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An Experimental Investigation of the Factors Supporting the Emergence of Spatial Agreement in Nicaraguan Sign Language

Emily Marie Carrigan, Ph.D.

University of Connecticut, 2016

Studies of natural language emergence provide unique opportunities for examining the learner-internal and environmental factors underlying language development, but lack the control of factors necessary to test hypotheses about language development. By 'language development,' I intend to encompass both language acquisition and modern-day language change/emergence, which I argue are driven by many of the same factors. Researchers of Nicaraguan Sign Language, an emerging language, have proposed that intergenerational transfer and particularly child language-learning mechanisms (e.g. the propensity to 'reanalyze' and systematize inconsistent input) shape the development of the language. We observe this potential pattern in the emergence of the systematic use of space to express argument structure from the first to the second cohort, but are unable to confirm it using only naturalistic data. I used an experimental semiotics approach to ask whether interaction between individuals in the same "generation" of adult hearing gesturers was sufficient to encourage the emergence of spatial devices to express argument structure like those of established sign languages. Pairs of adult, hearing non-signers participated in an interactive gesture communication task designed to elicit the use of space to express argument structure. No pairs spontaneously generated linguistic spatial devices for expressing argument structure as complex as those in established sign

languages, but their strategies resembled such devices in some ways. For instance, hearing gesturers did represent the actions of different characters in distinct spatial locations, and some hearing gesturers generated separate gestures for identifying characters independently of their spatial location (similar to ‘lexical items’). I conclude that while interaction promotes a degree of systematicity in this communicative task, it is not solely responsible for the emergence of complex linguistic devices like the use of space to express argument structure. I further discuss how this work informs the cross-disciplinary discussion on how (or whether) to distinguish gesture from language, our classification of spatial devices for argument structure in established sign languages as gestural or linguistic, and hypotheses regarding learner-internal versus learner-external contributions to language development.

An Experimental Investigation of the Factors Supporting the Emergence of Spatial Agreement in Nicaraguan Sign Language

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B.A., Wellesley College, 2006

M.A., University of Connecticut, 2012

A Dissertation

Submitted in Partial Fulfillment of the

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at the

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Emily Marie Carrigan

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APPROVAL PAGE

Doctor of Philosophy Dissertation

An Experimental Investigation of the Factors Supporting the Emergence of Spatial Agreement in Nicaraguan Sign Language

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2016

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Chapter 1: Introduction

1.1 Purpose

The research in this dissertation investigates how the process of language emergence unfolds. In particular, I aim to clarify the environmental conditions necessary for, and language learning mechanisms responsible for, certain types of language change. This dissertation focuses on one case of modern-day language evolution: the emergence and development of Nicaraguan Sign Language (NSL). In this emerging language, we observe new grammatical devices developing as the language is acquired by different generations of users. However, naturalistic data cannot definitively identify the factors supporting the emergence of these devices. Therefore, this dissertation uses an experimental paradigm to test a hypothesis about the emergence of one linguistic device in NSL—the consistent use of space to represent argument structure.

1.2 Theoretical framework

Languages use different devices to represent argument structure, that is, to express how arguments relate to predicates. English, for instance, uses word order—in a basic sentence arguments that precede the verb are typically subjects or agents, and arguments that follow the verb are typically objects or patients (Greenberg, 1963). Other languages use morphological markings to designate the semantic or grammatical role of arguments. Many signed languages have a spatial morphological system for representing argument structure, which takes unique advantage of the modality in which these languages occur (e.g. Casey, 2003). Specifically, referents are linked to arbitrary spatial locations (that is, to locations which do not necessarily reflect the actual spatial configuration of the entities

to which they refer), which can then serve as linguistic placeholders for the referents in the remainder of the discourse (Bellugi et al., 1987; Padden, 1988; see Figure 1 in Section 2.2). Verbs can be moved between referential loci (‘R-loci,’ Lillo-Martin & Klima, 1990) to indicate the thematic or grammatical roles of the referents with respect to the verb. Like case-markers in spoken languages, the starting and ending locations of the verbs serve as morphological markings; modulating verbs in this way is referred to as 'verb agreement'[1].

Senghas and colleagues (1997, 2001) and Senghas (2003, 2010) examined how spatial modulations (that is, moving manual gestures toward non-neutral locations) are used for argument structure across different groups of users of Nicaraguan Sign Language at a special education school in the capital city, Managua. Signers were divided into groups according to their year of entry into the school—though the divisions were initially somewhat arbitrary (a median split of year of entry for the signers who participated in the earliest studies), they have corresponded with clear changes in some lexical and grammatical aspects of the language. For instance, although some signers in the first cohort (those who entered the school between approximately 1974 and 1983; R. J. Senghas, Senghas, & Pyers, 2005) do spatially modulate their gestures, the cohort as a whole does not consistently produce or interpret the directionality of these spatial modulations. The second cohort (who entered the school between approximately 1984 and 1993), in contrast, is consistent in producing and interpreting spatial modulations in the expression of argument structure.

[1] There is some disagreement regarding whether this use of space with verbs constitutes agreement (see, e.g. Liddell, 2000)—this will be addressed further in Section 2.2.

Sign languages can also analogically represent spatial relations that occur in the real world. It is therefore possible to use space to talk about "where" characters are located in addition to using space to talk about "who" did what (this will be further addressed in various parts of Section 2). The two uses of space are distinct for native users of established sign languages (Emmorey et al., 1995). While space is often used in established sign languages for "where," one crucial feature of the use of space for argument structure ("who") is that the relative positions of R-loci can be decoupled from the relative spatial locations of referents in the real world. Senghas (2010) showed that the use of space to represent argument structure in NSL did not arise directly from a use of space to describe the relative location of items. Instead, Senghas and colleagues (2001, 2003, 2010) propose that the process of intergenerational transfer is crucial for conventionalizing of the use of space for argument structure. Senghas (2010) suggests that the language acquisition mechanisms of the second cohort allowed a "reanalysis" of the input provided by the first cohort such that they made consistent a previously inconsistent use of space. Specifically, this "reanalysis" mechanism has to do with the propensity of children to consistently interpret and produce particular form-meaning mappings (grammatical form-function mappings) when those mappings are inconsistent in their input.

However, perhaps intergenerational transfer is not necessary. It is important to point out that the first cohort signers of NSL needed to conventionalize many aspects of language in a short time period; therefore, perhaps the grammatical use of space for argument structure simply required more resources than they had available. The experimental work discussed in this dissertation tests whether the consistent use of space

for argument structure (that is, a spatial agreement system) can be innovated without intergenerational transfer. In the three studies reported here, I asked hearing individuals who had no experience with a natural sign language to gesture, without speaking, about simple video events to a partner who had not seen the events, and who was required to select a picture that matched the producer's description[2].

The Interactive Gesture Communication Paradigm developed for and used in this dissertation encourages the development of a spatial agreement system in several ways. First, the experiment is modeled on experimental semiotics work showing that interaction is crucial to the development of regularity and structure (e.g. Galantucci & Garrod, 2010; Galantucci, Garrod, & Roberts, 2012; Garrod, Fay, Lee, Oberlander, & Macleod, 2007). Two participants interact in each study, and they take turns, over a high number of trials, in producer/describer and receiver/comprehender roles. Second, participants stand, highlighting the affordances of their bodies (e.g. Clark, 1997) and the possibility of using the physical space around them to represent characters. Third, the stimuli feature actions that typically elicit the use of spatial agreement in established sign languages (verbs of transfer; Meir, 2002). Finally, the stimuli are structured to draw participants' attention to the use of space as a cue to the characters' identities in the first part of each experiment, and then this reliability is either continued or selectively removed in different ways to assess whether spatial features of their productions are being used to express "who" or "where," and how their use of space changes over multiple interactions.

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[2] Hearing gesturers are somewhat different from the deaf individuals in the first cohort of Nicaraguan Signers, especially in the fact that hearing gesturers have exposure to a fully structured first language. However, both are modern humans with modern human brains, and the field of experimental semiotics (of which this dissertation is one example) is founded on the premise that observing the genesis of human communication systems in the lab can provide information about the learner-internal and learner-external factors relevant to language development.

1.3 Research questions

The overarching question to be answered in this dissertation is whether participants in the Interactive Gesture Communication Paradigm can use space in a consistent way for argument structure. The dissertation contains three studies that aim to answer this question.

In **Study 1**, I aimed to establish a baseline for hearing gesturers' use of space in the task. The stimuli remained stable throughout the task in a way that drew participants' attention to the possibility of using space as a means for representing argument structure, and allowed them a sufficient number of trials in which to conventionalize their use of space.

Studies 2 and 3 begin with the same stability that Study 1 has, encouraging participants to use space to represent the characters. However, halfway through the experiment, the stability is disrupted to get at how robust the spatial strategy is that participants used in the first half. In the second half of **Study 2**, I required participants to focus on both the locations of the characters and their semantic roles. In the second half of **Study 3**, I manipulated the stimuli such that providing information about the characters' spatial locations might actually hinder performance in the task. With these manipulations I aimed to see whether any strategies generated in the first half that used space for representing argument structure were maintained when the stability of the environment changed, and if the strategies changed, how they did so.

The following table summarizes the question posed in each of the three studies:

	Question Answered
Study 1	*Do participants use space at all in their descriptions of these events? (Baseline use of space; Does not distinguish between "where" and "who")*
Study 2	*How do participants use space when they must attend to both the "who" and "where" of characters?*
Study 3	*Can participants use space for "who" (ignoring "where" characters are)?*

Table 1. *Summary of the questions addressed in Studies 1, 2, and 3.*

In order to get a sense of what uses of space were possible in the paradigm used in this task, I asked native users of American Sign Language (ASL) to complete Study 3 in ASL. These signers use a language that has several devices for using space to represent argument structure. Measuring ASL signers' use of space in my task: 1) confirms that the stimuli in my tasks do in fact elicit spatial modulations; 2) provides examples of the types of spatial modulations that may be used; and 3) provides a baseline regarding both the degree to which spatial modulations can be used, and how consistently they can be used.

1.4 Significance

The results of these studies are a first step in addressing the hypothesis proposed in the NSL literature regarding whether vertical transmission is necessary for spatial modulation to emerge as a linguistic device. The paradigm used in this work is novel one that draws on large bodies of research in several domains (sign language linguistics, experimental semiotics, language acquisition, and language emergence). This findings inform important questions in several of these fields: the cross-disciplinary discussion on how (or whether) to distinguish gesture from language; the cognitive and linguistic foundations necessary to use spatial devices for argument structure, and the classification of such devices in established sign languages as gestural or linguistic; and hypotheses

regarding the learner-internal versus learner-external contributions to language development.

In the present work, I define criteria for characterizing a communication device as "systematic" or linguistic. The specific operationalization of features which have heretofore been discussed in less concrete terms furthers defines the meaning space in which researchers debating the language/gesture divide operate. Studying how space is used by individuals who have no experience with a sign language tells us more about the complexity of the use of space as a linguistic device. It may be the case that the systematic use of space for argument structure is cognitively more straightforward to generate than previous research has been able to show, if individuals are not distracted by having to generate other features of language concurrently.

Finally, if the present study finds that genesis of spatial devices to express argument structure within a single generation is possible, that would suggest that it may be the conditions of the environment more than the nature of the child brain that promotes the genesis of linguistic structure[3]. If, instead, interacting pairs of hearing adults are *not* able to generate sophisticated spatial agreement systems within the context of the experimental paradigm, other factors must be responsible for the development of this structure. I can then further explore other factors that might support its development: for instance, the number of interacting users, the structure of the interactions between and among users (as in Richie et al. 2014), transmission of the system from one generation to the next, community size, the length of time using the system, and the age of learners. In

[3] Many other differences exist between the hearing adults in my study and the deaf individuals in the first and second cohorts of Nicaraguan Sign Language. These differences will be further discussed in Chapter 6.

sum, the findings generated by this work will provide important insight regarding our understanding of language and gesture, and of the human capacity for language and language learning.

1.5 Organization of the dissertation:

1.5.1 Chapter 2

Chapter 2 contains a review of relevant literature. In particular, I define what I mean by "argument structure," and provide a brief discussion of the linguistic devices different languages might use to represent argument structure. I then describe how space is used to represent argument structure in established sign languages, and how this is acquired by children learning sign languages. I review what is known about the devices for representing argument structure in Nicaraguan Sign Language, and how the use of space for representing argument structure differs in different groups of signers. I discuss how the field of Experimental Semiotics informs this work, and describe in more detail the structure and predictions for the studies in this dissertation.

1.5.2 Chapter 3

Chapter 3 discusses the Methods for Studies 1 through 3, and the ASL signers. I describe participants, explain the structure and provide examples of the stimuli in each of the three studies, and describe the procedure for the Interactive Gesture Communication Paradigm. I also describe the coding procedures and categories, with examples.

1.5.3 Chapter 4

Chapter 4 presents the results regarding how the hearing gesturers in Studies 1 through 3 use space in their event descriptions. I describe how often participants

represent different event elements (agent, patient, or action), and then describe how often they used space in representing those elements. I present descriptive and inferential statistics regarding three measures of participants' consistency of space use, as well as how that consistency relates to rates of comprehension for all pairs. Finally, I describe how ASL signers use space in their completion of Study 3.

1.5.4 Chapter 5

Chapter 5 examines how the results of Studies 1 through 3 answer the question of whether it is possible to generate a spatial agreement system without intergenerational transfer. I discuss what the changes in participants' use of space within and across the different studies tells us about the components required for an effective and robust use of space for argument structure to develop. I also descriptively compare hearing participants' use of space to that of ASL signers, in order to see the degree to which hearing gesturers' uses of space in these studies resemble spatial devices for argument structure in an established sign language.

1.5.5 Chapter 6

In Chapter 6 I summarize the findings from Studies 1 through 3, and from the comparison of hearing gesturers' use of space with that of ASL signers. I discuss how these findings speak to the overarching question of the relative influence of learner-internal versus learner-external factors on language development. I also discuss how the results inform our understanding of the components or features of linguistic spatial devices to express argument structure, with an eye toward what linguistic and cognitive skills or tools one needs in order to effectively use such devices. I then tie this back to the emergence of spatial devices to express argument structure in Nicaraguan Sign

Language, and discuss whether members of the first and second cohorts possess the cognitive and linguistic skills necessary to use space for argument structure. Throughout the General Discussion I present suggestions for future avenues of research.

Chapter 2: The Literature

The current chapter reviews the literature that establishes both the foundation for my research questions and the means of addressing them. Section 2.1 introduces the concept of "argument structure" as I define it for the purposes of this dissertation. I provide a brief discussion of the linguistic devices different languages use to represent argument structure. In order to understand how the use of space to express argument structure might develop, it is necessary to understand the different semantic elements that can be represented using space, and the cognitive skills that support the use of space for those elements. I therefore describe in more detail how space is used to express argument structure in established sign languages (Section 2.2), summarizing the components and features of the spatial devices to express argument structure that have been identified thus far. Furthermore, I discuss how such devices are acquired by children learning signed languages (Section 2.3), and what this tells us about the cognitive complexity of these components.

In Section 2.4 I review what is known about the devices for representing argument structure in Nicaraguan Sign Language, and how the use of space for representing argument structure differs in first versus second cohort (and early-exposed versus later-exposed) signers, and how it differs from similar devices in American Sign Language. I discuss how the differences between the first and second cohort signers' use of space compare to the features of devices in older established sign languages, and identify the specific components or features missing from cohort one's use of space. I then discuss the hypothesis in the literature on Nicaraguan Sign Language that intergenerational

transfer, and particularly the minds of young language learners, is the key factor leading to the differences between the use of space in the second and the first cohort.

In Section 2.5 I discuss how I plan to test a hypothesis about natural language emergence using a laboratory experiment. I introduce the field of Experimental Semiotics, research from which has shown that certain features of language change may be studied in the lab. I discuss how the findings from experimental semiotics literature inform the structure of the experiments in this dissertation, and identify the type of experimental semiotics paradigm I plan to use to address my question.

Finally, in Section 2.6 I present the specific research questions addressed in each Study, and my predictions for the outcomes of the studies, based on the prior literature.

2.1 Argument structure

Argument structure refers to the relationship of arguments to their predicates. Predicates express events or states, and arguments express the participants in the event or state. Predicates, typically instantiated as verbs, are said to take a certain number arguments or dependents (e.g. summarized in Alsina, 2006; Comrie, 1993). For example, the verb “push” in English takes two arguments, one of which designates the entity doing the pushing and one of which designates the entity getting pushed.

The expression of argument structure in an utterance (like “the woman pushed the chair”) involves specifying the arguments (“woman” and “chair”) taken by a predicate (“push”), and their semantic and syntactic roles (agent/subject and theme/object). This process is crucial for successful acquisition of and communication using a language; in order to understand a speaker’s description of an event, the listener must know how its

participants relate to the event (i.e. who is doing what to whom). This is particularly crucial when the verb takes more than one argument of the same semantic class (e.g., animate), because both arguments could plausibly occupy either argument slot. For example, in describing an event in which a woman pushes a man, it is important to designate which animate participant (the man or the woman) is the 'pusher' (the agent) and which is the 'pushee' (the patient), as either the man or the woman could conceivably occupy either semantic role. We use grammatical devices for expressing argument structure to indicate this information, and comprehension is based on the grammar rather than the plausibility of the event (for instance, in a sentence like, "The small boy lifted the large man").

2.1.1 How do languages indicate argument structure?

Languages use different linguistic devices to indicate argument structure. English, for instance, uses constituent or word order—in a basic sentence arguments that precede the verb are typically subjects or agents, and arguments that follow the verb are typically objects or patients (Greenberg, 1963). Other languages use morphological markings to designate the semantic or grammatical role of arguments. These typically take the form of morphological affixes that either precede or follow arguments (e.g. as in Korean or Japanese), and that specify the grammatical or semantic roles of the arguments to which they are linked.

How emerging or young languages represent argument structure is worthy of study because the representation of argument structure is a fundamental component of any language. Users of emerging or young languages must select a means for representing argument structure (although this typically does not occur consciously). Although the

use of morphological markings might be classified as a more complex means of representing argument structure than constituent order, Aronoff and colleagues (Aronoff, Meir, & Sandler, 2005) point out that even as relatively 'young' languages, sign languages around the world do use morphological affixes for certain verb types. However, Senghas and colleagues note that in the earliest stages of language emergence for both spoken and signed languages, morphological complexity is limited, and word order is used more frequently than morphological markings for argument structure (Kay & Sankoff 1974, Hymes 1971, cited in Senghas, Coppola, Newport, & Supalla, 1997). In the following sections, I describe how sign languages use space morphologically in their representation of argument structure, how this system is acquired by native signing children, and how one emerging sign language (Nicaraguan Sign Language) develops the use of space to represent argument structure over multiple generations.

2.2 The use of space for argument structure in established sign languages

Many signed languages have linguistic devices[4] for representing argument structure that take unique advantage of the modality in which these languages occur. In such devices, referents are linked to arbitrary spatial locations (that is, locations which do not necessarily reflect the actual spatial configuration of the entities to which they refer). These spatial locations then serve as linguistic placeholders for the referents in the remainder of the discourse. This piece of the process has been termed 'nominal establishment' (Bellugi et al., 1987; Padden, 1988).

