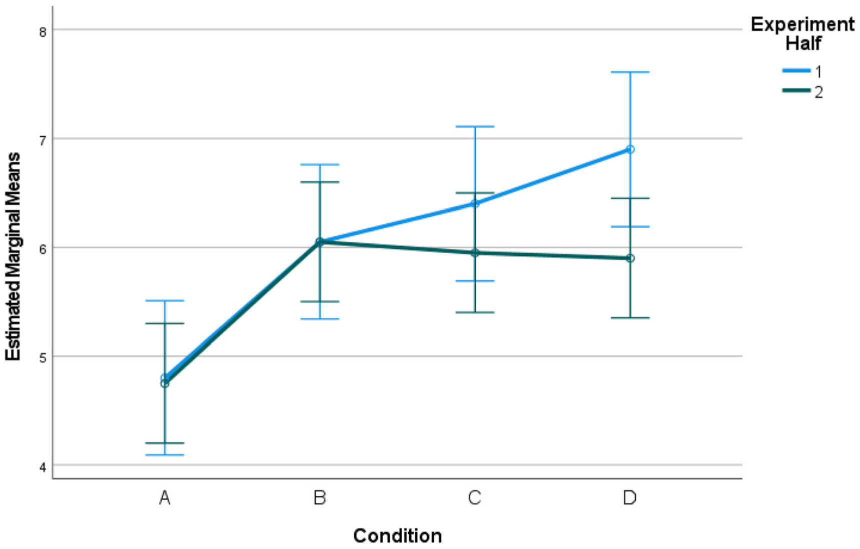


Figure 6: Mean number of handshapes by experiment half and communicative condition (Error Bars: 95 % CI).

a small decrease in the number of handshapes in conditions C and D but not in A and B.

However, the small decrease in the means we observed in C and D did not translate into significant results. A two-way 2 × 4 mixed ANOVA, with experiment half as the within factor and communicative condition as the between factor, showed a main effect of condition (F (3, 76) = 9.55, $p < 0.001$, $\eta p^2 = 0.274$) but no main effect of experiment half (F (1, 76) = 3.10, $p = 0.082$, $\eta p^2 = 0.039$) and no interaction between experiment half and communicative condition (F (3, 76) = 1.18, $p = 0.323$, $\eta p^2 = 0.045$).[5] Post hoc Tukey's HSD test for multiple comparisons revealed that the mean number of handshapes in Condition A differed significantly from B ($p = 0.002$, 95 % CI = [–2.15, –0.40]), from C ($p < 0.001$, 95 % CI = [–2.28, –0.52]) and from D ($p < 0.001$, 95 % CI = [–2.50, –0.75]). However, Condition B did not differ from C ($p = 0.982$) or from D ($p = 0.723$) and conditions C and D did not differ from each other ($p = 0.907$). Therefore, the condition that incorporated no communicative element at all, namely A, resulted in participants generating the smallest range of handshapes.

5 As with our first analysis (see Note 3), we have presented the results here as generated in SPSS. The results of our R analyses are given in Appendix 1. The R analyses also resulted in a significant effect of condition ($p < 0.01$) and not of experiment half ($p = 0.90$) on the range of handshapes.

4 Discussion

The study reported in this article considered some of the first challenges faced by hearing learners of a Sign Language, the tools that they bring to the learning task, and the conditions that might propel them to initiate a system that can lead to the conventionalisation of forms. Of the many new linguistic constructions that such learners need to acquire, we investigated classifiers. These have gestural roots and retain an iconic link between object and form yet have been adapted and conventionalised within the language in which they are embedded. Thus, by observing how non-signers produce classifier-like gestures, we strove to gain insight into what a hearing person brings from their manual gesture substrate, and what can help them to hone this heterogeneous set of handshapes into a more restricted and consistent one. We focused on two key hurdles at this preliminary stage. One is to initiate a system that represents objects in space using just their hands, namely to shape and configure their hands to emulate object characteristics. This task leans heavily on iconicity as Sign novices explore how to represent objects accurately and precisely. The other is to become more consistent within this system, and start to produce the same handshapes for similarly shaped, yet different, objects. This aspect requires a move away from strict iconicity as a one-to-one mapping between symbol and referent is supplanted by a one-to-many mapping. Our study simulated this incipient stage. We examined what non-signers brought to an elicited production task in which they needed to spontaneously describe objects with their hands, and tested whether, in the absence of explicit coaching, the variety of their productions changed over the course of a microgenetic time span in different communicative conditions.