[4] I make a distinction here between a full spatial verb agreement system and spatial devices for expressing argument structure. Spatial verb agreement systems include features such as verb classes, in which sets of verbs require the use of space in particular ways (e.g., agreement with both subject and object). I do not expect that the hearing gesturers in my studies will develop such a system; discovering whether hearing gesturers can develop verb classes in the gestural modality is a secondary question to those I ask in the present work, and one that is beyond the scope of this dissertation. Instead, I ask whether they can develop linguistic devices for indicating argument structure.

Once the loci of referents have been established, verbs can be produced moving between referential loci (referred to as ‘R-loci,’ Lillo-Martin & Klima, 1990) in order to express the thematic or grammatical roles of the referents with respect to the verb. The starting and ending locations of the verbs indicate the subject and/or object, or agent and/or patient. The process of changing verbs in this way is referred to as 'verb agreement' in the literature. Verbs that move between two R-loci representing human entities are said to be 'inflected' for person (and are also called ‘person agreeing verbs,’ e.g. Padden, 1988).

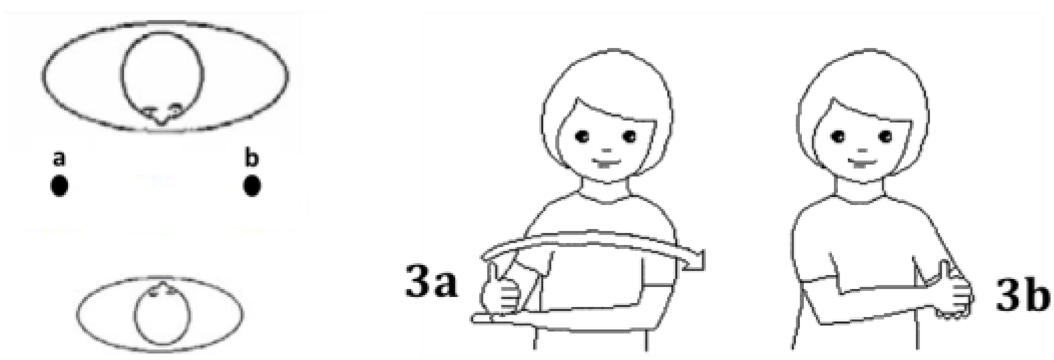

Figure 1. *Left: Possible locations—3a and 3b—that might be used as R-loci from Bauer, 2012. Right: The ASL verb HELP moving between two locations, 3b to 3a, as it would if inflected for person (original in Casey, 2003; modified for use here).*

To give an example of how person agreeing verbs work, imagine the signer at location 2 in Figure 1 wishes to describe an event in which a man helps a woman. The signer might produce the sign for "man" then point to the location at 3a, produce the sign for "woman," and point to 3b to associate those two location with the man and woman, respectively. Then the signer could produce the verb for "help," beginning at 3a and ending at 3b (as shown in Figure 1), to indicate that the character associated with 3a (the

man) is the agent and the character at 3b is the patient [5]. There is some disagreement about whether these spatial devices in sign languages serve to mark syntactic or semantic roles of the arguments (reviewed, e.g. in Sandler & Lillo-Martin, 2006). For the purposes of this dissertation, the distinction between syntactic and semantic analyses of verb agreement is not relevant, and I use the semantic/thematic terms throughout.

Bauer (2012) compiled a list of 26 sign languages around the world in which we can find what she terms 'directional' verbs. This term refers to the 'person agreeing' verbs discussed in the current section, but also includes any verbs that use space to distinguish arguments. Thus, the use of space to express argument structure seems to be a robust characteristic of sign languages around the world[6].

There is some debate about whether the use of space for argument structure constitutes a grammatical process. Liddell (2000), for instance, maintains that the R-loci are gestural rather than linguistic placeholders; in his view, referents are "fixed" at spatial locations rather than the spatial locations actually becoming equivalent to the referents. In subsequent work (Liddell, 2003), he adds that the use of space is linguistic despite having a gestural component, because gesture should be considered part of language. He nevertheless concludes that the term "agreement" does not apply to the use of space to represent argument structure. Lillo-Martin and Meier (2011) address the objections to a

[5] Established sign languages often have multiple ways of both designating R-loci and moving verbs to indicate thematic roles. Another common way of designating R-loci in ASL is to use 'role shift' (Padden, 1986). For the example in Figure 1, the signer might shift their torso to the location in 3a and produce the sign for "man," then produce the sign for "push" while their torso is still at 3a, and direct the sign toward 3b (with or without explicitly identifying the character in 3b). Non-manual devices, like directing one's eye gaze or tilting one's head toward a particular location, can also use used for nominal establishment (Bahan, 1996).

[6] Bauer (2012) notes that village languages (e.g. Kata Kolok, a sign language in Bali (De Vos, 2012), and Yolngu Sign Language, the language in Australia that is the focus of Bauer's dissertation) tend to differ both from established large-community sign languages and from one another in their use of space for argument structure. She suggests that sociolinguistic factors (e.g. size of the community, number of hearing vs. deaf users) influence how the use of space in a sign language develops. I will discuss these factors further in the discussion.

grammatical account of the use of space; they find that the use of space with person agreeing verbs interacts with other grammatical devices in sign languages in much the same way that other grammatical processes do. They conclude that the phenomenon is justly classified as "person marking," and is in many ways consistent with the linguistic process of agreement. For the purposes of this dissertation, I consider the use of space in established sign languages to be a linguistic process. However, it may be that hearing individuals' use of space is more in line with the gestural account than the grammatical account of the use of space. I will therefore take into consideration the gestural account of the use of space when analyzing the use of space by hearing gesturers in Studies 1-3.

2.3 The acquisition of person agreement for users of established sign languages

Understanding how person agreement is acquired by children learning sign language can provide a metric of the cognitive difficulty underlying this use of space. Furthermore, the errors children make during the acquisition of this system can tell about the nature of the cognitive difficulties, as well as make predictions about what we might expect to see in the *de novo* generation of the use of space for argument structure.

Bellugi et al. (1987) describe the trajectory of acquisition of person agreement in 30 deaf children acquiring American Sign Language (ASL) from their parents. They asked children between the ages of 1 year 7 months and 10 years 5 months to tell a story based on a series of cartoon pictures. The paper identifies four periods of acquisition of person agreement in ASL. In the first stage (around 2 years of age) they did not observe any use of spatial devices either to refer to characters or in the production of verbs (but children's

utterances were extremely short, and their narratives of relatively poor quality). Between 2;6 and 3;6 (the second stage) children pointed to the characters in the pictures for nominal establishment, and would inflect verbs toward pictures. They did not, however, use arbitrary loci for nominal establishment or verb inflection (as has also been found in case studies by Hoffmeister, 1978 and Loew, 1984).

The third period (between 3;6 and 5;0) was divided into two parts; in the first, children began to use more grammatical and complex sentences, but used word order as the primary device for representing argument structure (and once again did not use spatial devices during this time). In the second half of this period, children began using abstract loci for nominal establishment, but in an errorful way—they either used the same location for several referents (an error called "stacking"), or used multiple locations in an inconsistent way (e.g. not keeping the same character associated with the same location throughout their narratives). In the fourth period (by age 6), children were able to produce adult-like nominal establishment, and inflect verbs accurately.

However, other research shows that children do use space earlier than Bellugi and colleagues found. Casey (2003) found that native signing deaf children produced gestures before the age of 2;0 that incorporated directionality with present referents. These were most often "give" gestures, which were moved between either the patient and the recipient or the agent and the recipient. Other longitudinal research has found that native signing children can accurately inflect verbs as young as approximately age 2 in spontaneous production (Quadros & Lillo-Martin, 2007; Quadros, Lillo-Martin, & Mathur, 2001). It should be noted that studies of any grammatical device in spontaneous production studies are likely to find fewer errors than those in elicited narratives, which

may lead children to use devices with which they are less proficient. Therefore, the results of these spontaneous production studies do not necessarily contradict those of Bellugi and colleagues.

Quadros and Lillo-Martin (2007) suggest that the reason the types of verbs classified as 'person agreeing' are not frequently used by children of this age (both hearing and deaf) is that children of this age do not wish to express many of the meanings encoded by verbs requiring person agreement. One caveat to consider is that these three studies observed a total of 9 different children, relative to the 30 children included in Bellugi et al. (1987). In sum, although children *can* produce correct agreement with certain agreeing verbs as young as age 2, they are not fully adult-like in their use of person agreement until later in development[7].

2.3.1 Why is the acquisition of spatial morphology difficult?

According to these findings, it seems one fundamental difficulty children have in the acquisition of spatial syntax is with the association of abstract loci with non-present referents. They point to present objects (e.g. pictures) or people as substitutes for setting up non-present referents in arbitrary spatial loci (Bellugi et al., 1987; Hoffmeister, 1978, 1987). Interestingly, although they have difficulty accurately using nominal establishment with non-present referents in production until at least age 5, Lillo-Martin, Bellugi, Struxness, and O'Grady (1985) showed that children can comprehend nominal establishment as young as 3 years of age. However, their comprehension did not reach ceiling for the task until around 5 years of age. Once children do begin attempting

[7] In fact, evidence using a large-scale assessment of ASL in native and non-native deaf children (the ASL-AI, Hoffmeister, Fish, Benedict, Henner, & Rosenburg, 2013) suggests that even native deaf children's use of person agreement is not fully productive (that is, used with all the agreeing verbs included in the assessment) until between 8 and 11 years of age (Henner & Hoffmeister, in prep).

nominal establishment using abstract loci, the difficulty seems to be in maintaining a representation in memory of which location is associated with which character. Berk (2003) found that two deaf children who were exposed to ASL around age 6 produced more errors in their use of space with person agreeing verbs than with other types of verbs that use space (e.g. spatial verbs). This underscores the notion that there is something more abstract in the use of space for argument structure that makes it difficult to acquire or develop.

Newport and Meier (1985) and Lillo-Martin (1999) suggest that children's poor spatial memories underlie their early inability to use space for argument structure correctly. Emmorey (2002) reports that older deaf children have been shown to have "longer spatial memory spans" than younger deaf children, which would account for their improved ability to encode and track R-loci in the use of space for argument structure. However, no studies to date have empirically tested this relationship.

If spatial memory is the primary cognitive skill underlying the ability to use space for argument structure, we might expect the creation of spatial devices for argument structure in emerging languages like Nicaraguan Sign Language (NSL) to depend upon the age of the individuals in the community. However, to further complicate the matter, not having early access to a language model has been shown to impact cognitive development in a variety of domains (e.g. Theory of Mind, narrative structure; number cognition, non-verbal reasoning; Gagne & Coppola, under review; Coppola & Gagne, in prep.; Spaepen, Coppola, Spelke, Carey, & Goldin-Meadow, 2011; Coppola & Henner, in prep.). We do not know the degree to which spatial memory is intact in users of emerging sign languages. It may be that the second cohort of NSL signers were able to systematize the

use of space for argument structure not because they are reanalyzing input from the first cohort of signers, but because they received sufficient linguistic input at an early age to support development of the spatial cognition skills that support the use of space for argument structure. This will be addressed further in the discussion.

A second possible reason why the acquisition of spatial syntax is difficult has to do with the cognitive load required by reference tracking. Data from Deaf children's narratives supports the idea that adult-like use of spatial devices to express argument structure is difficult because it requires the individual to track and maintain the referents across utterances. van Hoek and colleagues (van Hoek, O'Grady, Bellugi, & Norman, 1990) found the use of space for intra-sentential reference was acquired earlier than the use of space for cross-sentential reference. This indicates that it is easier to maintain consistent spatial locations for referents within a clause than across clauses.

In the following section, I discuss how argument structure is represented in NSL, and how space comes to be used as one device for representing argument structure as the language evolves.

2.4 Argument structure in Nicaraguan Sign Language

Nicaraguan Sign Language first emerged in the late 1970s when a critical mass of deaf students gathered at a special education school in the capital city of Managua. These deaf children had no previous exposure to an established natural sign language (as none existed in Nicaragua at the time), and were unable to acquire spoken Spanish. Although the instruction these deaf children received at the school was in spoken Spanish, the students had the opportunity to communicate with one another using their hands and bodies during break times and in-transit to and from school. During this time, individuals

began to converge on various aspects of gestural communication, and a new sign language began to emerge. Successive generations of students entering the school (referred to as cohorts) received as their language input the conventions developed by previous generations, which they might then maintain as received or change (R. J. Senghas et al., 2005). In studying how different cohorts of NSL signers approach a particular linguistic task—for instance, the representation of argument structure—we can learn more about how certain linguistic devices emerge.

2.4.1 Use of space and word order for argument structure in NSL

Senghas and colleagues (A. Senghas, 2003, 2010; A. Senghas & Coppola, 2001; A. Senghas et al., 1997) have examined the devices used to express argument structure across 2 successive cohorts of users of Nicaraguan Sign Language: cohort one, who entered the school between 1974 and 1983, and cohort two, who entered the school between 1984 and 1993. Comparing these two cohorts, research has documented general changes in the frequency of use of different devices, and changes specifically in the systematicity of the use of space to represent the argument structure.

In analyzing how NSL signers describe events, they find that the first (older) cohort of users used a small set of word orders that reliably distinguish semantic roles. However, first cohort signers did not use their spatial modulations (movements of verbs to and from spatial locations) in a consistent fashion: that is, they did not reliably associate a spatial location or direction with a specific argument/referent. The second cohort, in contrast, uses a larger set of word orders, which distinguish semantic roles less reliably. However, individuals in the second cohort also consistently use a *spatial* device for indicating who did what to whom. The spatial device looks similar to those that exist in other sign

languages—referents are established in spatial loci and verbs are produced moving between those loci.

Senghas and Coppola (2001) found that only members of the second cohort who were exposed to NSL before the age of 10 were consistent about the ways they used space. They compared individuals from the first and second cohorts who began acquiring the language before the age of 6;6 (early-exposed), before the age of 10 (middle-exposed), or after the age of 10 (late-exposed). They noted the number of spatial modulations per verb, as well as the number of spatial modulations used for shared reference (this referred to the maintenance of R-loci across different clauses or utterances). They found that both first and second cohort signers exposed to NSL earlier produced more spatial modulations in general, but early- and middle-exposed second cohort signers produced more spatial modulations per verb than early- and middle-exposed first cohort signers, respectively. This difference was due entirely to early- and middle-exposed second cohort signers producing more shared reference spatial modulations than first cohort signers.

Senghas et al. (1997) found that the second cohort signers were more consistent in their uses of space both internally (within and across utterances) and across signers than were members of the first cohort[8]. In describing videotaped events that involved two characters, both first and second cohort signers would sometimes move their verbs toward locations previously associated with a character.

When multiple verbs were produced in an utterance, second cohort signers were more consistent in the direction of verb movement than were first cohort signers (that is, verbs

[8] Senghas and Coppola (2001) examined use of space for argument structure in NSL signers in narratives, and found the same pattern across utterances: the second cohort was more consistent in their use of space across utterances than was the first cohort.

produced in the same direction referred to the same character). Individual second cohort signers were also internally consistent in their direction of movement of verbs across utterances. Finally, different members of the second cohort were consistent in the spatial layout they used to represent actions—they produced verbs in a direction that was *rotated* with respect to their own perception of the direction of movement in the videotaped events.

Interestingly, first cohort users of Nicaraguan Sign Language used space in ways that in some ways resemble the errors children acquiring established spatial agreement systems make; they use the same location for several different referents (an error called "stacking," Loew 1984), or fail to maintain consistent loci for same characters across utterances. However, first cohort NSL signers' failure to use space coreferentially may not necessarily have been due to the same factors that underlie sign-acquiring children's difficulties with space use (that is, the cognitive load imposed by reference tracking). Their changes in use of space across utterances were driven by a variety of factors (Senghas, 1995), such as changes of scene or timeframe.

Consistency in production within and across users is only part of the story—for true systematicity, a device must not only be produced in the same way by different members of a community, but interpreted in the same way. Senghas (2003) examined whether different members of cohorts one and two were consistent in the way they interpreted spatial modulations. She asked six signers from cohort one and six signers from cohort two to comprehend a selection of the productions analyzed in Senghas and Coppola (2001)[9]. Eight of the productions included spatially modulated verbs, and signers were

[9] Four of the signers from each group completing the comprehension task in Senghas (2003) were in fact the same signers who produced the descriptions in Senghas and Coppola (2001). Thus a signer might see

asked to indicate on an array of four pictures which event or events the production could have described. For the eight productions that included spatially modulated verbs, the picture arrays showed one picture that exactly matched the direction of the event from the original producer's perspective of the video event (unrotated), and another picture that was reversed with respect to the original producer's perspective of the video event (rotated).

Senghas examined whether participants were consistent and specific in their interpretations of signed sentences with spatially modulated verbs. With respect to consistency, she asked if participants always interpreted spatial modulations to the right or left in the same ways (respectively). With respect to specificity, participants were allowed to choose more than one picture if they thought the production could describe multiple events—thus Senghas asked whether participants were willing to ascribe multiple meanings to a particular direction of verb, or whether the meaning space was more restricted.

Participants from cohort two were both more consistent and more specific than participants from cohort one. Cohort one members overwhelmingly selected pictures with both rotated and unrotated layouts when deciding which picture matched the productions with spatially modulated verbs, but cohort two members almost entirely selected only pictures with rotated layouts. Thus members of cohort two show a greater degree of consistency and specificity in their comprehension of spatial modulations than do members of cohort one.

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their own productions, but would also see productions made by other members of the same cohort and members of a different cohort.

Flaherty (2014) provides a further detailed examination of the development of argument structure in NSL. She examined both the frequency and the characteristics of word order and spatial modulation devices in production, and included an additional group of signers—known as cohort three, who entered the school between 1994 and 2003—in her analyses. She showed participants video events similar to those used in previous work with these populations (e.g. Senghas et al., 1997), and analyzed participants' productions for events containing 2 arguments (either with two animate arguments, or one animate and one inanimate argument).

One subset of her analyses examined utterances containing two nouns that represented the subject and object (802 total utterances). This is of particular interest for assessing the treatment of argument structure because the two nouns need to be related to the verb with respect to their semantic roles. She found that a majority (61%) of these utterances used SOV word order, and that the use of SOV word order did not differ depending on group. That is, signers from each cohort of NSL do not differ in their use of the primary word order. She also found that participants (again, regardless of group membership) were more likely to use SOV word order when at least one entity in the stimulus video was inanimate. This accords with experimental work with hearing gesturers by Hall and colleagues (Hall, Ferreira, & Mayberry, 2014; Hall, Mayberry, & Ferreira, 2013), which shows that hearing individuals are more likely to use SOV order when gesturing about events in which one entity is inanimate than they are when both entities are animate. This is an expedient strategy both for internal as well as external comprehension, as the possibility for confusion about semantic roles is increased when both nouns precede the verb and both entities could possibly take the agent role.

In another analysis, Flaherty examines another common word order in Nicaraguan Sign Language for describing events in which there were two animate entities. Referred to as 'paired verb constructions,' the basic structure of this word order is $Noun_1$-$Verb_1$ $Noun_2$-$Verb_2$ (e.g. MAN PUSH, WOMAN GET-PUSHED; Senghas et al., 1997). In this word order, each verb is associated with one of the animate arguments, and each character's 'perspective' of the event is represented by a single verb. Analyzing 851 utterances[10], she found that approximately 50% (424) of the utterances used paired verb constructions. Because it contains one verb for each noun, and each verb immediately follows the noun to which it refers, this construction avoids the potential confusion inherent in word orders with two nouns and a single verb.

Flaherty finds that later cohorts (including the second cohort) use the paired verb construction *more* than earlier cohorts, and all groups tend to use this construction more for events with two animate arguments than for events with one animate and one inanimate object. This appears to be contrary to the findings in Senghas and colleagues (Senghas et al., 1997) that NVNV constructions were rare in the second cohort, but it may be that the patterns of language use have changed in the time between the data collection for the two studies (likely around 15 years).

With respect to the use of space in these groups, Flaherty found that members of the three NSL cohorts used a variety of devices for nominal establishment (e.g., producing nouns in a non-neutral location, producing nouns in a neutral location followed by a point to a non-neutral location, producing an adjective in a non-neutral location immediately

[10] It is not clear whether the set of utterances analyzed here is at all overlapping with the set analyzed for the SOV/SVO analyses discussed in the previous paragraph.

following a noun produced in a neutral location). The use of a particular device did not differ depending on the group.

The three groups moved their verbs in space along three different axes (depicted in Figure 2): the Z-axis (beginning at a signer's body and moving outward in a straight line), the XZ-axis (beginning at the signer's body and moving diagonally outward), and the X-axis (from a signer's left to right or vice versa). The particular axis on which a verb movement can be relevant in determining person agreement—for instance, a verb produced moving along the X-axis might indicate third-to-third person agreement ("She gave [something] to him"), while a verb produced along this Z-axis might indicate first-to third person agreement ("I gave [something] to him"), or possibly a third-to-third person agreement in which the signer adopts the role of one character ("The woman (whose role I now adopt), gave [something] to the man"; Sandler & Lillo-Martin, 2006).

Figure 2. *Illustration of the three axes described above (from Padden, Meir, Aronoff, & Sandler, 2010). The center panel--the Z+X diagonal—is equivalent to what Flaherty (2014) terms the XZ-axis.*

Although all groups used all three axes in moving their verbs, Flaherty found that younger signers (members of later cohorts) were more likely to use the X-axis in their spatial modulations of verbs, and all signers were more likely to use the X-axis when the

patient of the event was animate. It may be that the language is developing a means of representing events that separates the signer from the representation of the event. This accords with the finding by Kocab and colleagues (Kocab, Pyers, & Senghas, 2015) that second cohort signers are more likely than first cohort signers to use a diagrammatic layout in their narratives, in which the signer relays events as a narrator rather than adopting the role of characters.

Finally, and most importantly, members of younger cohorts were more likely to use space for co-reference than members of older cohorts. Furthermore, youngers signers are more likely than older signers to use space for coreference in the most 'complete' way, in which two nouns are set up in distinct spatial locations and the verb moves from one locus to the other. Table 2 summarizes main differences in the ways cohorts 1 and 2 use space for argument structure (data from Flaherty, 2014; Senghas & Coppola, 2001).

In Production:	**Cohort 1**	**Cohort 2**
Do signers spatially modulate gestures?	Yes	Yes
Are spatial locations used contrastively?	Not always ("stacking")	Yes
Are locations maintained across utterances?	No	Yes
Percentage of within-utterance use of spatial coreference	~50%	~70%
Percentage use of X-axis	~20%	~30%
Comprehension/ interpretation of "GIVE-RIGHT"	Accept rotated & unrotated pictures	ONLY accept rotated pictures

Table 2. *Summary of differences between Cohort 1 and Cohort 2 signers in the use of space for argument structure. Data are from Senghas et al. (1997), Senghas and Coppola (2001), Senghas (2003), and Flaherty (2014).*

2.4.2 Why do we see a change from 1st to 2nd cohort?

Exactly what pressures underlie the increased use of spatial modulations by later cohorts is less clear. Perhaps the spatial device apparently innovated by second cohort signers leads to the production of fewer gestures in their descriptions? In the most common word order, signers produce two noun-verb pairs (a minimum of four separate gestures). Having to produce two verbs that represent complementary perspectives of an event (e.g., PUSH and GET-PUSHED) might require a fair amount of mental effort, although it has the advantage of being maximally clear with respect to argument structure. Perhaps having a device (like using space) that indicates the relationship of the two arguments to the verb might allow second cohort signers to drop the second verb. It does not seem to be the case that a desire to reduce the production load is driving this change: word order data from Senghas et al. (1997) indicates that 7 out of the 13 attested common word orders *do include the second verb*.

It might be possible that the use of space as a grammatical device in a manual-visual language is more modality-friendly than the use of a device like word order. While word order is inherently sequential in nature, the use of space might permit the more simultaneous articulation of features that is found in sign languages (Sandler & Lillo-Martin, 2006). Although the sequential two-verb construction used by the first cohort still shows up in the second cohort's word orders, it might be that successive cohorts drop this sequential pattern in favor of the simultaneous constructions that were made possible by the use of spatial devices.

Senghas and Coppola's (2001) findings suggest that the age of acquisition influences an individual's use of spatial modulations—but it is not clear whether the crucial

component is age of acquisition to a language generally, to a manual-visual language specifically, or to spatial modulations even more specifically. However, the fact that even late-exposed signers in both the first and second cohort spatially modulated their verbs indicates that the spatial modulation of signs is not inherently difficult or unlikely to occur.

Senghas and colleagues (Senghas et al., 1997) found that neither the first nor second cohort signers showed evidence of having a device for the nominal establishment component of spatial devices for expressing argument structure that appear in established sign languages. Flaherty (2014) finds that members of the first, second, and third cohorts *do* produce a few different devices for nominal establishment in their productions, and finds that the three cohorts do not differ with respect to their use of a particular device. However, no data exists with respect to the degree of internal consistency within person or within utterance, or the degree to which devices for nominal establishment are shared by different members of a cohort. In fact, no such published data exists for native users of established sign languages either.

The findings from Senghas and Coppola (2001) show that the earlier-exposed second cohort signers used space in a qualitatively different way than first cohort signers or later-exposed second cohort signers. The fact that late-exposed second cohort and all first cohort signers produced fewer shared reference spatial modulations in their verb gestures means that their use of space does not provide reliable information about characters' grammatical roles. Thus the use of space by first cohort and late-exposed second cohort signers does not function as a coherent means of representing argument structure. The notion that the first cohort's use of space cannot reliably represent argument structure is

further supported by the finding that the spatial modulations used by the first cohort are not consistently interpreted across different members of the first cohort.

2.4.3 Origin of spatial agreement in Nicaraguan Sign Language

Sign languages are also able to make use of the manual-visual modality to analogically represent real-world spatial information. A signer can use the signing space to describe the locations of objects, people, and places. It is therefore possible to use space to talk about "where" characters are located in an event in addition to using space to talk about "who" the characters are and/or their relative role (e.g., "the man is to the left of the woman"). This use of space for "where" is distinct from the use of so-called 'spatial verbs' in established sign languages like ASL (Padden, 1988). Spatial verbs are used to represent the movement of objects in space (Meir, 2002), while the use of space for "where" describes the relative spatial locations of two or more entities.

While space is often used in established sign languages for "where," one crucial feature of the use of space for argument structure ("who") is that the relative positions of R-loci can be decoupled from the real-world relative spatial locations[11]. Emmorey, Corina, and Bellugi (1995) report on a number of findings that suggest the two uses of space are distinct for native users of established sign languages. First, signers with brain injuries to the left versus right hemisphere show divergent errors patterns in the use of space for grammatical versus locative functions. Second, neurotypical signers also show better semantic memory for locations presented in the context of spatial verbs than for

[11] In practice, the use of space for "where" might be indistinguishable from the use of space for "who"—the difference is that the use of space for "who" can (theoretically) not match the actual spatial configuration of the referents. There is extremely limited evidence regarding the frequency of these two uses of space in natural language samples. One of the only currently published pieces of evidence comes from a corpus of British Sign Language (Cormier, Fenlon, & Schembri, 2015). The authors term the uses of space for "who" and "where," "arbitrary" and "motivated," and find that the fully "arbitrary" uses of space are extremely infrequent in their corpus.

those presented in the context of person-agreeing verbs.

Senghas' (2000, 2001, 2010) findings that the use of space for argument structure in Nicaraguan Sign Language is conventionalized prior to the use of space to represent spatial relations suggests that the two develop via distinct pathways[12]. Thus, any study that observes the use of space by individuals without exposure to a sign language must show whether any use of space for argument structure can be distinguished from a use of space to represent actual space.

Senghas (2010) argues that the use of space to represent argument structure in NSL did not arise directly from a use of space to describe the relative location of items. Senghas (2010) found that second cohort signers, who did have a conventional spatial device for representing argument structure, did not yet have a conventional, systematic use of space to describe the location of objects in relation to one another. She suggests that there may be less pressure on the use of space for locative relations to conventionalize than on the use of space for argument structure. While confusion arising from inconsistent use of space to describe locative relations can be resolved by using shared knowledge (e.g. of the spatial layout of familiar areas), or by directly indicating people and objects in the environment (e.g. via pointing), the same is not true of the use of space to represent argument structure (which is more abstract).

Instead, Senghas and colleagues (Senghas & Coppola, 2001; Senghas, 2003, 2010) propose that the process of intergenerational transfer is crucial to the conventionalization

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[12] The findings that NSL shows linguistic spatial devices for expressing argument structure before linguistic devices for representing locative relations *is* compatible with data showing that later-exposed deaf children acquire and can use spatial verbs appropriately before they do so with person agreeing verbs (Berk, 2003). It is also compatible with the finding that Al-Sayyid Bedouin Sign Language develops spatial verbs prior to developing spatial devices for expressing argument structure (Padden et al., 2010). Recall that spatial verbs describe the *movement* of objects in space, whereas the use of space for locative relations is about the relative spatial position of stationary objects.

of the use of space for argument structure. In particular, they propose that *early-exposed child learners* are the key ingredients in this aspect of language change.

Early-exposed signers in the second cohort are both internally consistent within and across utterances, and are consistent as a group in their spatial modulations. Later-exposed second cohort signers were not consistent in this way, nor were early- or later-exposed first cohort signers. Senghas (2010) suggests that the language acquisition mechanisms of the early-exposed second cohort signers performed a "reanalysis" of the input provided by the first cohort signers such that they made consistent a previously inconsistent use of space. The hypothesis that child learners changed the language is bolstered by the finding (Senghas & Coppola, 2001) that late-exposed second cohort signers do not show the same degree of consistency. If the change in consistency were simply a result of intergenerational transfer, even the late-exposed second cohort signers should have shown the same increased consistency of use of space that early-exposed second cohort signers show.

The experimental work I propose in this dissertation aims to further examine the hypotheses put forth by Senghas and colleagues. If child learners are truly necessary, we should not be able to observe the creation of spatial devices to express argument structure in an interactive experiment between two adults. I use a gesture creation paradigm based in experimental semiotics methodology with hearing adults to simulate the conditions of the late-exposed first and second cohort signers. In the following section I explain the experimental semiotics framework and its relevance to the topic under study.

2.5 Experimental semiotics methodology

The methodologies used in this dissertation draw on the field of experimental semiotics (e.g. Galantucci, 2005; Galantucci & Garrod, 2010; Kirby, Cornish, & Smith, 2008). Typically language change and language emergence are studied in two contexts: in natural environments or using computer simulations (Galantucci, 2005). In the former, it is impossible to control the features of the situation in which language change is occurring, and may even be impossible to observe those features. Computer simulations allow for the explicit identification and direct manipulation of features researchers believe play a role in language change, but lack the human component that is an essential part of language use. Galantucci (2005) points out that the complexity of human interaction still far exceeds the complexity researchers are able to model using computer simulations of human interaction.

Experimental semiotics methodology offers unique insight into the phenomenon of language change or emergence. In particular, experimental semiotics studies examine meaningful and communicative conventions generated *de novo*. The methodology uses actual humans engaged in joint actions (often the act of communication) under carefully controlled conditions. As such, it maintains the human component of naturalistic situations while allowing researchers to directly manipulate variables of interest and control the properties of the emergence context. Furthermore, experimental semiotics methodology offers a picture of change/emergence on an abbreviated time scale compared to the timescale of natural language emergence, allowing researchers to observe a broader timespan of the course of emergence (Galantucci, 2009; Galantucci &

Garrod, 2010; Galantucci et al., 2012; Galantucci & Roberts, 2012; Scott-Phillips & Kirby, 2010).

Different types of experimental semiotics research designs are appropriate for answering different types of questions. Galantucci and colleagues (Galantucci et al., 2012) summarize and describe three types of research designs within the field of experimental semiotics, and the primary goal of each type. All three designs involve pairs of individuals interacting to complete a goal specified by the experimenter, and participants are not allowed to use their native language(s) or standardized symbols in completing the task.

Semiotic matching games require participants to either discover or invent mappings between a set of forms and meanings that is pre-specified by the experimenter. This design allows maximal control of the form and meaning space by the experimenter, but limits the degree to which participants' creativity can influence the genesis of communicative conventions. Semiotic referential designs (also called referential semiotics designs) also require people to communicate about a set of referents provided by the experimenter, but participants must invent and agree with their partner on their own forms. Semiotic coordination designs are similar to referential semiotics designs, but participants are asked to complete a task that does not explicitly involve identifying or inventing forms to go with referents. Instead, participants must develop and converge on communicative conventions that enable them to complete a non-linguistic task—like coordinating the movements of two virtual agents in a virtual 'room.' This design has the advantage of observing the genesis of communicative conventions in a task that does not focus participants' attention on the creation of form-meaning mappings. However, the

challenges posed by this type of task often result in participants failing to generate many communicative conventions by the end of the experiment.

In the studies discussed here, I used a referential semiotics paradigm. This design balances allowing participants to creatively generate forms in a way that more closely resembles natural language emergence, but limits the cognitive load participants are under by providing a limited set of referents about which participants must communicate. A protracted period of time seems to be necessary for both the acquisition of spatial devices for expressing argument structure in Deaf children, and the development of such a system in Nicaraguan Sign Language. If I hope to observe the genesis of such a system in the lab, I must significantly limit the genesic burden on participants. The structure of the referential semiotics paradigm allows me to focus the communicative task in a way that particularly encourages the use of space (for more information on the specific elements of the task that do this, see Chapter 3).

Furthermore, referential semiotics paradigms support the interaction between individuals in the context of the task (as opposed to semiotic matching games, that often use iterated-learning paradigms in which participants do not engage in reciprocal interaction). This is appropriate for my primary research question for two reasons. First, the interactive structure of the referential semiotics paradigm mirrors the intra-generational nature of the interaction in which members of the first Cohort of Nicaraguan Signers engage. My primary research question is whether spatial devices to express argument structure can be developed within a single generation of individuals—pairs of interacting agents in a referential semiotics task simulate this “generation” at a very basic level. Second, previous research using a referential semiotics paradigm found that

interaction (in the form of feedback between participants engaged in producer and receiver roles) encouraged abstraction of form (from iconic to symbolic; Garrod, Fay, Lee, Oberlander, & Macleod, 2007). The use of abstract loci as anaphora in spatial devices for argument structure may require such interaction to emerge (and may only emerge if the communicative challenge faced by participants is constrained).

2.6 The present studies

In the present studies, interacting pairs of hearing adults were asked to gesturally describe simple events involving two human characters. Other research has looked at the types of gestures hearing individuals can invent when asked to gesture, rather than speak (e.g. Gershkoff-Stowe & Goldin-Meadow, 2002; So et al. 2005; Goldin-Meadow, So, Ozyürek, & Mylander, 2008; Hall et al., 2013, 2014; Langus & Nespor, 2010). However, the bulk of these experiments involve a single participant gesturing to an experimenter or to the camera, rather than an interaction between multiple participants[13].

According to previous experimental semiotics research on the emergence of structured, symbolic communication systems, interaction between humans is a crucial component in the process (summarized, e.g. in Galantucci & Garrod, 2010[14]). Garrod and colleagues found that increased interaction and feedback encouraged conventionalization and abstraction (Garrod et al., 2007). In the natural language emergence situation this experimental work is based on, users of Nicaraguan Sign Language interact with one another on a daily basis. Thus, this experiment aims to both replicate the interactive nature of the natural language emergence context as much as

[13] Excepting the work of Hall and colleagues (cited above), which examines cognitive constraints on constituent order specifically rather than the use of space for argument structure.
[14] This point has also been made in research comparing gesture, homesign, and sign language (e.g., Singleton, Goldin-Medow, & McNeill, 1995; Singleton, Morford, & Goldin-Meadow, 1993).

possible, and capitalize on the power of interaction to facilitate the genesis of linguistic structure. Because of its unique nature, I refer to this paradigm as an Interactive Gesture Communication Paradigm.

Researchers have suggested that the use of space for argument structure conventionalizes as a result of children entering the community and reanalyzing inconsistent input provided by existing community members (Senghas & Coppola, 2001; Senghas, 2003, 2010); that is, that it requires vertical language transmission to *child learners*. However, naturalistic data cannot definitively answer whether vertical transmission to child learners is required for the use of space for argument structure to emerge. The individuals in the first cohort of NSL had to conventionalize many aspects of language in a short time period—perhaps the use of space for argument structure simply required more attention to emerge than they were able to devote to its conventionalization. In the present studies, I use experimental semiotics methodology (described in Section VI) to assess whether the consistent use of space for argument structure can emerge within a single 'generation'.

Previous work has looked at whether individuals with limited or no previous exposure to a sign language can use space to represent argument structure. Padden and colleagues (2010) examined spatial modulations in users of two emerging sign languages, Al-Sayyid Bedouin Sign Language (ABSL) and Israeli Sign Language (ISL). They found that signers of both these languages do sometimes spatially modulate nouns, but then often do not move verbs between established R-loci (instead moving verbs from their body outward in neutral space). This indicates that neither of these emerging languages exhibits spatial devices for expressing argument structure to the degree that

such devices exist in established sign languages. Interestingly, the use of space in ABSL and ISL is complementary to the use of space in NSL. Nicaraguan signers—even those in the second cohort—rarely spatially modulate nouns, but do consistently spatially modulate verbs (Senghas et al., 1997). This suggests that different factors may support the spatial modulation of nouns versus verbs, and that there may not be a strict order in which the use of space for these different elements becomes systematic (either in an individual acquiring a sign language or in emerging languages).