Our discussion focuses first on the degree to which communicative conditions and time affected participants' ability to initiate a system based on hand-as-object responses. The second part turns to the question of whether condition and time impacted upon consistency developing within that system and to a decrease in the variety of forms produced. To anticipate, communicative condition affected the degree to which non-signers initiated a systematic manual representation of object properties but time did not. With respect to organisation within that system, again, communicative condition impacted on the range of handshapes produced but time, though suggestive, did not. We discuss each of these findings in turn.

4.1 Research Focus One

Research Focus One centred on the extent to which a system based on hand-as-object responses would emerge in non-signers. Of first note is that regardless of condition, non-signers utilised their hands in mostly relevant ways immediately. Across all conditions, participants produced hand-as-object responses for more than 80 % of their responses, reflecting deliberate attempts to shape their hands to approximate the characteristics of the objects they were depicting. This first observation echoes Singleton et al. (1993) and Janke and Marshall (2017), and has replicated their findings, despite using a substantially larger group of participants, a more demanding task than that used by Singleton et al. (1993), and a different set of materials. Given the varied nature of the materials used, it is impressive that the non-signers produced such a high percentage of strictly hand-as-object responses on first encountering this conceptual challenge.

Turning to the different conditions, we found that communicative pressure and the addition of an interlocutor did affect the extent to which non-signers restricted their productions to hand-as-object responses. Importantly, Condition A, which involved no communicative pressure or interlocutor, resulted in the lowest number of hand-as-object responses, namely 81 %. This figure rose gradually as layers of communicative pressure and interlocutor input were added but it was only when both these factors were present that differences reached statistical significance. That is, although the mean percentage in Condition B (87 %) exceeded that of A, this difference was not significant. Conditions C and D, however, which incorporated communicative pressure and (different kinds of) interlocutor input saw a significant jump in hand-as-object responses, totalling 91 and 94 %, respectively. This pattern suggests that both these factors encourage participants to use hand-as-object responses more frequently. If we compare the lower percentages of hand-as-object responses produced in our conditions A and B with the lack of internal standards reported in Singleton et al. (1993), our suggestion that both communicative pressure and interaction are important seems accurate. Singleton et al.'s incorporation of a passive recipient most closely resembles our Condition B. They attributed the lack of internal standards to an absence of communicative input and insufficient time. Our incorporation of conditions C and D allows us to unpack this a little further. We have shown that incorporation of a communicative partner in an interleaving task is sufficient to increase relevant productions from those produced in complete isolation (A), and from those produced under communicative pressure alone (B). However, the fact that there was no significant difference between participants in C and D suggests that the combination of two naïve participants exploring possibilities for the first time is as effective in encouraging hand-as-object responses as when a participant witnesses a more restricted and systematic set of handshapes from a confederate. For this first step towards systematicity, in which participants strive to emulate objects' characteristics by shaping their hands, it seems that presence of an active interlocutor per se is sufficient to make a difference.

We next considered if time impacted on their progression towards a higher proportion of hand-as-object productions. Recall that the experiment comprised 40 trials. We separated the first 20 trials from the last 20 trials to see whether the mean percentage of hand-as-object symbols increased. We found no effect of experiment half. Singleton et al.'s paradigm could not have revealed a change as they did not separate responses that were made at the beginning of the experiment from those at the end. To our knowledge, they also did not look at this aspect of development – i.e., production of hand-as-object responses, only at changes within handshapes themselves. We found no interaction between experiment half and communicative condition, which meant that groups made comparable progress between the first and second halves. That is, no communicative condition led to a significantly greater proportion of hand-as-object responses over time than another. It would seem that a longer period of time than the snapshot considered here would be needed in order to witness the remaining 'other' responses transfer to hand-as-object ones.