Coppola and So (2005) examined the degree to which four homesigners used space to represent argument structure. These homesigners were deaf individuals with no access to conventional signed or spoken language input, who additionally did not interact with each other. Using the same materials used with NSL signers in Senghas et al. (1997) and Senghas (2003), they asked the homesigners to describe simple events ("a man taps a woman"). They measured how often homesigners used spatial modulation (movement) of their gestures for actions (Spatial Modulations), or pointed either to real objects or abstract locations that had been previous associated with nouns (Object-anchored and Abstract Deixis, respectively).

They found that although homesigners did use Object-Anchored and Abstract Deixis, and Spatial Modulations, homesigners vary in the degree to which they have an internally consistent spatial means of representing argument structure, and none of the homesigners uses a single strategy more than 90% of the time. Instead, each homesigner used these features in ways that suggested they were spatial strategies for representing argument structure rather than the linguistic spatial devices for expressing argument structure observed in established sign languages.

A few studies have examined whether hearing individuals with no previous exposure to a signed language can use space when asked to gesturally describe events. Dufour (1993) showed that hearing individuals with no experience with sign languages showed some use of space in gesturing different stories over the course of 7 weeks. However, these uses of space were not fully consistent or systematic: participants sometimes used nominal establishment, but then failed to move gestures for actions between the established R-loci. Alternatively, they would move gestures for actions in space without having established R-loci explicitly.

Casey (2003) found that hearing adults were more likely to move gestures for actions or events between two locations distinct from their own bodies when participants were provided with photographs of the characters involved in the actions (placed next to the screen on which the stimulus videos were viewed). The performance of participants in the two studies described above suggests that, as for children acquiring sign languages, the establishment and maintenance of R-loci in the gestural description of events is cognitively taxing. Furthermore, participants in Casey (2003) used space in a way that was inherently tied to the actual spatial location of the characters, so it is not possible to determine whether they were using space for “who” or for “where.”

Work by So, Coppola, Licciardello, and Goldin-Meadow (2005) found that hearing gesturers could use space for argument structure, to a greater degree than Dufour (1993) and Casey (2003) observed. They measured participants’ production of gestures for actions or objects that were spatially modulated, and determined whether consistent locations for the same characters or objects were maintained within and across different stimulus vignettes. They found that hearing individuals sometimes used space

coreferentially—that is, using the same space to refer to the same entity across multiple gestures. However, because this study had participants producing gestural descriptions individually, its results cannot speak to the development of conventionalized (that is, shared) spatial devices for expressing argument structure.

The authors also did not report whether participants who used space did so in a way that could be decoupled from the actual spatial locations of the characters in the stimulus videos (e.g. distinguishing between space for “where” vs. “who”). Interestingly, participants found it more difficult to successfully use space coreferentially when stimulus vignettes were shown in an unconnected order. This may indicate that participants’ use of space in this task still did not comprise a fully realized spatial device for expressing argument structure like those observed in established sign languages. However, there is currently no data on whether signers use space coreferentially when shown video events in an unconnected order.

In sum, these studies show that individuals who are not exposed to full, linguistic spatial agreement systems like those in established sign languages do nevertheless use space in their gestures. These individuals do produce some aspects of spatial devices for expressing argument structure, although they are unable to generate devices equivalent to those that exist in established sign languages. However, perhaps the fact that complex spatial devices for expressing argument structure do not emerge in these studies was a result of their conditions; in none of the studies were participants asked to stand, nor were participants engaging in communicative interactions with a partner.

2.6.1 Study summaries and design

The present studies aim to determine whether spatial devices for expressing argument structure can be generated within a single 'generation' of hearing gesturers—two individuals participating in an interactive communication task. The studies in this dissertation used a basic setup that is standard in both gesture production and naturalistic language emergence studies. I asked participants to describe videotaped events, and to interpret descriptions of such events by selecting a picture from an array of possible pictures.

It may be that child learners are not the key ingredient in the emergence of spatial devices for expressing argument structure—perhaps instead, specific features of the environment and the communicative context affect whether such devices can emerge within a single generation. The three studies in this dissertation are both tailored to encourage the use of space in representing characters and events (see Chapter 3 for more details), and have varying degrees and types of 'environmental' regularity that impact the communicative context in which participants complete the task.

In Study 1, the stimuli are consistent throughout the experiment, to provide a baseline regarding how often and in what ways participants use space, and whether that use of space changes in any way (e.g., becoming more abstract or systematic) over the course of the experiment. The basic design for Studies 2 and 3 is the same as that for Study 1, but the stimuli in the second half of Studies 2 and 3 are more variable in a way that may influence participants' use of space. I measured how much participants in each study use space for argument structure, and if they do, the degree to which they are consistent in their use of space. Table 3 summarizes the question posed in each of the three studies.

	Question Answered
Study 1	*Can participants use space and how might space use change over multiple interactions?* *(Baseline use of space when 'environment' is consistent)*
Study 2	*How do participants use space when 'environment' becomes less regular, and they must attend to both "who" and "where" characters are?*
Study 3	*How do participants use space when the 'environment' becomes less regular, and they must attend to "who" but ignore "where" characters are?*

Table 3. *Summary of questions addressed in Studies 1, 2, and 3*

2.6.2 Is the use of space more like a linguistic device or an improvised strategy?

In studying the emergence of the use of space for argument structure in any novel situation, it is important to note whether observed phenomena constitute a linguistic (that is, systematic) spatial device for expressing argument structure like those in established sign languages, or something more like a strategy for representation or communication. Although linguistic devices are certainly a means of representation or communication, strategies for communication are not necessarily fully linguistic. Here I describe in more detail how I conceptualize the differences between a linguistic device and an improvised strategy.

Given that previous experimental and naturalistic work has demonstrated the use of spatial modulations by child and adult hearing gesturers, I expected that participants in my study would spatially modulate gestures in their descriptions. In order to address the question of whether linguistic devices for argument structure can emerge without reanalysis by child learners, I enumerate how I distinguish between a linguistic device and a strategy. I do not envision the distinction as a categorical one, despite using categorical terms. I encourage the reader to think of these terms as representing

endpoints on a continuum—a particular use of space for argument structure might therefore be classified as more or less 'systematic' based on how it compares to the continuum endpoint characteristics enumerated below

Linguistic devices are structured, consistent, and, in the context of language systems, shared across users to a larger degree than are strategies (these characteristics are similar to, but not completely overlapping with, "Duality of Patterning," "Semanticity," and "Interchangeability," in Hockett, 1960). Although both linguistic devices and strategies can have structure, the structure of linguistic devices is more complex (e.g. hierarchical) than that in strategies. This increased complexity of structure leads to both increased expressive power (e.g. 'infinite generativity,' Chomsky, 1957; or "Productivity," Hockett, 1960) and increased stability of expression under different conditions[15]. While linguistic devices are not invulnerable to environmental or internal perturbations (e.g. changes in the context or in the learner, respectively), they should be more stable than strategies in the face of such perturbations. This is why communicating ideas is so difficult in the game 'charades,' in which players are not allowed to use their language system. Despite having some conventions (strategies) to facilitate communication (e.g. holding up 2 fingers at the start of the game to indicate that the target idea is two words), these strategies lack the same level of expressivity or clarity that linguistic devices have.

Both strategies and linguistic devices may support cognitive organization or representation for producers, but linguistic devices, by virtue of being shared, also support cognitive representation in receivers. That is to say, they contain content that is

[15] 'Stability' might be considered a criterion for systematicity independently of the other criteria I have listed. However, because I argue that this stability is a result of increased complexity and consistency, in the present work I consider stability to be a facet of internal consistency (as in (1a) and (4a) in Section 2.6.3).

more likely to be interpretable by an individual who shares the device than the information that may be contained in strategies. Strategies may or may not be comprehensible to receivers, and are more likely to change as a result of changes in the context.

Note that with multiple criteria for defining what constitutes a linguistic device, it is theoretically possible for a particular use of space to be more systematic on some criteria than on others. I again remind the reader to keep in mind these different criteria and the continua on which they each fall, rather than using a single criterion to classify a particular use of space as a linguistic device versus a strategy.

I argue that the different uses of space to express argument structure in established sign languages each constitute linguistic devices for representing argument structure in part because they are structured, consistent, and shared across users. The structure dictates both how they are to be used (e.g. in ASL, with nominal establishment and the movement of verbs between R-loci), and the contexts in which they are to be used (e.g. with verbs of transfer). Signers are *internally consistent* in their use of space for argument structure, both within an utterance (making sure spatial modulation of verbs corresponds with the appropriate semantic roles of the characters represented in different locations), and across utterances (e.g. Senghas et al., 1997). Finally, spatial modulations produced by native signers are interpretable by other native signers—the structure and consistency are *shared by a community* of users. All of these characteristics result in the different uses of space for argument structure in established sign languages being both flexible and robust in the face of environmental variability (e.g. changes in interlocutor, changes in the discourse topic, etc.).

2.6.3 Predictions regarding the systematic use of space

If any hearing gesturers use space for argument structure in a way that is more like a linguistic device, we should observe the following in each of the three criteria[16]:

1) Uses of space in productions should be consistent for an individual producer within and across utterances.
    a. Furthermore, the manipulations in Studies 2 and 3 should not affect the participants' consistency in their strategy from the first to the second half of the experiment.
2) Uses of space should be shared (that is, produced) by both members of a pair, who represent a miniature 'community' in the context of the study.
    a. Although different pairs of individuals may develop different spatial devices for expressing argument structure, each of these pairs should be consistent in the way that they use these features with respect to the stimuli.
3) The consistency of space use in productions described in 2a and 2b should correlate with/predict increased comprehension rates by receivers.

If the use of space by hearing gesturers is more like a strategy rather than a linguistic device, we should observe the following:

4) Use of space in production will not be consistent for an individual producer within and across utterances

[16] These need not necessarily pattern together; rather, each represent the most systematic degree for that particular criterion.

a. Space use may remain steady throughout the experiment in Study 1, but will likely change from the first to the second half in Studies 2 (increase) and 3 (decrease/change character).

5) Use of space will not be shared (that is, produced) by both members of a pair

b. One member of a pair may use space in a different way than their partner, or may not use space at all.

6) The increased consistency of production described in 2a and 2b should not correlate with/predict comprehension rates by receivers.

In Chapter 3, I describe in more detail how the study design encourages the use of space, and how each study manipulates the ‘environmental’ regularity to get at whether any observed use of space is a linguistic device or a strategy.

Chapter 3: Methods

The present work uses a basic setup that is standard in both gesture production and naturalistic language emergence studies. I asked participants to describe videotaped events, and interpret descriptions of these events by selecting a picture from an array. In order to encourage both the use of space generally, and the conventionalization of spatial devices for argument structure specifically, I have made five modifications to this basic setup.

First, I use actions that tend to elicit agreeing verbs in established sign languages—that is, *verbs of transfer* (Meir, 2002; see Appendices for list of items). Second, the *spatial locations of the characters in the video events remain constant* for the first half of the experiment (64 trials). These two design features increase the likelihood that participants will choose to use space by gesturally representing both the characters and the actions.

Third, *participants were asked to stand throughout the experiment* to direct their attention to the possibility for using the physical space around them as a means for distinguishing the characters in the events they describe. Previous studies (e.g. Hall, Ahn, Mayberry, & Ferreira, 2015; Hall, Ferreira, & Mayberry, 2014; So, Coppola, Licciardello, & Goldin-Meadow, 2005) had participants seated either in front of a computer or a camera, which can both restrict their movement and reduce their ability to take advantage of the affordances of the environment for representing characters in contrastive spatial locations. Having participants stand should improve participants' use of space to represent argument structure by allowing participants to iconically replicate the actions observed. Fourth, *a still frame of the beginning of each video event remains*

on the screen following the presentation of the video stimulus so producers do not need to remember characters' spatial locations when gesturing about the event. The intention of these two features is to reduce the cognitive load imposed by the establishment and maintenance of R-loci.

Finally, the task includes pairs of individuals *interacting* over a *high number of trials*. Most previous gesture studies had participants complete their productions without a receiver/comprehender, or did not have participants take on both roles (that is, of producer and receiver) in the course of the task[17]. Experimental semiotics studies demonstrate that repeated interaction with a partner in a communication task (i.e. in a task in which participants are required to take on both the roles of producer and receiver/comprehender) promotes conventionalization and abstraction (Garrod et al., 2007). Thus, I expected that having pairs of individuals who repeatedly switch roles in the task would encourage the conventionalization and abstraction of any spatial strategies used.

3.1 Participants

Fifty-nine pairs of young adults (total N = 118) recruited at the University of Connecticut participated in Studies 1-3. Participants all had typical hearing, and had no exposure to a sign language or signed system. Each study session involved two participants, who each signed up for the study without knowing who the other participant for that study session would be. Pairs were not specifically matched according to their identified gender, and various combinations genders were represented in the present sample.

[17] Excepting Gershkoff-Stowe and Goldin-Meadow (2002), which did have participants in both producer and receiver roles, but which examined the use of word order rather than the use of space.

Twenty pairs of participants participated in Study 1. Four pairs were excluded because of an error with the stimuli or equipment, two pairs were excluded because they did not understand the task (producers accepted incorrect answers from receivers), and one pair did not complete the task. This left 13 pairs remaining in Study 1. Eighteen pairs participated in Study 2. One pair was excluded because they did not complete the study, leaving 17 pairs in Study 2. Twenty-one pairs participated in Study 3; one pair was excluded because participants knew each other prior to the experiment.

Because this dissertation is concerned with the conditions required for the emergence of spatial devices for expressing argument structure, the remainder of the dissertation focuses on those pairs who used space as a 'primary strategy' (see section 4.1.1 for how 'primary strategy' was determined for each pair). Of the 13 pairs in Study 1, **seven pairs** used space as a primary strategy. In Study 2, **seven pairs** (out of 17) used space as a primary strategy. **Eight pairs** (out of 20) in Study 3 used space as a primary strategy. Thus the analyses are based on a total of twenty-two pairs (n=44, ages 17-26 years[18]) across the three Studies. No participants in the 22 pairs included for final analysis knew each other prior to the start of the experiment.

[18] Three participants did not provide their birthdates, so age of these participants could not be calculated.

3.2 Materials

3.2.1 Video events:

Videos of simple two-argument, semantically reversible events were used in this study (e.g., see Figure 3 for a still-frame of the event "a man taps a woman"). All events involved the same 4 human characters (a man, a woman, a boy, and a girl) engaged in 8 actions involving transfer (tapping, petting, pushing, kicking, feeding an orange to the other character, feeding a tortilla to the other character, putting a hat on the other character, and putting a bandana on the other character). Characters were always paired with a character of a different gender, resulting in 4 possible pairings of these 4 characters (man-woman, boy-girl, man-girl, boy-woman). Each member of each character pair participated as agent AND patient in each event (2 possible roles), resulting in 64 total unique events. The 64 events were shown twice, blocked by character pair (e.g. man-woman, boy-girl) but randomized within blocks, for a total of 128 trials in each condition.

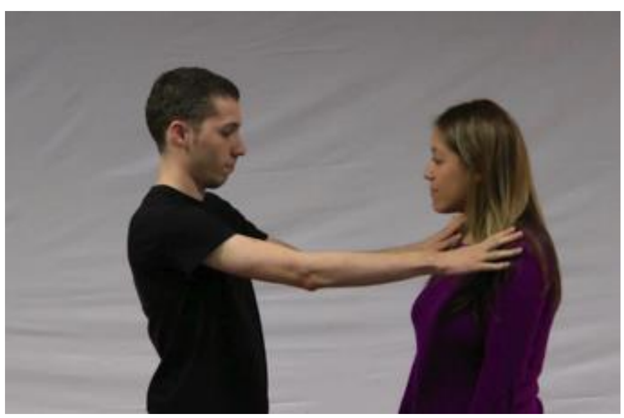

Figure 3. *Still frame of the event "A man on the left pushes a woman on the right"*

3.2.2 Comprehension arrays

Comprehension arrays each contained 4 pictures, all of which depicted the same two characters in the target video. Pictures either matched or did not match the target video event with respect to three features: the action that occurred (Act), the spatial location of characters (SpLoc), and the semantic role of characters (SemRol). The specific structure of the video events and comprehension arrays for each study are described below:

3.2.3 Study 1

Study 1 aimed to test whether hearing gesturers would in fact use space in their descriptions of the video events. In this study, the relative spatial locations (SpLoc) of male versus female characters in both the video events and the comprehension arrays remained stable throughout the task—the male character was always on the left, and the female character was on the right. The task included this regularity in order to draw participants' attention to the possible use of space as a means of representing the characters[19].

The pictures in comprehension arrays in Study 1 were organized as follows: two depicted the target characters engaging in the target action (Act), and two depicted the target characters engaging in (the same) random non-target action. In the both pairs of pictures, one contained the target agent and patient (matching the semantic roles—SemRol—of the characters in the stimulus event), and the other contained the same two characters in the reverse semantic roles (see Figure 4). Target and foil picture locations were randomized across items.

[19] In previous work asking hearing participants to describe events similar to those used here the author communicated that participants rarely used space as a means to represent characters (Hall, personal communication regarding Hall, Ferreira, & Mayberry, 2014; Hall, Mayberry, & Ferreira, 2013, 2015). However, participants in this task were seated, and not engaging in an interactive context.

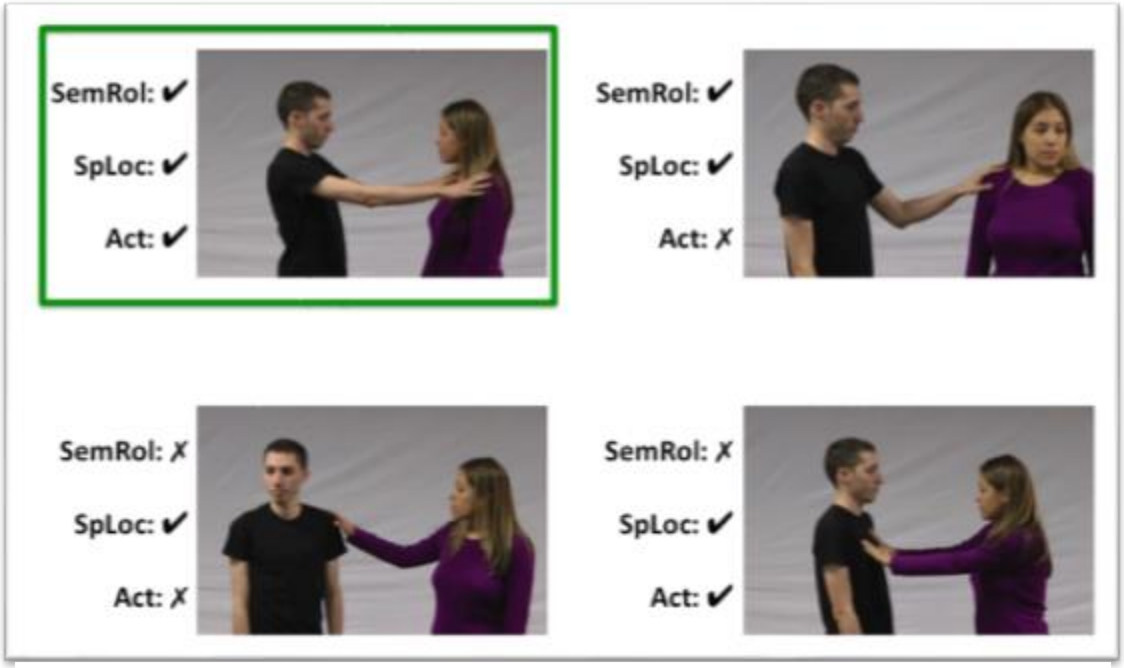

Figure 4. *Sample Comprehension Array for Study 1 for the event "A man on the left pushes a woman on the right" (target event depicted in* Figure 3*). The target picture has a green box around it. How each picture either matches or differs from the target video event on the three dimensions of interest is listed to the left of the picture (SemRol: Semantic Role; SpLoc: Spatial Location; Act: Action).*

3.2.4 Study 2

Study 2 was a first step at disambiguating the use of space for "who" and for "where." In this study, the "where" of the characters in the events participants described was made more salient in the second half of the study, so participants were required to attend to both who the agent was and where that character was (on the left or on the right) in order to successfully communicate about the event.

The first 64 video events and comprehension arrays were identical to those in Study 1. In the second 64 trials, the video events were changed such that the male and female characters each appeared on the left and the right in fifty percent of the video events (and the location of the characters was randomized across items). If participants used space for

"where" in the first 64 trials rather than for "who," the change in the second half of the study should perturb their strategy/device in both production and comprehension. Comprehension should dip for some period of time following the change, as participants realize they must adjust their productions to provide more information (about the "who" rather than just the "where").

All pictures in the comprehension arrays for Study 2 (Figure 5) contained the target characters engaged in the target action, with the following additional specifications regarding the semantic roles and spatial locations of the characters (again, picture locations were randomized across items):

a) Target semantic roles, target spatial locations

b) Reversed semantic roles, target spatial locations

c) Target semantic roles, reversed spatial location

d) Reversed semantic roles, reversed spatial location

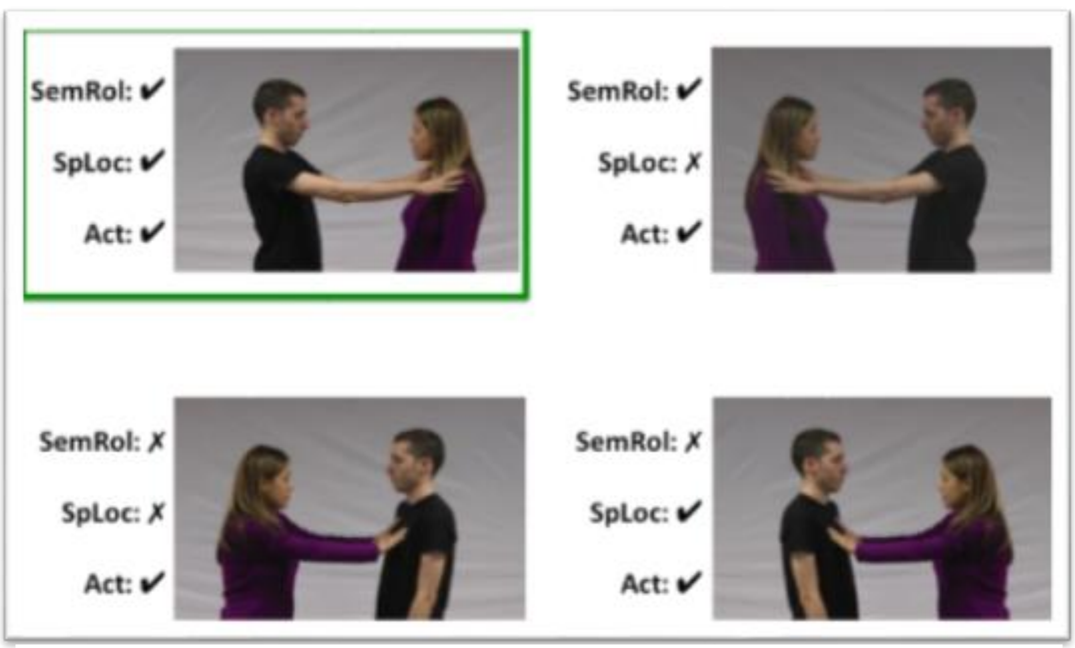

Figure 5. *Sample comprehension array for Study 2 for the event "A man on the left pushes a woman on the right" (target event depicted in* Figure 3*). The target picture has a green box around it.*

3.2.5 Study 3

Study 3 tested whether participants' use of space for argument structure could be decoupled from the actual spatial locations of the characters—that is, whether participants could use space for "who," ignoring the "where" of characters in the video events. This condition encouraged the use of space for "who" by keeping the locations of the characters in the video events consistent for half the trials, then manipulating them such that the actual spatial location of the characters no longer provided a present, reliable real-world cue to the characters' identities.

The structure of the video stimuli in this condition was the same as that of Study 2—that is, in the first 64 trials the video events and comprehension arrays were identical to those in Study 1, and in the second 64 trials, the left-right locations of the male and female characters in the video events were randomized such that the male and female characters each appeared on the left and the right in fifty percent of the video events.

The crucial feature of the comprehension arrays in the second 64 trials of Study 3 (Figure 6) was that 50% of them did <u>not</u> contain a picture that exactly matched the video event in terms of spatial location ("no exact match"). Instead, in such arrays the "target" picture was one in which the action and the semantic roles of the male and female characters matched the video event, but the spatial location of the characters was reversed relative to their locations in the stimulus event. The comprehension arrays were structured as follows:

a) Target action, target semantic roles, target spatial locations (50%) OR Target action, target semantic roles, reversed spatial locations[20] (50%). *Selection of*

[20] This foil is the same as foil (c) in Study 2. While a choice of that foil was considered an 'incorrect' choice for Study 2, it was considered a 'correct' choice for Study 3 (provided that participants prioritized

this foil would indicate that a receiver had understood the characters' identities and semantic roles from their partner's production.

b) Non-target action, target semantic roles, target spatial locations. *Selection of this foil would indicate that a receiver did not understand the action gesture produced by their partner.*

c) Target action, reversed semantic roles, reversed spatial locations. *Selection of this foil would indicate that a receiver did not understand their partner's strategy for indicating characters' semantic roles.*

d) Target action, reversed semantic roles, target spatial location. *Selection of this foil would indicate, like (c), that a receiver did not understand their partner's strategy for indicating characters' semantic roles.*

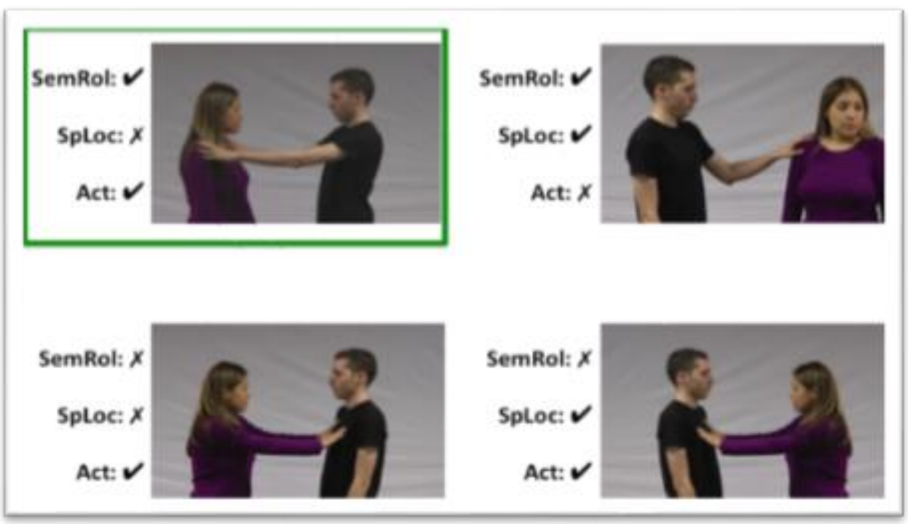

Figure 6. *Sample Comprehension Array with "no exact match" for Study 3 for the event "A man on the left pushes a woman on the right" (target event depicted in* Figure 3*). The intended target picture (based on the Semantic Role and Action dimensions) has a green box around it.*

matching the action and characters' semantic roles more than matching characters' spatial locations). Excepting one pair of ASL signers, no participants protested at this foil being the 'best' answer on Study 3 trials where it appeared.

3.3 How the stimuli in Studies 1, 2, and 3 compare

Table 4 summarizes the relevant features of the videos and comprehension arrays in each Study. In the first half for all studies, the video stimuli and comprehension arrays are identical. The intended target picture in each comprehension array exactly matched the stimulus videos in terms of action, semantic role and spatial location of the characters. The items in the second half of Study 1 are the same as those in the first half, pseudo-randomly reshuffled.

In the second half of Study 2, the spatial location of characters in the stimulus videos are randomized so that each character appears on each side in 50% of trials. The intended target in the comprehension array matches the video stimulus exactly on all three dimensions. The video stimuli in the second half of Study 3 are identical to those in Study 2, but in the comprehension arrays, 50% of comprehension arrays have as the intended target a picture that does not match the video in terms of characters' spatial location (but does match on the other two dimensions).

<table>
<tr><th>Study</th><th colspan="3">1st half (trials 1-64)</th><th colspan="3">2nd half (trials 64-128</th></tr>
<tr><th></th><th>Videos</th><th>Comprehension Arays</th><th>Does Target Picture Match Video?</th><th>Videos</th><th>Comp Arays</th><th>Does Target Picture Match Video?</th></tr>
<tr><td>1</td><td>♂ character: Left
♀ character: Right</td><td>♂ character: Left
♀ character: Right</td><td>SemRol: YES
SpLoc: YES
Act: YES</td><td>♂ character: Left
♀ character: Right</td><td>♂ character: Left
♀ character: Right</td><td>SemRol: YES
SpLoc: YES
Act: YES</td></tr>
<tr><td rowspan="2">2</td><td rowspan="2">♂ character: Left
♀ character: Right</td><td rowspan="2">♂ character: Left
♀ character: Right</td><td rowspan="2">SemRol: YES
SpLoc: YES
Act: YES</td><td>50% of trials
♂ character: Left
♀ character: Right</td><td>♂ character: Left
♀ character: Right</td><td>SemRol: YES
SpLoc: YES
Act: YES</td></tr>
<tr><td>50% of trials
♂ character: Right
♀ character: Left</td><td>♂ character: Right
♀ character: Left</td><td>SemRol: YES
SpLoc: YES
Act: YES</td></tr>
<tr><td rowspan="4">3</td><td rowspan="4">♂ character: Left
♀ character: Right</td><td rowspan="4">♂ character: Left
♀ character: Right</td><td rowspan="4">SemRol: YES
SpLoc: YES
Act: YES</td><td rowspan="2">50% of trials
♂ character: Left
♀ character: Right</td><td>25% of TARGET FOILS
♂ character: Left
♀ character: Right</td><td>SemRol: YES
SpLoc: YES
Act: YES</td></tr>
<tr><td>25% of TARGET FOILS
♂ character: Right
♀ character: Left</td><td>SemRol: YES
SpLoc: NO
Act: YES</td></tr>
<tr><td rowspan="2">50% of trials
♂ character: Right
♀ character: Left</td><td>25% of TARGET FOILS
♂ character: Left
♀ character: Right</td><td>SemRol: YES
SpLoc: YES
Act: YES</td></tr>
<tr><td>25% of TARGET FOILS
♂ character: Right
♀ character: Left</td><td>SemRol: YES
SpLoc: NO
Act: YES</td></tr>
</table>

Table 4. *Summary of Spatial Location (SpLoc) of characters in stimulus videos and comprehension arrays in Studies 1, 2, and 3, divided by first and second half.*

3.4 Procedure

Participants stood facing each other in a room, with a small laptop behind one participant on which stimulus videos was shown, and a large TV screen mounted in the wall at the other end of the room on which the comprehension arrays were displayed (Figure 7).

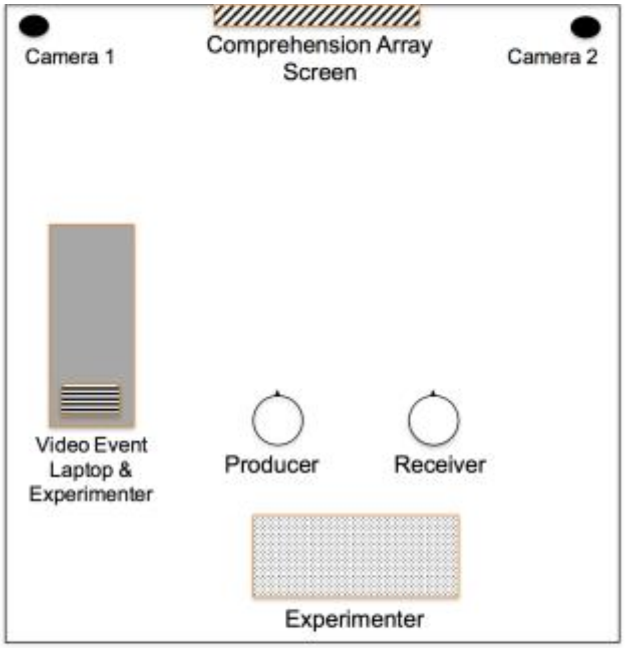

Figure 7. *Schematic of room layout for all studies. The laptop on which the video events were displayed was oriented in the same direction as the screen on which the comprehension arrays were projected. Participants were allowed to move freely in the room, so long as they did not turn their back to both cameras.*

The experimenter read the following instructions to both participants: "You will watch simple videos on this computer [gestured to Video Event Laptop, see Figure 7]. Do whatever you need to do to get your partner to pick a matching picture on that screen [gestured to Comprehension Array Screen, Figure 7], except you may not point at either screen, talk, or mouth words." For each trial, one member of the pair took the role of the producer, and one member of the pair took the role of receiver. The producer viewed a video, and communicated the contents of that video to the receiver (who had not seen the video). Receivers were required to demonstrate comprehension of the event by pointing to the picture in the array displayed on the TV that matched the event the producer has just described. After incorrect choices, the producer was instructed to attempt their communication again, and the receiver instructed to select a picture again.

Interaction was built into the task at three levels. The first form of interaction occurred within a production. Receivers were allowed to interact (still without speaking or mouthing words) with the producer during a production to request more information or clarification. In the instructions, we provided them with an example of a gesture they might use to request more information (a flat palm rotating at the wrist, used as a "go on/continue" co-speech gesture in many cultures).

The second form of interaction occurred at the item level. Producers were required to indicate whether a receiver's selected picture matched or did not match the event they had described. When a receiver selected an incorrect answer (as indicated by the producer), producers were required to describe the event again, and the receiver required to select a picture again. Producers were able to see the full comprehension array, and could therefore infer what the receiver had misunderstood based on which picture the receiver selected, and could modify their descriptions accordingly.

The final form of interaction occurred across items: participants switched roles every 8 trials, so one participant acted as the producer for a block of 8 trials, then acted as a receiver for the following 8 trials (*et cetera*). Each block of 16 trials included the same 2 characters and 8 unique events, repeated twice (with each character participating as an agent in each event exactly once). Thus, participants each had the opportunity to describe and comprehend a semi-overlapping set of events with the same characters.
Immediately following the instructions, each member of the pair completed one practice trial in the role of producer, during which time feedback was given verbally, and participants were allowed to ask questions. At the end of the two practice trials,

participants were reminded that the rest of the experiment would continue without talking.

3.5 Study 4 (ASL signers: A comparison group)

The use of space in the grammar of established sign languages has been characterized (see Section III above); however, we do not have data about how often, or under what conditions, spatial devices to express argument structure are used in describing the types of events used in this dissertation. Furthermore, there is limited evidence regarding the effect of a comprehension partner on the use of space by native signers.

I asked four native users[21] of American Sign Language (ASL) to produce descriptions in ASL (without a partner) for the 128 video events used in studies 2 and 3, in order to determine how users of a sign language with an established spatial agreement system describe these events (that is, whether they use space in their descriptions, how often, and in what ways).

Finally, 2 pairs of native ASL signers (the same four individuals who produced the descriptions referenced in the paragraph above) completed all or part of Study 3 in ASL, using the same procedure that was used with hearing gesturers[22]. Asking signers to describe events both alone and with a partner to determine whether the study setup (that is, the presence of a partner and the content of the comprehension arrays) influenced ASL

[21] All 4 signers were exposed to ASL before age 2; three signers were deaf, and one signer was hearing, but had one deaf and one hearing parent, both of whom were fluent signers.

[22] One pair described all 128 items each independently, then completed all 128 items again as a pair. The second pair each described all 128 items in Study 3 independently. Their productions took longer than the first pair's, and I became concerned that asking this pair to repeat all 128 productions a second time as a pair would result in fatigue. Because their descriptions were extremely consistent in their independent productions, they were not asked to produce all 64 items in the first half of the Study 3 stimuli—instead, they produced descriptions for one block each (8 items per person) for the last 16 items in the first half of Study 3. They then completed all 64 items (32 each) in the second half of Study 3.

signers' use of space, and whether and how the manipulation in Study 3 would impact signers' production and comprehension.

3.6 Coding and analyses

The coding and analyses for this dissertation aimed to determine whether participants used space at all in their productions, and how they did so. In particular, I asked whether participants associated characters with locations (either using the hands or the body) and moved gestures representing events between those locations in a systematic way. For all analyses, when multiple productions occurred within a trial (e.g. if a receiver guessed the incorrect picture), only the first production is included for analysis. This means that, in some cases where there were multiple productions, a production that was not correctly comprehended was included in these analyses. I prioritized including first productions over correctly-comprehended productions for two reasons. First, the analysis of the relationship between consistency and comprehension requires that there be some variability in comprehension scores. Second, I maintain that first productions, on average, provide a more "true" measure of the state of a strategy or device in its current state. If participants' uses of space becomes more systematic over the course of the experiment, producers should change their productions over time in response to the receiver's comprehension.

The first step in the analyses of these data is to determine how often producers used space in representing different elements of the videos they watched. For all studies, I coded how participants represented the agent and/or[23] patient in the event, and how

[23] Participants did not always represent both characters in their productions.

participants represented the event. I assessed whether participants used space in any of these representations—that is, whether their gestures for any of these elements were spatially modulated (produced in a location outside the participant's own "neutral" starting location and position; see Figure 8). The neutral position was defined relative to each person's body at the start of each trial. "Neutral" gestures were those in which the participant did not take steps, shift their torso to the left, right, front, or back, or move their hands either further than their shoulder on the ipsilateral or contralateral side, or extend their arm such that their elbow formed an angle greater than 90 degrees.