On the occasions that participants did not produce hand-as-object responses, they adopted a variety of strategies but primarily these were short-cuts and unanalysed wholes. These responses were notably different from the others in this category because they were both stable and static representations of the objects and so resembled classifier constructions more closely. The motivation for their use seemed to stem from an attempt to resolve what the non-signers considered a conflict: namely representing plurality but doing so simultaneously. The fluent signers encountered no such conflict as the temporal use of their hands was second nature to them. Interestingly, Özyürek et al. (2010) in their study of Türk İşaret Dili found examples of short-cuts in fluent signers' productions. They separated these into two different categories due to the way in which they were used. The first kind, which they described as "incorporation of number in classifier predicates" (2010: 1127), were used to describe several objects that if depicted individually, would prompt use of a G-hand (see Figure 3). In this instance, the shape of the hand closely resembled the shape of the object being depicted (for example, a pen) but also identified the number of objects (for example, three fingers extended). The second kind, which they termed "next-to forms" (2010: 1129) did not provide information about the referents' characteristics but focused instead on their positioning in relation to each other. In these cases, description of the position and spatial properties of the objects took precedence over attention to the object's shape.

The distinction drawn by Özyürek et al. (2010) between these two types of short-cuts used by fluent signers relates to our non-signers' productions in the following way. Although they used both types of short-cuts, 56 % of them were restricted to G targets, as opposed to the other three object shapes (B, C, Claw 5). This uneven distribution indicates that whilst they strived to represent plural objects simultaneously, unlike Özyürek et al.'s fluent signers, they preferred to illustrate the shape of the object. Use of this strategy indicates a strong commitment to the iconic link between the object and its referent as it maintains a representation of the object's physical properties. We see further evidence of their prioritising iconicity when we examine the way in which they used short-cuts for the C, B, or Claw 5 targets. These were only produced for trials which had three or more tokens of the same object, such as three tennis balls. When three objects contrasted in terms of their shape, for example, two oranges and a book, participants abandoned short-cuts in favour of approaches that distinguished the objects' shapes. Interestingly, short-cuts were also present on a few occasions in two of our fluent BSL signers but only 'the incorporation of number' type. They used them to depict two G objects (pens) next to an anchored object of a different shape. In these instances, the differently shaped object had been described first as it was the largest. The signers then used separate fingers to highlight the number of G objects whilst maintaining the anchored classifier that provided spatial information. One motivation for this method might be that it reduces the risk of misunderstandings: if a signer produces a G-hand twice, it could be misconstrued as an attempt to clarify the position of one G object rather than to depict two G objects next to each other.

The second ad hoc strategy that non-signers adopted when trying to represent more than two objects was what we termed 'unanalysed wholes'. A participant would configure their hands to describe the overall shape of the object cluster, sometimes with individual objects represented by different parts of the same hand. This is illustrated in Figure 7, where the left index finger represents the cigarette while the rest of the left hand is depicting a coconut. These iconically motivated responses shared with hand-as-object productions the aim of depicting the physical properties of the referents as accurately as possible. The key difference was that one hand represented more than one object. However, while this strategy was also adopted to resolve the plurality-simultaneity issue, it was used far less frequently, making up only 2.2 % of all trials.

Figure 7: Use of an unanalysed whole to depict 3+ objects.

4.2 Research Focus Two

Research Focus Two centred solely on hand-as-object responses, and the forms these took. We first compared the range of handshapes produced by fluent signers with that of non-signers. Participants in Condition A were included for this contrast, as they provided a baseline, given the absence of any communicative pressure or identification requirement in that condition. Our expectation was that non-signers would exploit a greater range of options, a prediction which was borne out. As shown in Table 3, there was a marked difference between the groups, where the mean set of handshapes produced by the non-signers was 30 and that of the fluent signers was seven. Based on the aforementioned work in Janke and Marshall (2017), the rationale was that non-signers approached the task equipped with a generous pool of gestural resources available from their co-speech gestures, and that these would feed into their explorations. This implied that a key task for learners of Sign was to narrow down from this pool. All the handshapes produced by the fluent signers were included in the set of handshapes produced by the non-signers, lending further support for this claim. With respect to the non-signers, it seemed that they came to the task comfortable with using a large array of handshapes which would need to be narrowed down to the four to six handshapes preferred by fluent signers. Different individuals might use a different sub-set of the general handshapes, but the fact that a set of 26 handshapes occurred more than five times across 100 participants with no knowledge of a signed language suggests that most people have these options to exploit. Thus, our results corroborate Singleton et al. (1993) and Janke and Marshall (2017) both of which used a smaller population and simpler tasks. In particular, prior to conducting their task using silent gesture, participants in Singleton et al. were shown all the experimental materials and had to describe each of them verbally. In contrast, ours made their productions on the hoof.

Although the overall range of non-signers' handshapes was larger than that of the fluent signers, one way in which the groups patterned similarly was that the variability of their handshapes for C and Claw 5 targets was larger than it was for B and G targets. An interesting question is why both groups' responses patterned in this way. Had this pattern only existed for the non-signers, an appeal to phonological markedness might have been made. Both B and G handshapes are considered less marked than Cs and Claw 5s (C is usually situated between B and G on the one hand and Claw 5 on the other), whether markedness is understood in terms of frequency, ease of articulation, or first-to-be-acquired in early language acquisition (Sandler and Lillo-Martin 2006). First-language learners of Sign acquire unmarked handshapes before marked ones (Siedlecki and Bonvillian 1997), and adult second-language learners produce unmarked handshapes more accurately than marked ones (Williams and Newman 2016). Ease of production might, therefore, contribute part of an answer for the pattern found here but it does not extend to the fluent signers. Another plausible reason for this pattern is the greater heterogeneity in the materials for C and Claw 5 trials than in the B and G trials. However, we think this possibility can be rejected because the materials for each category differed in size but not shape: B targets included large folders or small books; G targets included short and skinny matches and longer chunky marker pens; C targets consisted of tall bottles and short jam jars; Claw 5s had coconuts and tennis balls. A more likely explanation is that one can create a greater number of iconic handshapes for rounded or spherical objects than for flat or long thin objects. For a pencil, for example, if one were approaching the task with attention to iconicity, credible options do not extend to much more than a G-hand, H-hand (see *EXTENDED-1* and *EXTENDED-2* on the inventory), a pinky finger, middle finger or B-hand, whereas for a coconut, one could use closed or open fists, small or spread Claw 5-like shapes, various O-shapes (see, e.g., *CURVED-2* on the inventory), and closed or open C-like shapes, which multiply the options for the latter category. Thus the 16 options exploited for Claw 5s versus the seven for Gs could be understood in this context. Claw 5 and C handshapes also differ because they represent the way in which the round/spherical objects are held, adding further possible representations. A non-signer might fluctuate between entity and handling choices when depicting these.

Moving our focus to the four non-signing groups, we next considered whether their range of handshapes was affected by communicative condition and found a significant main effect. It was the lower number of handshapes in A that was the main source of the difference. Thus, the different levels of communicative pressure might affect the conventionalisation process differently. In Condition A, the participant has no contact with anyone, and their productions do not need to be identified by a partner as they work through the task, rendering this the task with the fewest demands. However, B, C, and D, in contrast, include a communicative element and or interaction. These different kinds of communicative requirements might stimulate the participant to explore more and so discover a greater range of possible handshapes. This would imply that at this early point in their development, their chief focus is an exploration of handshape alternatives to accurately depict an object's characteristics rather than a burgeoning recognition of object classes. Finally, with respect to experiment half, despite the small reductions we observed in conditions C and D, and the absence of them in A and B, these differences were not significant.