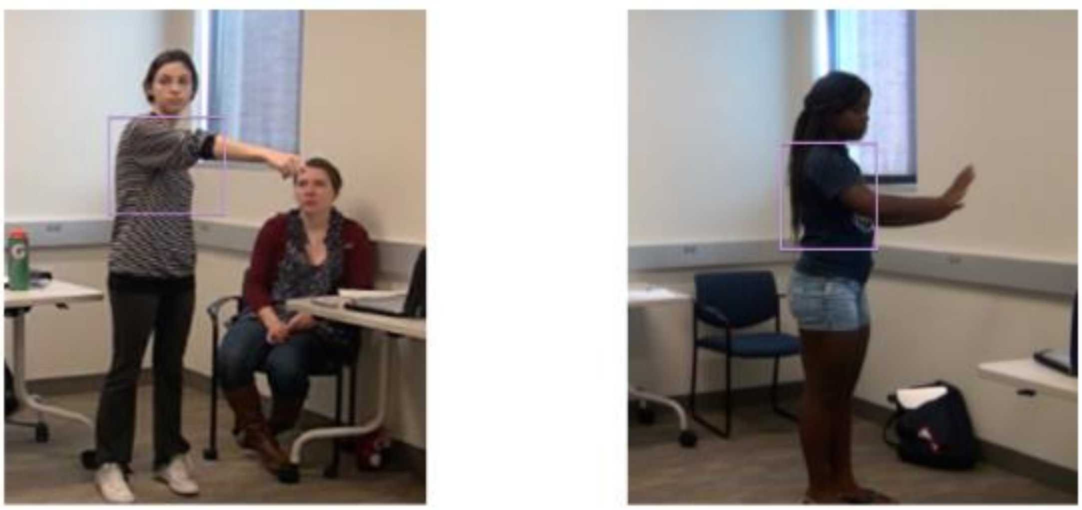

Figure 8. *Two participants producing manual gestures in non-neutral space—their "neutral box" is delineated with a purple box.*

3.6.1 Agent and patient representation

Gestures intended to represent the agent or patient were identified as such by virtue of preceding a gesture for an event. If the event gesture following the character gesture represented the event from the perspective of the agent, the character representation was

considered to be the agent representation. If the event gesture represented the patient's role, the character gesture was considered a patient representation. One common gesture ordering for productions was Ag-Act-Pa-Act. Sometimes productions only contained half of this ordering (e.g. Ag-Act or Pa-Act).

In assessing the use of space in the representation of the agent or patient, I asked whether participants moved their hands or their bodies to a non-neutral location when referring to a character. For instance, in representing the event "the man (on the left) feeds the woman (on the right)," participants might produce the following: STEP-LEFT FEED-RIGHT STEP-RIGHT EAT (see Figure **9**).

Figure 9. *Participant using space to represent the characters and action in the stimulus event "the man (on the left) feeds the woman (on the right)." The participant steps to his left while representing the man's role in the event, and steps to his right when representing the female's role in the event.*

The "STEP-LEFT" gesture, produced using the whole body, precedes the gesture representing the role that the man embodies in the stimulus video. Therefore, the "STEP-LEFT" gesture was considered to be a representation of the man.

In some productions, participants represented the agent and/or patient using some means other than space. The three most common ways of doing this were: 1) using a gesture that represented some feature of the character (e.g. in Figure 11, a gesture like "glasses" to represent the girl, or a gesture representing "short hair" to indicate the male character; these were considered "lexical items"); 2) embodying the role of a single character in event gestures ("self-as-character"); or 3) representing the character's height (either in or separate from the event gesture; "height") For the purposes of this dissertation, all these representations of the agent or patient were coded as "Other," since they do not involve space.

Figure 10. *Left: Example of gesture representing "glasses" to indicate the girl; Right: Example of gesture representing short hair to indicate the man or boy*

3.6.2 Event representation: starting and ending locations

The actual physical locations where participants started and ended their gestures expressing the stimulus event were coded as: Neutral, Space, Self, or Receiver. "Neutral" gestures started or ended in the 'neutral' space immediately in front of the producer's body, provided the producer had not moved their body in some way to represent the character (as in the example above). Specifically, the participant's hand did not extend beyond their shoulder on the ipsilateral or contralateral side, and the angle of the participant's elbow did not exceed approximately 90 degrees. Event gestures starting or ending on the producer's or receiver's body (or inside the receiver's "neutral space") were coded as starting or ending at Self or Receiver, respectively.

The "Space" value was used for gestures starting or ending outside the participant's "neutral space" (as defined above). If the participant moved their body outside their starting "neutral" location in order to represent a character—as in the example provided in Figure 9 where the participant steps to the right to represent the woman—gestures that started in the new "character space" (like EAT) were coded as starting in space. If, in producing an action in this new "character space," the producer's hand extended past the shoulder on the ipsilateral side at the end of the event (as in Figure 8, left panel), that event gesture was coded as ending in space. Alternatively, if the producer turned to the side as they stepped into the new "character space," and then produced an event gesture toward that side such that their elbows created an angle greater than 90-degrees, that event gesture was coded as ending in space (as in Figure 8, right panel). If the event gesture did not meet either of these two criteria, the ending location of the gesture was coded as "Neutral."

3.6.3 Do spatial gestures match stimulus space?

In order to see whether participants used space consistently, for any agent, patient, or event gesture that used space, I coded whether the spatial location matched that of the character it represented or was associated with. For the first half of all three conditions, the male character was on the left and the female character was on the right. For example, in the stimulus video for the item "the woman feeds the man," the woman is standing on the right, and the man on the left. If the producer stepped or shifted their torso to their right when representing the woman, their production would be coded as "using space" for the agent representation, and as "matching the stimulus space." If the participant stepped or shifted their torso to their left when representing the woman, their production would be coded as "using space" for the agent representation, and as "not matching the stimulus space." Similarly, a FEED-LEFT gesture would be coded as "matching the stimulus space" in the event representation, and a FEED-RIGHT gesture would be coded as "not matching the stimulus space."

3.6.4 Examples of coding for four productions

For the event "the man on the left pushes the woman on the right," see Figure 11 for an example of one participant's gestures describing this event, and Table 5 for how this production was coded.

Figure 11. *One participant's gesture production for the event "the man (on the left) pushes the woman (on the right)." To represent the man, the producer steps to her left and directs a pushing gesture to the space on her right. (Coding for this is in* Table 5*)*

	Agent Rep			Patient Rep			Event Rep		
Production Gloss	Use Space?	Match Stim.?	Use Other?	Use Space?	Match Stim.?	Use Other?	Start Loc.	End Loc.	Event Space Match?
STAND-LEFT PUSH-RIGHT	**1**	**1**	**0**	**0**	**0**	**0**	**SPACE**	**SPACE**	**1**

Table 5. *Example of coding for one gesture production by a participant in Study 2 (production depicted in Figure 11)*

In the gesture production in represented in Figure 11 and Table 5, the producer steps to her left and turns slightly to face her right, then directs a “pushing” gesture to their right. Stepping to the left or standing on the left, facing the right and then gesturally representing the action performed by the agent was considered a use of space to represent the agent. Furthermore, because the stimulus video depicts the man to the left of the woman, and the producer represents what the man is doing on their own left side, this production was considered to “match” the stimulus space. The producer did not step to the right or otherwise indicate the woman in any way in this production, so all Patient Representation columns were coded as “zero.” The Event Representation, because it begins in the space to the left of the producer’s original location (before they stepped/shifted to the left), was coded as starting in “Space.” In producing the “push” gesture, the producer’s arms extend such that her elbows create an angle greater than 90 degrees. The ending location of the “push” gesture was therefore also coded as “Space.”

Following are several more example gesture productions and their respective coding values. The first (depiction of production in Figure 12; coding in Table 6) shows a participant representing the agent and event using a non-matching (rotated) spatial layout, on an axis that was parallel to the table on which the laptop showing the video stimuli sat. This was somewhat unusual, as most participants used an axis that was approximately perpendicular to that table (e.g. in Figure 9). Figure 13 (coding in Table 7) shows a participant using a non-matching spatial layout (coincidentally on the same axis as in Figure 12) to represent the agent, the target event, *and* the patient and a corresponding (non-target) event. Figure 14 (coding in Table 8) shows a participant using a non-spatial strategy to represent the agent, patient, and event.

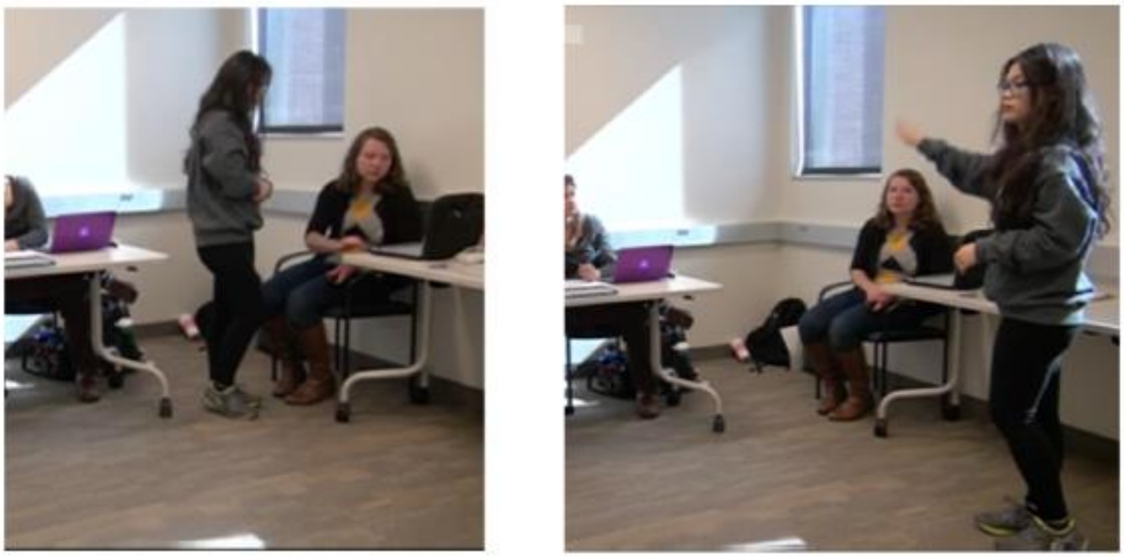

Figure 12. *One participant's gesture production of the event "the girl (on the right) taps the man (on the left)." The participant uses a spatial layout that does not match the stimulus space, standing on her left to represent the female character, and tapping toward her right. (Coding for this in* Table 6*)*

	Agent Rep			Patient Rep			Event Rep		
Production Gloss	Use Space?	Match Stim.?	Use Other?	Use Space?	Match Stim.?	Use Other?	Start Loc.	End Loc.	Event Space Match?
STAND-LEFT TAP-RIGHT	**1**	**0**	**0**	**0**	**0**	**0**	**SPACE**	**SPACE**	**0**

Table 6. *Example of coding for a participant's description of the event "the girl (on the right) taps the man (on the left)." (production depicted in* Figure 12*)*

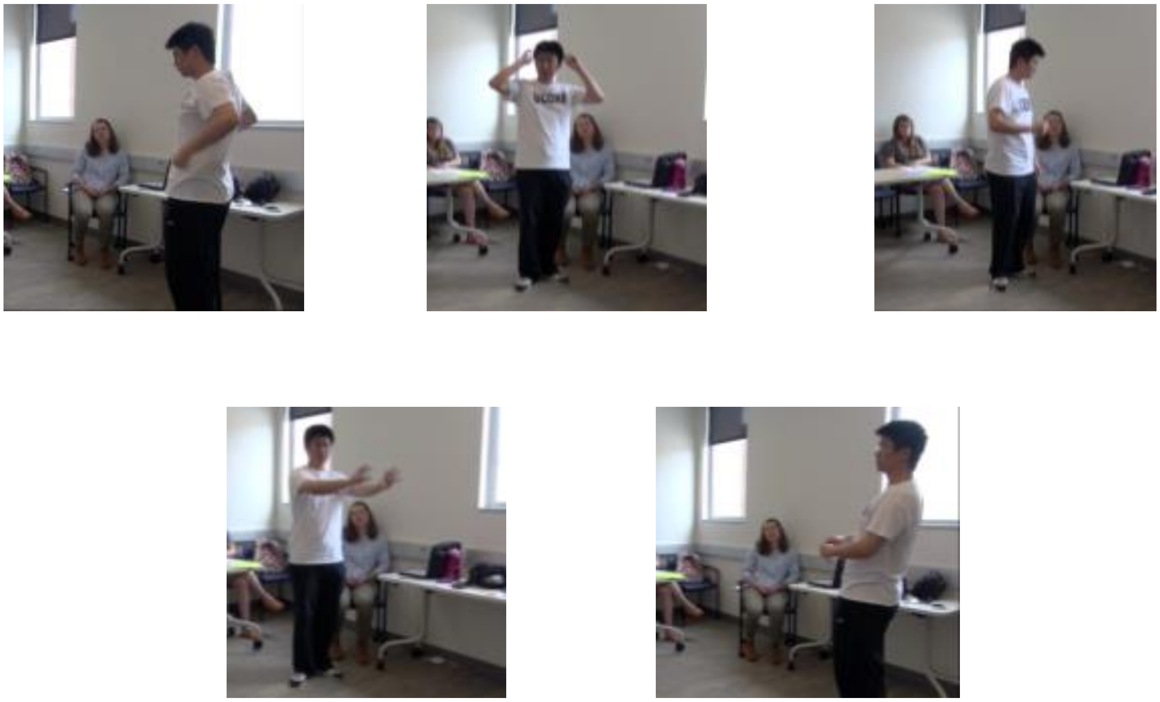

Figure 13. *One participant's gesture production for the event "the girl (on the right) taps the man (on the left)." The participant represented both the agent and patient using a non-matching spatial layout, and identified both characters using lexical items indicating characters' hair length (first and second panels). The participant also directed event gestures in space using the same non-matching spatial layout that was used for character representations. (Coding depicted in Table 7)*

	Agent Rep			Patient Rep			Event 1 Rep		Event 2 Rep		
Production Gloss	Use Space?	Match Stim.?	Use Other?	Use Space?	Match Stim.?	Use Other?	Start Loc.	End Loc.	Start Loc.	End Loc.	Event Space Match?
WOMAN-L MAN-R PUSH-L WOMAN-L ROCK-BACK	**1**	**0**	**1**	**1**	**0**	**1**	**SPACE**	**SPACE**	**NEUTRAL**	**SPACE**	**1**

Table 7. *Example of coding for a gesture production by a participant's description of the stimulus item "A man (on the left) pushes a woman (on the right)" (production depicted in Figure 13). The agent, the patient, and the target event are represented using a non-matching spatial layout.*

Figure 14. *One participant's gesture production of the event "the man (on the left) kicks the girl (on the right)." The participant represented the agent and patient by associating the male character with her partner and the female character with herself, using points (first and third panels). Her event gesture (middle panel) is producer in the "neutral" space directly in front of her. (Coding for this in Table 8)*

	Agent Rep			Patient Rep			Event Rep		
Production Gloss	Use Space?	Match Stim.?	Use Other?	Use Space?	Match Stim.?	Use Other?	Start Loc.	End Loc.	Event Space Match?
MAN (point to receiver) KICK WOMAN (point to self)	**0**	**0**	**1**	**0**	**0**	**1**	**NEUTRAL**	**NEUTRAL**	**0**

Table 8. *Example of coding for a gesture production describing the stimulus item "The man (on the left) kicks the girl (on the right)" (production depicted in Figure 14).*

3.7 Consistency measures

The second step in the analyses is determining the degree to which participants' uses of space are consistent, and whether that consistency varies across studies. This addresses the degree to which environmental perturbations affect the system-ness of participants' use of space (and thus, whether those uses of space are in fact more like linguistic devices than strategies).

I calculated three measures to determine whether participants' use of space was more like a linguistic device—consistent within and across users, and robust to environmental perturbations—than like a strategy. The first looked at whether participants were consistent in their use of space within a single production. The second measured how consistent individuals were in space use across productions. The third measured the degree to which both members of a pair were consistent throughout the experiment. Below I describe in greater detail each measure and how it was calculated.

3.7.1 Within-trial consistency of space use

When producers used space in more than one element of their description (e.g. in the Agent Representation and Event Representation), I analyzed whether their use of space was consistent across the different elements of their production. This measure illustrates one component of the degree to which producers are systematic in their use of space.

This measure was calculated by first determining which elements in the description used space, then comparing the "Match stimulus space?" for each column to determine whether producers had employed a matching or non-matching layout in their productions.

I then determined, for each producer, the proportion of trials (typically out of 64) on which that producer demonstrated within-trial consistency of space use.

3.7.2 Determination of strategy by block

For each block, I examined how the producer represented the agent and/or patient. If they did so across trials in a way that made clear the link between a character and that character's semantic role, I considered the producer to have a 'suspected' spatial or non-spatial strategy. I then defined a "consistent" strategy (spatial or non-spatial) as a strategy that was used in at least 6 (75%) of 8 trials in that block[24].

3.7.3 Within-producer and across-block consistency of space use

It is possible for a producer to be consistent in their space use within trials, but vary their use of space across trials. They might use space in a "matching" (unrotated) way for some percentage of trials, but use space in a "non-matching" (rotated) way in other trials. I therefore also calculated whether an individual producer's use of space was internally consistent throughout the experiment. This consistency provides insight into the degree to which that producer's use of space is systematic.

To accomplish this, I first determined whether a producer was consistent in their use of space within a block, and then coded whether they were consistent across the blocks in which they were the producer.

[24] I initially used a binomial probability calculation to determine whether participants used the same strategy in significantly more trials than would be expected by chance. This calculation required that participants use the same strategy in 7 or 8 out of 8 trials. Because there were a small number of trials per block, and I did not want to overly restrict what I considered a "consistent" strategy, I opted to give participants credit for "consistency" within a block if they used the same strategy in at least 6/8 trials.

For each block I defined "consistent" use of space as using space in the same way in at least 6 (75%) of 8 trials for representing at least the agent and/or patient.[25] If a producer used space in a way that matched the stimulus video in 4/8 trials, and used space in a way that did not match the stimulus videos in the other 4/8 trials, they would not receive credit for a consistent spatial strategy for that block.

I then determined whether each producer used space in a given block the same way they used space in the previous block in which they were the producer. There were 16 blocks of 8 trials in an experiment, and each participant produced descriptions for 8 of those blocks. Given that in the first block, there is no "previous" block to compare to, the determination of within-participant consistency across blocks is out of 7 blocks. If a producer's use of space in one block did not reach the set criterion (even if they used space in the same way as in previous blocks), they received a "0" in this coding category for that block. To illustrate how this coding was applied, I provide three examples below of how participants used space in their successive production blocks.

<u>Example A</u>: Producer A used space in at least 6/8 trials in Blocks 1 and 3, so they received a "1" in this coding category for Block 3 (and "n/a" for Block 1, since it is their first production block). Producer A then used space in Block 5 in at least 6/8 trials in the same way they used space in Block 3, so they would receive a "1" in this coding category for Block 5.

[25] When I calculated a strategy for a given block, I defined 'strategy' as a means of representing the agent/patient that helped a receiver identify the matching picture. This means that descriptions in which producers used space for the event representation only were not considered to have a spatial strategy.

Example B: Producer B used space consistently in Blocks 1 and 3, so they received a "1" for Block 3 (and "n/a" for Block 1). Producer B did not use space consistently (or at all) in Block 5, and then re-established consistent use of space in Block 7; they would receive a "0" for both Blocks 5 and 7.