For future work, it would be fruitful to extend the microgenetic timespan we adopted here to a slightly longer period. The hints of progression suggested in the communicative conditions (recall Figure 6) but not significantly so may have become more visible with just a little more time. A further study might set participants the task twice, in two blocks, and then measure changes between these blocks. We would predict the differences between the communicative conditions

(B, C, and D) to become more prominent relative to the non-communicative one (A). In addition, we might expect a further shift between the condition limited to communicative pressure (B) and those incorporating interaction (C and D), where the latter two's slight reduction in handshapes could be an indication of the beginning of a move towards a system based on shared classes – a speculation that a follow-up study with a longer time span could resolve. Such a study might also incorporate a larger sample size. Our study was limited to 20 participants (or 20 pairs) per condition, and a larger number might have given rise to slightly different inventory, although our sample sizes are comparable to others that have used similar paradigms (N = 22 in Brentari et al. [2017] and N = 25 in Schembri et al. [2005]). Finally, the transition from spontaneously produced unschooled handshapes to those produced during an initial formal learning period, and consequently under explicit instruction, would be an exciting progression to track. A direct monitoring of the learning process would enable us to identify the type of instruction and kinds of conditions that best bolster the linguistic structuring of handshapes that must occur for these gestures to become classifiers.

5 Summary

This study considered two challenges facing learners of Sign – how to configure hands to represent differently shaped objects with accuracy and how to deploy the same handshapes to depict similarly shaped, yet different, objects. In the present experiment, we observed that non-signers found it relatively easy to start using shaping their hands to portray object characteristics, whatever the communicative condition. It seems that production of classifier-like gestures might not be difficult *per se* (cf. Boers-Visker 2020) but when transferred to a language-learning context, the challenge is of course compounded by the need to deploy classifiers during a communicative exchange crowded with numerous other novel linguistic facets. When the task is stripped down, as it was for our participants, non-signers mostly came up with a credible exemplar. This finding corroborates our earlier suggestion that a new learner of Sign embarks on the task equipped with a broad range of options available from their gestural repertoire but they must hone them. This honing is a developmental step that requires a departure from a strict 'iconicity strategy'. Freed from the constraints of iconicity, the learner can progress linguistically by generalising and so reducing the number of forms they produce to a conventionalised set. We have also seen that communicative interaction – be this unstructured (as in C) or limited to legitimate exemplars (as in D) – results in the highest proportions of hand-as-object productions. The initiation of this system, then, seems to be boosted by reciprocal exchanges, as demonstrated in Motamedi et al. (2019) for artificial sentence strings. However, further organisation within that system requires a longer time span than the one adopted here. The fact that the three conditions encompassing a communicative context resulted in a higher mean number of handshapes than the one condition that did not suggests that, at this incipient stage, communicative pressure spurs people to investigate representational possibilities rather than to curtail them.

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Author contributions: Vikki Janke: conceptualisation; formal analysis; funding acquisition; investigation; methodology; project administration and supervision; resources; writing – original draft preparation; writing – review & editing. **Lizzy Aumônier**: conceptualisation; data collection and curation; formal analysis; investigation; methodology; writing – original draft preparation; writing – review & editing. **Julia Hofweber**: conceptualisation; methodology; formal analysis; investigation; writing – original draft preparation; writing – review & editing. **Marianne Gullberg**: conceptualisation; funding acquisition; methodology; writing – original draft preparation; writing – review & editing. **Chloë Marshall**: conceptualisation; formal analysis; funding acquisition; investigation; methodology; project administration and supervision; writing – original draft preparation; writing – review & editing.

Appendix 1

To show that our results were robust and independent of random effects of subjects or items, we also present their replication using generalised linear models controlling for random effects. The results we presented in the main body of the paper were generated by SPSS, which is better suited for conducting pairwise comparisons. For both the analyses of 'hand-as-object responses' and 'number of handshapes', one of our crucial predictor variables, *Condition*, had four levels (A, B, C, D). However, analyses involving independent variables with more than two levels requiring multiple pair-wise comparisons are challenging in R (Winter 2020). In 1, we present our results in R. Condition A was set as the intercept or baseline of the comparison. In all analyses, we used the lmer.test package in *R* (Kuznetsova et al. 2017), which allows for the use of mixed models and provides the results of significance testing automatically in the form of a *p*-value. Categorical dependent variables were centred using the dummy codes "–1" and "+1". The summary tables of our results are presented using the style adopted by Ortega et al. (2019). In the analysis for Research Focus One (mean hand-as-object responses), we adopted a maximally conservative approach to random effects, allowing both items and subjects to vary by intercept and slope (Winter 2020). The analysis for Research Focus Two (number of handshapes) was conducted at the subject-level, so we considered only random effects of subjects. We present the comparisons in a table for both analyses: first for hand-as-object responses, then for range of handshapes.

1 R Analyses for Research Focus One and Research Focus Two

1.1 Comparison of the effects of experiment half and condition on the mean number of hand-as-object responses

Hand as Object (Yes, No) Predictors	β	SE	Z	*p*-Value
Intercept	2.19	0.31	7.01	<0.001
Condition B	0.53	0.41	1.29	0.20
Condition C	1.27	0.43	2.98	<0.05
Condition D	1.91	0.44	4.35	<0.001
ExperimentHalf	0.05	0.06	0.84	0.40
ConditionB:ExperimentHalf	0.13	0.09	1.37	0.17
ConditionC:ExperimentHalf	−0.14	0.14	−0.97	0.33
ConditionD:ExperimentHalf	0.15	0.16	0.92	0.36

Glmer (HandAsObject(Yes,No)~Condition(A,B,C,D)*ExperimentHalf(1,2)+(1+1|subject)+(1+1|item), data, family="binomial").

1.2 Comparison of the effects of experiment half and condition on the number of handshapes

Handshapes number Predictors	β	SE	Z	*p*-Value
Intercept	4.85	0.66	7.30	<0.001
Condition B	1.20	0.94	1.28	0.20
Condition C	2.00	0.94	2.13	0.02
Condition D	3.05	0.94	3.25	<0.001
ExperimentHalf	−0.05	0.42	−0.12	0.90
ConditionB:ExperimentHalf	0.05	0.59	−0.09	0.93
ConditionC:ExperimentHalf	−0.40	0.59	−0.68	0.50
ConditionD:ExperimentHalf	−0.95	0.59	−1.62	0.11

Lmer (HandshapesNumber~Condition(A,B,C,D)*ExperimentHalf(1,2)+(1+1|subject), data, REML=false).

Appendix 2: SPSS analysis of the effect of condition and experiment half on number of handshapes using ALL trials

As indicated in Section 3 and Note 3, the amount of data produced in the four conditions was not the same. Whereas in A and B, participants completed 40 trials, in C and D, they completed 20. In the body of the paper, we showed the results for when trials were equalised (by comparing the first 20 trials of participants in A and B with the entire 20 trials of those in C and D). Here, we show the analysis based on all the trials participants completed (i.e., 40 for A and B; 20 for C and D).

A two-way 2 × 4 mixed ANOVA, with experiment half as the within factor and communicative condition as the between factor, showed a main effect of condition (F (3, 76) = 6.100, $p < 0.001$, $\eta p^2 = 0.194$) and a main effect of experiment half (F (1, 76) = 6.013 $p = 0.016$, $\eta p^2 = 0.073$) but no interaction between experiment half and communicative condition (F (3, 76) = 0.841, $p = 0.476$, $\eta p^2 = 0.032$). Post hoc Tukey's HSD test for multiple comparisons revealed that the mean number of handshapes in Condition A differed significantly from B ($p < 0.001$, 95 % CI = [–2.50, –0.55]) but not from C ($p = 0.702$) or from D ($p = 0.336$). The mean number of handshapes in Condition B differed from C ($p = 0.017$, 95 % CI = [0.1539, 2.096]) but not from D ($p = 0.079$) and conditions C and D did not differ from each other ($p = 0.929$). These results indicate that the findings for conditions A and B are the same when we consider only half the data (as presented in the paper) or all of the data, namely that a greater range of handshapes occurs in B than in A (see Figure 8).