Example C: Producer C used space consistently in Blocks 1 and 3, so they received a "1" for Block 3 (and "n/a" for Block 1). Producer C then switched to a non-spatial strategy for Blocks 5 and 7, so they would receive a "0" for both Blocks 5 and 7 in the "internally consistent spatial strategy use" coding category.

In the final calculation for this analysis, I integrated the 'suspected' strategy information with the consistency of space use coding described above. This was so that blocks where participants attempted (and stuck with) a non-spatial strategy did not artificially deflate their consistency of space use measure. Thus, if a producer did not use space at all in a particular block, that block wasn't included in this analysis.

For Examples A and B, therefore the internal consistency measure would be calculated using Blocks 3, 5, and 7, since both producers attempted spatial strategies in those blocks (despite Producer B not using space consistently in Block 5). For Example C, however, the internal consistency measure would be calculated only using Block 3, as Producer C did not attempt a spatial strategy in Blocks 5 and 7.

3.7.4 Across-producer and across-block consistency of space use

In addition to measuring whether producers were internally consistent in their use of space across blocks, I calculated whether both members of a pair used space in the same way as each other. This is a measure of the degree to which a spatial strategy is shared by both members of a pair. For this calculation, I coded whether the use of space in a given block was the same as the use of space in the immediately preceding block. Given that in the first block, there is no "previous" block to compare to, the determination of across-producer consistency across blocks is out of 15 total blocks.

3.8 Comprehension accuracy

For each item, I also coded which picture the receiver selected following the producer's first gesture production. I then coded whether the receiver's selection matched the intended target ("1") or did not match the intended target ("0").

There were a few items for which the comprehension arrays were particularly confusing for both receivers and producers. The highly distracting foil in these confusing arrays contained characters in the same semantic roles as the intended target, engaged in events that looked similar to the target event when depicted pictorially (e.g. "tap" vs "pet," see Figure 15, and "feed orange" vs "feed tortilla"). Comprehension arrays were counterbalanced so two similar-looking events were not always contrasted in comprehension arrays (but they did sometimes appear together).

Although participants were told in the instructions to "select a matching picture," they were permitted to select more than one picture if they wished. However, no hearing

participants did this[26]. For the items with confusing arrays, receivers were given credit for selecting either the intended target or the similar-looking foil.

Figure 15. *'Confusing' comprehension array (Item 19; appeared in Studies 1-3). The target event is "the man (on the left) taps the girl (on the right)" (target picture is in the bottom left panel). One foil depicted the event "the man (on the left) pets the girl (on the right)" (upper right panel), which involves the same semantic roles and a similar-looking event.*

3.8.1 Reliability coding

Twenty out of the twenty-two pairs included in the analyses were coded by either the primary research assistant (12 pairs) or by me (8 pairs). To ensure that our coding aligned, particularly for the second half of Studies 2 and 3, I conducted reliability coding on one pair that my RA coded (from Study 3), and she conducted reliability coding on one pair that I coded (from Study 2). Reliability coding was conducted on 20% of items (25/128).

Reliability for the pair from Study 2 was between 84-100% for all coding

[26] This may have been because we instructed participants not to talk, and they did not feel they could communicate that they believed the matching picture could be either of two in the four-picture array. All four ASL signers indicated in ASL when they believed the matching picture could be either of 2 similar-looking pictures.

categories. Reliability for the pair from Study 3 was between 84-100% for all categories except Event Starting and Ending Locations (for which reliability was extremely low—8% for both columns). This initial low reliability resulted in an updated operationalized definition of use of space for the event representation (described in Section 3.6.2). Following the initially low reliability, the primary RA then recoded the Starting and Ending Locations of event gestures for all previously coded pairs so that coding aligned with the newly specified definition.

Reliability was also conducted on the two pairs coded by other research assistants. For one pair, reliability was between 96-100% for all coding categories. For the other pair, reliability was between 84-100% for all coding categories except for those the use of space for the agent and the event representations (for which reliability was between 64-72%). I reviewed the coding and the video data for all items this pair, who used an extremely subtle torso shift to indicate contrastive spatial locations of each character. All the discrepancies in coding stemmed from the reliability coder, who, having not watched all of this pair's productions, was unable to see the pattern of torso shifting in two different producers across randomly selected trials. After conferring with both the original coder and the reliability coder, the original coder's determinations of use of space for the agent and patient representation were upheld.

In addition to the reliability coding conducted on the 4 pairs described above, I also reviewed each pair's coding when calculating attempted strategies for each block. When I noted apparent errors or had difficulty determining participants' strategies on the basis of the coding, I re-watched the data videos and made adjustments to the coding where appropriate.

Chapter 4: Results

The results are reported in three main sections. The first section discusses how pairs of participants were selected for further analysis, and some considerations regarding the appropriate unit of analysis for these dyadic data. This section also presents general descriptive and inferential statistics for the first and second halves of each study for all pairs selected for further analysis. The descriptive statistics include: how often participants in each study **represented the agent, patient, and event** in each half of the experiment, and **how often space was used** in these representations. The inferential statistics examine whether the use of space for representing the agent and patient differed across studies in the first and second halves of the experiment.

The second section addresses the degree to which **uses of space were consistent or systematic**. I begin by calculating participants' consistency in production in the three ways described in Chapter 3. First, I determined whether individual participants used space the same way across multiple elements (e.g. the agent and the event) within the same production. Second, I calculated the degree to which an individual producer used space in the same way across their own productions throughout the experiment. Third, I asked whether the two members of a given pair used space the same way as each other. I present inferential statistics comparing these measures across studies to determine whether the conditions under which participants completed the studies affected the degree to which participants were internally and externally consistent in their uses of space. Finally, I present a measure that asks whether a participant's consistency in production, overall, and in terms of spatial strategies specifically, related to their partner's comprehension.

The final section details how **ASL signers** in Study 4 described the events. I use the same descriptive measures as those used for hearing individuals, and some item-level inferential analyses examining how signers' descriptions and use of space changed over the course of the task.

4.1 How often pairs used space as a primary strategy and who was selected for further analysis

4.1.1 Determination of primary strategy

Not all participants spatially modulated their gestures while producing descriptions of the video events. Because I am interested in specifically examining participants' use of space, each pair's primary strategy was first estimated by the project's lead research assistant, who completed 90% of the testing and approximately 75% of the coding. The research assistant watched a selection of trials through the experiment, and observed whether participants spatially modulated their gestures in at least 50% of the trials watched. A pair that did so was provisionally considered a "space-using" pair, and coded in its entirety. If the lead research assistant was unsure about whether a production contained spatial modulations, I watched the videos of the trials in question and made a determination.

This resulted in 53.85% of pairs (7/13) coded for Study 1, 43.75% of pairs (7/16) coded for Study 2, and 38.10% of pairs (8/21) coded for Study 3. All 22 of these pairs are included in the analyses reported here. A Chi-square analysis including space- and non-space-using pairs found that the proportion of pairs who used space did not differ across conditions, $\chi^2(2, N = 50) = 0.81$, $p = 0.67$). The remaining analyses are conducted on only those pairs who used space as their primary strategy.

4.1.2 Implications of data distributions for inferential analyses

The data on the proportion of items on which participants use space in different elements of their descriptions violate some of the assumptions that must be met in order to use traditional parametric inferential analyses. The uses of space, particularly in the first half of the experiment, are not normally distributed. This is an intentional consequence of selecting those pairs who did use space as a primary strategy in that half of the experiment. Because of how the data are distributed, common transformations either are not applicable (e.g. cube root), or do not change the underlying skewness of the data (e.g. log). Many of the sets of data compared (e.g. comparisons of use of space between studies, and within study comparisons of uses of space in the first and the second halves) also do not have equal variances, and thus violate the assumption of homoscedasticity. Furthermore, in some cases sample sizes are unequal because some producers in different studies chose not to represent a given element at all, for instance.

Because the various distributions of these data violate *both* the assumption of normality and the assumption of homoscedasticity, and sometimes are unequal in size, tests which are robust to the violation of either the first or the second assumption (e.g. the Mann-Whitney U tests or Welch's ANOVA or t-test, respectively) are not appropriate. I therefore used a randomized resampling procedure (also known as a "permutation test") to generate a hypothetical "population" distribution specifically for each dataset, and ANOVAs and t-tests are run comparing observed distributions to the hypothetical population distribution (Pitman, 1937).

Furthermore, although I am conducting multiple two-sample comparisons, I do not apply Bonferroni corrections to the alpha levels used in comparisons. This is largely a

result of concerns that the corrections are overly conservative. I instead present effect sizes for any statistically significant differences obtained from two-sample comparisons (as recommended, e.g., in Cabin & Mitchell, 2000; Nakagawa, 2004).

4.1.3 How often were the agent, patient, and event represented at all and using space?

The first set of analyses are concerned with determining how frequent the use of space is for those 22 pairs who were determined to have space as a primary strategy. I anticipated that percentages of space use would be relatively high, given the criterion for designating pairs as space-using. These analyses specifically determine whether space use is affected by the different components of the experimental design: the high number of trials, the interactive nature of the experiment; and the manipulations in Studies 2 and 3. This is a means of assessing whether the design of the three Studies in fact had the intended effects of influencing participants' use of space. However, even if I find that overall rates of space use were not affected by the different study manipulations, I can still then examine whether *consistency of space use* was affected.

In Table 9 I report how often participants in Studies 1, 2, and 3 represented each element portrayed in the video stimuli at all—that is, how often their gestures represented the agent, patient, and event, in any way, in the first and the second halves of the experiment. In Table 10, I report how often participants used space in their representations of these elements. For each element, I then compared rates of space use across Studies 1, 2, and 3 in the first half, and then compared rates of space use across Studies 1, 2, and 3 in the second half. The analyses include the data from 7 pairs of participants in Studies 1 and 2, and 8 pairs in Study 3. Each pair described 128 items,

resulting in 895 productions analyzed from Study 1, 895 productions analyzed from Study 2, and 1023 productions analyzed from Study 3[27].

Element represented in any way	First half			Second half		
	Study 1 **M** (R)	Study 2 **M** (R)	Study 3 **M** (R)	Study 1 **M** (R)	Study 2 **M** (R)	Study 3 **M** (R)
Agent	**88%** (42-100%)	**97%** (78-100%)	**85%** (9-100%)	**95%** (66-100%)	**99%** (94-100%)	**89%** (13-100%)
Patient	**38%** (0-81%)	**42%** (0-100%)	**25%** (0-100%)	**39%** (0-94%)	**43%** (0-100%)	**31%** (0-100%)
Event	**99%** (91-100%)	**100%** (n/a)	**100%** (97-100%)	**100%** (94-100%)	**100%** (n/a)	**100%** (98-100%)

Table 9. *Mean and Range percentages of productions in which the agent, patient and event were represented at all, divided by* Study *and by 1st half (items 1-64) and 2nd half (items 65-128) of the experiment. Representations did not differ by* Study *in either first or second half.*

Participants in all studies produced descriptions of the events containing at least one target element (Agent, Patient, and Event) in all but one trial (in which the producer represented only the Theme—the cap—in the event "A woman puts a baseball cap on a man"). They overwhelmingly represented the agent, and nearly always represented the event. The patient was represented less often across the three studies—however, representing the patient was not essential to ensuring receiver comprehension.

[27] The number of productions in each study is 1 fewer than 128 trials x the number of pairs in that study. This is a result of a single item being excluded from one pair's productions in each study. The excluded items were not related in any way, nor were they excluded for the same reason.

Element represented using space	First half			Second half		
	Study 1 **M** (R)	Study 2 **M** (R)	Study 3 **M** (R)	Study 1 **M** (R)	Study 2 **M** (R)	Study 3 **M** (R)
Agent	**84%** (45-100%)	**92%** (24-100%)	**88%** (0-100%)	**82%** (0-100%)	**100%** (97-100%)	**63%** (0-100%)
Patient	**80%** (0-100%)	**80%** (6-100%)	**60%** (0-100%)	**75%** (0-100%)	**76%** (9-100%)	**32%** (0-100%)
Event	**89%** (59-100%)	**93%** (53-100%)	**83%** (0-100%)	**85%** (0-100%)	**100%** (97-100%)	**67%** (0-100%)

Table 10. *Mean and Range percentages of productions in which the agent, patient and event were represented using space, out of total number of items in which the elements were represented at all, divided by* Study *and by* 1^{st} *half (items 1-64) and* 2^{nd} *half (items 65-128) of the experiment. Uses of space for event elements did not differ by* Study *in the first half, but did differ in the second half.*

Most often descriptions contained at least the agent and the target event, and sometimes included the patient. Because participants represented the patient much less often overall than either the agent or the event representation, and because representing the patient is not essential to the goal of the task (receiver comprehension), I will not consider the use of space in the patient representation in the next few analyses (though it is reported in Table 10).

The use of space to represent agent or event did not differ by study in the first half of the experiment, $F(2, 41) = .42$, $p = .67$, and $F(2, 41) = .68$, $p = .54$, respectively. However, the use of space for these same elements differed significantly by study in the second half of the experiment, $F(2, 41) = 5.06$, $p = .01$ and $F(2, 41) = 4.33$, $p = .02$.

Table 10 shows that the use of space to represent the agent and the event between the first and second half of the experiment remained relatively constant for Study 1, increased slightly for Study 2, and decreased for Study 3. Paired-sample first-to-second-half comparisons for Study 1 (in which characters' spatial locations remained stable)

showed that the use of space for agent and event did not differ between the two halves, (Agent p = .72; Event p = .49). For Study 2, in which participants were required to represent characters' spatial locations in order to successfully communicate the event to their partner, the use of space in the agent representation did not differ from first to second half (p = .34), but did increase significantly from the first to second half for event representation (p = .03, Cohen's d = .71). For Study 3, in which the most effective strategy for communication would be to ignore characters' spatial location and focus on their semantic roles, the agent was represented significantly less often using space in the second half than in the first half ($p < .001$, d = .74), but there was no significant difference in the use of space to represent the event from the first to the second half (p = .12 d = .71).

In the following section I examine the use of space as a strategy for representing the characters in the stimulus videos and distinguishing their respective semantic roles. That is, I determine the degree to which individual participants and pairs are consistent in their use of space to express argument structure.

4.2 Consistency measures

In determining whether participants' use of space constituted a systematic means of representing argument structure, I used four measures. First, I asked whether a single producer was *consistent in their use of space within a single production*. When participants used space in more than one element of their description (e.g. in the Agent Representation and Event Representation), I analyzed whether their use of space was consistent across the different elements of that production. Second, I calculated whether an *individual producer's use of space was consistent across trials*. I determined

consistency first across trials within blocks, then across all blocks in which a participant had the producer role. This measures the degree to which an individual's use of space is stable and robust to environmental perturbations. Third, I analyzed whether the *two members of the pair used space in the same way across blocks*. This indicates the degree to which two participants converge on the same use of space within the experiment. Finally, I asked whether an individual's consistency in the use of spatial strategies correlated with their partner's comprehension—this addresses the degree to which spatial strategies are mutually comprehensible. Taken together, these measures provide insight into the degree of systematicity present in hearing gesturers' use of space.

4.2.1 Consistency of use of space within trials (Is the use of space coreferential at the trial level?)

The first measure of consistency of space use is within-trial. When participants used space in more than one element of a single production (e.g. in the Agent Representation and Event Representation), I analyzed whether their use of space was consistent across those elements.

First, I asked how often they represented more than one element in a single production. This gives the reader an idea of how many opportunities there were for participants to use space consistently within trials. Table 11 shows that participants in all three studies were fairly variable in the first half of the experiment in terms of the number of trials containing multiple elements that used space. That variability persisted in Study 3 in the second half of the experiment, but decreased in Studies 1 and 2. When participants used space in more than one element of their descriptions, they always used space with either the agent or patient (or both) and the event.

	First half			Second half		
	Study 1 M (R)	Study 2 M (R)	Study 3 M (R)	Study 1 M (R)	Study 2 M (R)	Study 3 M (R)
Number of trials in which multiple elements were represented using space	**24** (6-32)	**29** (5-32)	**21** (0-32)	**29** (17-32)	**32** (29-32)	**16** (0-32)

Table 11. *Average number of trials in which participants used space in more than one element. Data are at the individual level, and are divided by study and experiment half; therefore, each cell is out of 32 items.*

The use of space in these trials was almost always consistent across the different elements of a production (in more than 93% of trials in each condition; see Table 12). Participants most often used a perspective that matched the spatial layout of characters in the video stimuli (60-97% of the time). The proportion of trials in which space was used consistently across multiple elements of a production was marginally different across the first half of the three studies, $F(2,41) = 2.47$, $p = 0.07$, but this was likely due to one outlier. The participant only used space in 6 trials, 3 of which were consistent. When this participant's data was removed, the difference between studies was lessened, $F(2,41) = 1.99$, $p = 0.13$. The consistency of space use across multiple elements of a production did not differ across the second half of the three studies, $F(2,41) = 0.44$, $p = 0.72$.

	First half			Second half		
	Study 1 M (R)	Study 2 M (R)	Study 3 M (R)	Study 1 M (R)	Study 2 M (R)	Study 3 M (R)
Percentage of blocks with consistent use of space across multiple elements	**93%** (50-100%)	**100%** (97-100%)	**100%** (96-100%)	**99%** (88-100%)	**99%** (97-100%)	**99%** (96-100%)

Table 12. *Average percentage of trials in which participants used space consistently across multiple elements within the same production (out of the total number of trials in which participants used space in more than one element).*

4.2.2 Consistency of use of space within a producer, across blocks (Are individuals internally consistent?)

This analysis measures the degree to which individual participants used space in the same way in their productions across trials, throughout the experiment. I start by discussing what types of strategies participants used in describing the events. Recall from Chapter 3 that 'strategies' are determined across trials within a single block, and refer to the means by which producers distinguished the two characters in a stimulus video, and indicated the appropriate semantic role for one or more characters. This provides a more cohesive measure of how participants are solving the communication task, and provides a higher-level analysis of their use of space in their event descriptions.

4.2.2.1 What kinds of strategies do participants use to describe the events?

I first looked at the overall number of blocks (out of 16) in which participants attempted to use spatial and/or non-spatial strategies (it was possible to use only one, or both). For these percentages, I did not consider whether the strategy was consistently used within a block—only whether it was attempted. Table 13 shows the rates of use of

spatial and non-spatial strategies across blocks in the three studies, divided by first half (items 1-64) and second half (items 65-128) of the experiment.