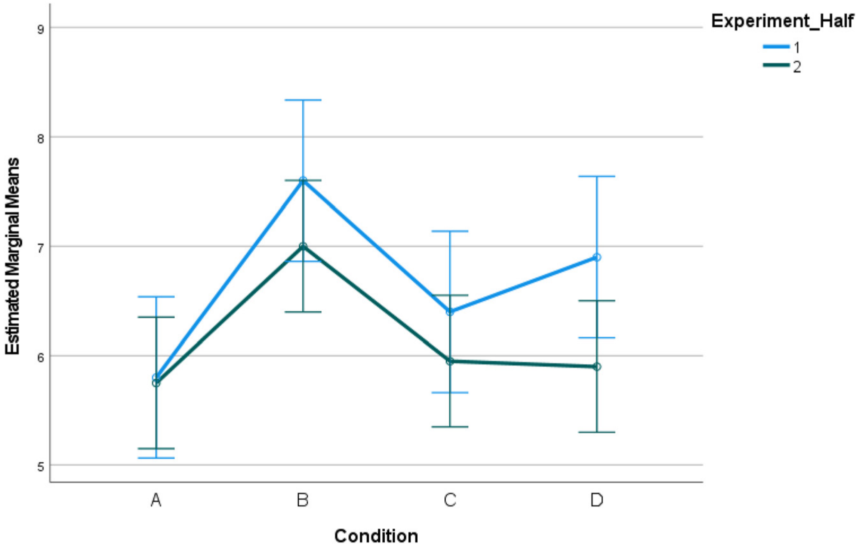


Figure 8: Mean number of handshapes by experiment half and communicative condition (Error Bars: 95 % CI).

Appendix 3: Handshape inventory

FISTS

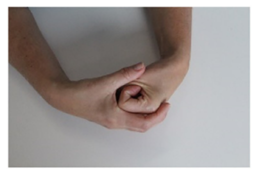

FIST – 1


FIST – 2


FIST – 3


FIST – 4


FIST – 5

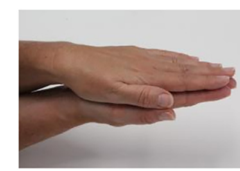

FIST – 6

FLAT HAND


FLAT HAND – 1

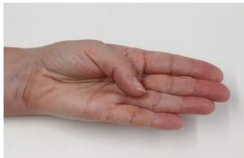

FLAT HAND – 2


FLAT HAND – 3


FLAT HAND – 4

(continued)

FISTS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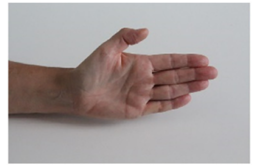
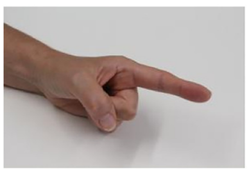
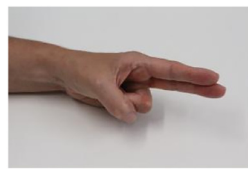

FLAT HAND – 6

FINGER EXTENDED


EXTENDED – 1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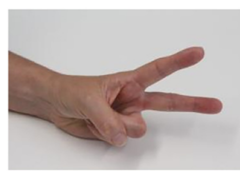
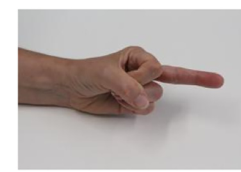
EXTENDED – 3


EXTENDED – 4


EXTENDED – 5

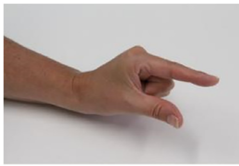

EXTENDED – 6


EXTENDED – 7


EXTENDED – 8

(continued)

FISTS


EXTENDED – 9


EXTENDED – 10


EXTENDED – 11


EXTENDED – 12

CURVED OR BENT


CURVED – 1

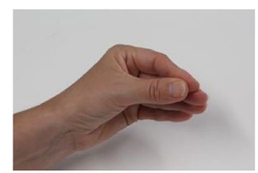

CURVED – 2


CURVED – 3


CURVED – 4


CURVED – 5

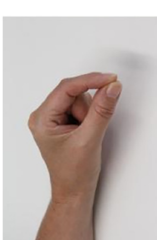

CURVED – 6

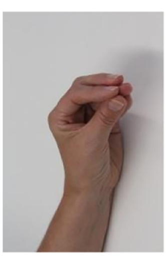

CURVED – 7


CURVED – 8

(continued)

FISTS


CURVED – 9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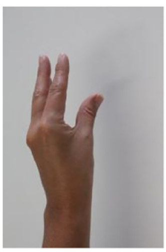
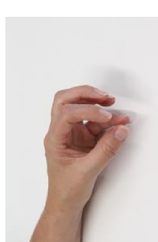
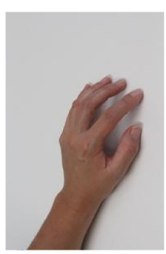
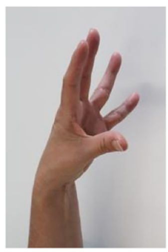
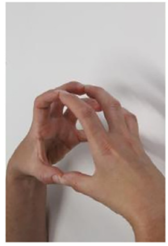

CURVED – 11

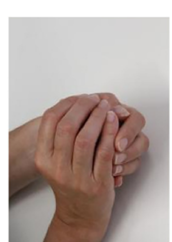

CURVED – 12

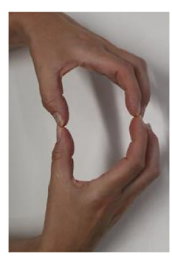

CURVED – 13

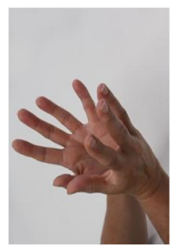

CURVED – 14

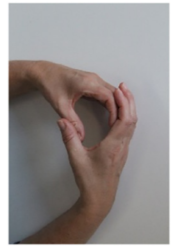

CURVED – 15

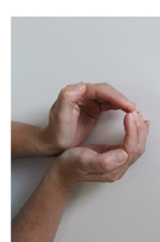

CURVED – 16


CURVED – 17

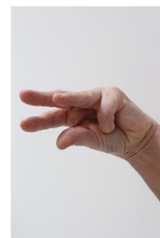

CURVED – 18


CURVED – 19


CURVED – 20


CURVED – 21


CURVED – 22

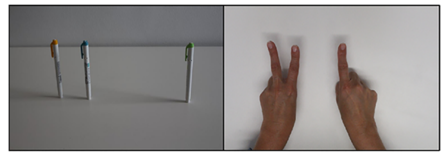

CURVED – 23

(continued)

FISTS

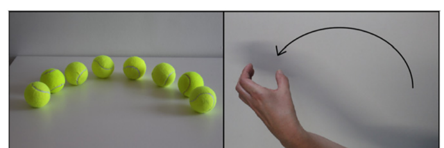
OTHER (i.e., NOT HAND-AS-OBJECT RESPONSES)

Short-Cut



Unanalysed Whole

Whole-Hand Trace



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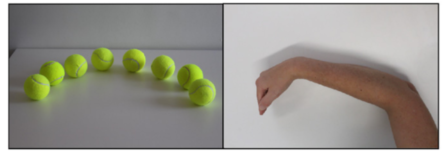
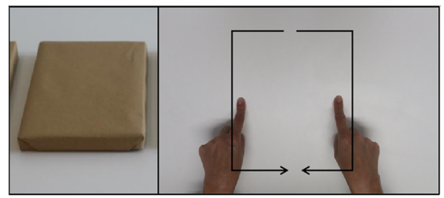
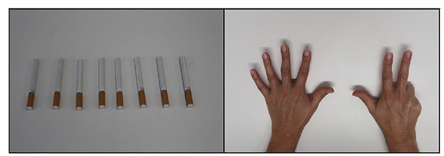
FISTS	
	
Index-Finger Trace	
Counting	
Pointing	

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