	First half			Second half		
	Study 1 M (R)	Study 2 M (R)	Study 3 M (R)	Study 1 M (R)	Study 2 M (R)	Study 3 M (R)
Spatial strategy	**80%** (25-100%)	**88%** (0-100%)	**84%** (0-100%)	**84%** (0-100%)	**98%** (75-100%)	**73%** (0-100%)
Non-spatial strategy	**29%** (0-100%)	**23%** (0-100%)	**23%** (0-100%)	**32%** (0-100%)	**91%** (25-100%)	**75%** (0-100%)

Table 13. *Rates of use of spatial and non-spatial attempted strategies across blocks, divided by Study and Half. Note that it is possible to use more than one strategy in a given trial (this represents providing more than one piece of information about the characters), so the sum of Spatial and Non-spatial strategy cells need not add up to 100% (and in fact are frequently greater than 100%).*

I did not expect the rates of spatial or non-spatial strategy use to differ across studies in the first half of the experiment, as the stimuli were identical. However, because the manipulation in Study 2 requires that participants communicate about characters' spatial locations in order to allow their partner to select the matching picture, I expected rates of spatial strategies to be higher in Study 2 than in Studies 1 and 3, especially in the second half of the experiment (items 65-128). One-way ANOVAS found that the use of spatial strategies did not differ by Study in the first half, $F(2, 41) = .19$, $p = .83$, but differed marginally in the second half, $F(2, 41) = 2.47$, $p = .10$. Paired-sample t-tests showed that the use of spatial strategies did not differ significantly from the first to the second half in Study 1 ($p = .81$), Study 2 ($p = .24$), or Study 3 ($p = .37$).

The use of non-spatial strategies did not differ by study for the first half, $F(2, 41) = .09$, $p = .93$, but did differ significantly for the second half, $F(2, 41) = 8.24$, $p < .001$. As

shown in Table 13, participants' uses of non-spatial strategies increased in the second half of the experiments by 68% and 52% in Study 2 and Study 3, respectively. Reasons for this will be addressed further in the discussion.

4.2.3 Are participants consistent in their use of strategies within blocks?

I then calculated whether participants had a consistent strategy (spatial or non-spatial) in any block. I defined a "consistent" strategy as one that was used in at least 6 (75%) of 8 trials for representing at least the agent and/or patient. Table 14 shows the percentage of blocks on which participants had a consistent strategy (spatial or non-spatial). The overall proportion of trials in which participants met criteria for having a consistent strategy did not differ across studies, $F(2, 41) = .49$, $p = .65$.

	Study 1 M **(R)**	**Study 2** M **(R)**	**Study 3** M **(R)**
Any consistent strategy used	**87%** (44-100%)	**95%** (88-100%)	**88%** (50-100%)

Table 14. *Mean and Range percentage of trials (for the whole experiment) in which participants used a consistent strategy (spatial or non-spatial). Data are divided by study, and show that participants in different studies used some consistent strategy approximately equal percentages of the time.*

4.2.4 Within-participant and across-block consistency of spatial strategy use

Focusing on the uses of spatial strategies, I asked whether individual participants were internally consistent in their use of spatial strategies across trials and across all blocks in which they served as the producer (Table 15). This is a measure of the degree to which participants' uses of space are more system-like. As above, I defined "consistent" spatial strategy as using space in the same way in at least 6 of 8 trials (75%) for representing at least the agent and/or patient.

For blocks in which a spatial strategy was used, I determined whether participants used space in that block the same way they used space in the previous block in which they produced. There were 16 blocks of 8 trials in an experiment, and each participant produced descriptions for 8 of those blocks. Given that in the first block, there is no "previous" block to compare to, the determination of within-participant consistency across blocks is out of 3 blocks for the first half, and 4 blocks for the second half.

	First half			Second half		
	Study 1 M (R)	Study 2 M (R)	Study 3 M (R)	Study 1 M (R)	Study 2 M (R)	Study 3 M (R)
Percentage of internally consistent spatial strategy use	**71%** (0-100%)	**92%** (33-100%)	**95%** (67-100%)	**80%** (25-100%)	**86%** (50-100%)	**67%** (0-100%)

Table 15. *Average degree of consistency in spatial strategy use within individual producers and across blocks*

Because some participants did not use spatial strategies in any of their production blocks in a given half, the calculation of the average percentages across participants in a single study varied (13 individuals for Studies 1 and 2, respectively, and 14 for Study 3). Furthermore, if a participant only used space in a single production block and was inconsistent in that block compared with their previous production block), their proportion consistency was zero. However, this calculation of internal consistency ensured that an individual participant's consistency was not artificially deflated by calculating their consistency of spatial strategy use out of blocks in which they did not use a spatial strategy.

Internal consistency of spatial strategy use differed significantly across the first half of trials in Studies 1, 2, and 3, $F(2, 37) = 4.64$, $p = .01$, as well as in the second half, F(2,

37) = 4.75, *p* = .01. Because of the way this measure was calculated (excluding blocks in which no spatial strategy was attempted), participants who did not use space at all in either the first or second block (or both) were excluded from the within-study across-half comparisons. For those pairs who used space in both the first and second half of the experiment, rates of internal consistency of spatial strategy use did not change significantly from the first to the second half of Studies 1 or 2 (*p* = .72. *d* = .11; *p* = .62, *d* = .20). However, internal consistency in spatial strategy use did decrease marginally from the first to the second half of trials in Study 3 (*p* = .08, *d* = .84).

4.2.5 Across-block and across-producer consistency of spatial strategies

In addition to measuring whether producers were internally consistent in their use of space across blocks, I calculated whether both members of a pair used space in the same way as each other (Table 16). This is a measure of the degree to which a spatial strategy is shared by both members of a pair. For each block, if a spatial strategy was used, I coded whether the use of space in that block was the same as the use of space in the immediately preceding block. Given that in the first block, there is no "previous" block to compare to, the determination of across-producer consistency across blocks is out of 15 total blocks.

	First half			Second half		
	Study 1 M (R)	Study 2 M (R)	Study 3 M (R)	Study 1 M (R)	Study 2 M (R)	Study 3 M (R)
Percentage of blocks with across-pair consistent spatial strategy use	**79%** (0-100%)	**83%** (25-100%)	**82%** (0-100%)	**80%** (25-100%)	**89%** (75-100%)	**45%** (0-100%)

Table 16. *Percentage of blocks in which a producer used a spatial strategy the same way as the immediately preceding block. Across-pair conventionalization was equivalent in Studies 1-3 in the first half of the experiment, but conventionalization decreased significantly in Study 3 in the second half of the experiment.*

Across-pair consistency did not significantly differ across studies in the first half of the experiment, $F(2, 37) = .85$, $p = .44$, but did differ significantly across studies in the second half, $F(2, 37) = 8.66$, $p = .002$. There was no significant change from the first to the second halves in Studies 1 and 2 ($p = .72$, $d = .20$; $p = .47$, $d = .26$), but the decrease in consistency from the first to the second half of Study 3 was marginally significant ($p = .06$, $d = .76$).

4.2.6 Consistency and comprehension correlation

Another important means of calculating the degree to which participants' uses of spatial strategies constituted a linguistic device is to examine whether consistency in a producer's use of a spatial strategy is related to their partner's comprehension. The relationship between a producer's consistency and their partner's comprehension is an indication of the degree to which the strategy is mutually comprehensible (as linguistic devices are).

First, I examined whether the proportion of blocks in which producers used *any* consistent strategy related to receivers' comprehension rates[28]. This measure does not assess whether strategies were consistent from one block to the next; it only looks at how within-block consistency. However, it does provide a rough estimate across the study of the degree to which participants had some reliable means of describing the video events, which we would expect to be related to their partners' comprehension in each block. A Spearman correlation indicated that the proportion of blocks in which participants had a

[28] The data points are non-independent in that Person A's production consistency is compared to Person B's comprehension, and then Person B's production consistency is being compared to Person A's comprehension. However, the two comparisons for each pair (A-B and B-A) involve completely non-overlapping data points because they are calculated based on different trials, so I include them as independent data points for the purposes of these analyses.

consistent strategy was significantly correlated with their partners' comprehension rates, $r_s(42) = .53$, $p < .001$.

Table 17 shows the percentage of blocks in which participants used a consistent *spatial* strategy, and the average comprehension rates for those blocks. Participants' consistency in their use of spatial strategies was marginally correlated with their partner's comprehension rates, $r_s(40) = .29$, $p = .06$[29]. The relationship between consistency of strategy was slightly less strong in the first half of trials, $r_s(38) = .28$, $p = .07$, than in the second half of trials, $r_s(38) = .47$, $p = .002$. In the first half of each study, none of the correlations between within-block consistency of spatial strategy and comprehension (between .03-.45) were significant. Within the second half of the study, the strongest correlation between within-block consistency of spatial strategy use and comprehension was for Study 1, $r_s(10) = .76$, $p = .004$, followed by Study 2, $r_s(12) = .47$, $p = .09$, then Study 3, $r_s(12) = .25$, $p = .40$.

	First half			Second half		
Average within-block	Study 1 M (R)	Study 2 M (R)	Study 3 M (R)	Study 1 M (R)	Study 2 M (R)	Study 3 M (R)
Spatial Strategy Consistency	**88%** (25-100%)	**91%** (50-100%)	**89%** (25-100%)	**86%** (25-100%)	**98%** (75-100%)	**86%** (0-100%)
Comprehension	**84%** (44-100%)	**86%** (50-100%)	**83%** (50-100%)	**89%** (47-100%)	**86%** (50-100%)	**85%** (44-100%)

Table 17. *Average percentage of blocks that met criteria for having a consistent spatial strategy, and the average comprehension of receivers in those blocks.*

[29] The number of observations in this and subsequent analyses is slightly lower than those included in the previous correlation because some participants either did not use (consistent) spatial strategies at all, or did not use them in either the first or second halves of the experiment.

4.2.7 Summary of results from hearing gesturers in Studies 1, 2, and 3

The results summarized here indicate that hearing gesturers understood the task they were set and were able to complete it. They also indicate that it is possible for hearing gesturers to use space in their descriptions of simple events, and to do so consistently (to a degree). Hearing gesturers showed a high degree of within-trial consistency of space use, and a fairly high rate of both across-trial internal consistency and conventionalization of space use with their partner. Patterns of space use differed across the three studies, indicating that the reliability of spatial information in the environment affected both the overall use of space to describe the stimulus videos and the across-trial consistency both within and across producers. Finally, correlations between strategy consistency and receiver's comprehension indicate that consistent spatial strategies only significantly facilitated comprehension in Study 1 when the spatial information in the environment remained stable throughout the entire task.

4.3 ASL signers' uses of space

Spatial devices for expressing argument structure in established sign languages allow for identification of the agent/patient and then subsequent utterances containing only verbs that move between the established R-loci for the agent and patient. To my knowledge, there is no published work that addresses the conditions under which users of established sign languages will use space in this way. It is thus useful to establish a baseline for how often and in what ways users of an established sign language with spatial devices for expressing argument structure use space in representing the agent, patient, and event under the present study conditions.

In this section I describe how 4 native ASL signers used space in their descriptions of the Study 3 stimuli. The data for ASL Signers are reported as percentages of the total number of items produced (64 items).

4.3.1 How often were the agent, patient, and event represented at all and using space?

Table 18 shows the percentage of trials in which the two pairs of signers represented the agent, patient, and event at all in their descriptions. The data are divided by pair (Pair 1 or Pair 2), and by experiment half (first versus second). Because there are only two members of each pair, the ranges (reported in parenthesis) indicate each pair member's average for that cell.

	First half		Second half	
	Pair 1 **M** (R)	Pair 2 **M** (R)	Pair 1 **M** (R)	Pair 2 **M** (R)
Agent Represented	**97%** (94-100%)	**100%** (n/a)	**97%** (94-100%)	**100%** (n/a)
Patient Represented	**98%** (97-100%)	**92%** (84-100%)	**98%** (97-100%)	**33%** (22-44%)
Event Represented	**100%** (n/a)	**100%** (n/a)	**100%** (n/a)	**100%** (n/a)

Table 18. *Percentage of trials on which ASL Signers represented the agent, patient or event, divided by Pair and Experiment Half.*

ASL signers represented the agent in some way in 94-100% of trials (*M* = 98.4%). Pair 1 and Pair 2 were similar in how often they represented the agent (Pair 1 *M* = 96%; Pair 2 *M* = 100%). Signers represented the patient in 61-100% of trials (*M* = 80%). Pair 2 represented the patient less often (*M* = 62%) than Pair 1 (*M* = 98%). Pair 1's representation of the patient did not differ across the first and second halves (*M* = 98% in both halves). However, a Chi-Square Test of Association determined that Pair 2 represented the patient significantly less often in the second half (*M* = 32%) than in the

first half (M = 92%), χ^2 (1, N = 128) = 46.79, $p < 0.001$[30]. All signers represented the event in 100% of their productions. They did so using ASL lexical items (e.g. PUSH or GIVE) or using role shift, in which they took on the role of one character and depicted that character's actions (Padden, 1986). These findings indicate that signers understood the task and were able to describe events with approximately the same degree of detail/completeness as the hearing gesturers in Studies 1-3.

Table 19 presents the average percentage of trials in which ASL signers used space in their representation of the different elements.

	First half		Second half	
	Pair 1 **M** (R)	Pair 2 **M** (R)	Pair 1 **M** (R)	Pair 2 **M** (R)
Space for Agent	**97%** (94-100%)	**94%** (88-100%)	**97%** (94-100%)	**11%** (9-13%)
Space for Patient	**78%** (59-97%)	**83%** (66-100%)	**92%** (88-97%)	**8%** (3-13%)
Space for Event	**95%** (91-100%)	**91%** (84-97%)	**100%** (n/a)	**81%** (74-88%)

Table 19. *Percentage of trials in which ASL signers used space in representing the agent, patient, and event. Data are divided by pair and by half.*

Signers used space in their representation of the **agent** in 49-100% of items (M = 74%). They did this in three ways: 1) they produced a classifier construction representing a person sitting or standing on the left or right side (using a 'bent-V' handshape or a '1' handshape, respectively); 2) they shifted their shoulders and/or upper torso to the left or right (shoulder shifting); or 3) they stepped to the left or right.

[30] Recall that it is not necessary for the producer to represent the patient in order for the receiver to select the correct picture, so descriptions in which the patient is not represented are not necessarily lacking. Reasons for this pair's reduction in patient representation will be discussed in Chapter 5.

The proportion of use of space in the agent representation differed by pair—Pair 1 used space in their Agent Representation in 94-100% of trials (*M* = 97%), and Pair 2 did so in 49-55% of trials (*M* = 52%). To see whether the manipulation in the Study 3 stimuli (which occurs starting at item 65 of 128 items total) affected the use of space for either pair (but especially for Pair 2), I examined the use of space for the Agent Representation subdivided by first versus second half of the experiment.

For Pair 1, use of space did not differ between the first and second halves (mean = 97% for each half). For Pair 2, the use of space in the representation of the agent changed markedly between the first and the second half of the trials. In the first half, Pair 2 used space in the Agent Representation an average of 94% of trials. In the second half of the experiment, they only used space in the Agent Representation in 9.5% of trials. A Chi-Square test showed that the frequency of use of space differed significantly in the first versus second half for Pair 2, χ^2 (1; N = 128) = 86.89, $p < 0.001$.

Both when they used space in the agent representation and when they did not, ASL signers overwhelmingly used lexical items to identify the agent in their productions. Typically the means used to represent the character's spatial location either immediately preceded, followed, or temporally coincided with the signer's production of the lexical item identifying the character. Three out of four signers represented the agent in all (100%) of their productions, using the ASL lexical items (MAN/WOMAN/BOY/GIRL) to identify the character. One signer used lexical items to identify the agent in 91% (58/64) of his productions. In the remaining 9% (6 productions), this signer either used space alone to represent the agent (2 productions), or did not identify the agent explicitly (4 productions). Of the four productions in which the agent was not identified, the signer

identified the patient explicitly using a lexical item in three items. In the single item in which neither the agent nor the patient were explicitly identified, the signer did use space contrastively to indicate that there were two characters in two distinct roles.

When the **patient** was represented, signers used space in their patient representation 60-97% of the time (*M* = 79%). The ways in which space was used for the patient representation were identical to the ways in which space was used for the agent representation. Pair 1 used space in their patient representations more often (M = 87%) than Pair 2 (*M* = 75%). For the remaining items on which they represented the patient and did *not* use space (13% of items for Pair 1, 25% of items for Pair 2), signers used the same lexical items (MAN/WOMAN/BOY/GIRL) that were used for agent identification.

Signers used space in their **event** representation between 84-100% of the time (*M* = 94%). Pair 1 overwhelmingly used space for both the starting and ending locations of their event gestures (*M* = 96%), and used space in either the starting or ending location an additional 4% of the time (that is, in a single trial each). Pair 2 used space for both the starting and ending locations of their event gestures in 39% of trials, and used space in either the starting or ending location of their event gestures an additional 52% of the time. When signers did not use space in their event representations (0-16% of trials, *M* = 6%), they produced events in neutral space (that is, the space directly in front of their torso, without extending their elbow joints more than 90 degrees).

4.3.2. Within-trial consistency of space use

When signers used space in more than one element of their description (e.g. in the Agent Representation and Event Representation), I analyzed whether their use of space was consistent across the different elements of their production. This measure illustrates

one component of the degree to which signers are systematic in their use of space. The spatial devices for argument structure in ASL allows for coreferentiality—that is, using the same space to refer to the same character across multiple productions. In order to do this successfully, a producer must first be consistent within trials in their establishment of the characters and the movement of verbs between those R-loci. These two components of a spatial device for argument structure might emerge on different timescales, both developmentally and in an emerging language, but the former is a necessary component of the latter (as noted, e.g. in Senghas, 2003; Senghas & Coppola, 2001).

I examined within-trial consistency of space use by determining whether the spatial layout in signers' productions was 'matching' or 'non-matching' with respect to the stimulus videos[31]. Signers' use of space for characters or event gestures typically matched the spatial location of the characters in the stimulus video. That is, if the agent stood on the left side of the computer screen, signers represented the agent to their left. This was true in 94-100% of productions in which space is used for the agent representation (M = 97%), and similarly in 94-100% of productions in which space was used to represent the patient (M = 98%). If the event moved from the left side of the screen to the right side of the screen, signers represented the event as moving from their left to their right (in 100% of productions in which all signers used space for their Event Representation).

Signers used space in more than one element of their productions in 48-100% of their productions (M = 74%). Pair 1's use of space in more than one element (Range = 95-100%, M = 98%) was much higher than Pair 2's use of space for multiple elements

[31] Senghas (2003) examined the spatial layouts used by second-cohort users of Nicaraguan Sign Language describing similar events to those used in the present studies. She called the 'Matching' spatial layout "unrotated," and a 'Non-matching' spatial layout "rotated."

(Range = 48-55%, *M* = 51%). This difference is due to the fact that Pair 2 reduced their use of space in Agent and Patient Representations (and in fact, decreased their representations of the patient overall) in the second half of the study. They did, however, continue to use space in their Event Representation only, in the second half of the study (Range = 74-88% of total productions in the second half, *M* = 81%).

Of those productions in which space was used in more than one element, signers used space in the same way (the "matching" spatial layout) for those elements in 92-100% of the time (*M* = 96%). One signer in each pair was 100% consistent in their use of space across multiple elements. The second signer in Pair 1 was consistent in 92% of (56/61) productions in which he used space for multiple elements. The second signer in Pair 2 was inconsistent in 93% (28/30) productions.

4.3.3. Within-individual and across-block consistency of space use

I also calculated whether an individual signer's use of space was consistent throughout the experiment. "Consistent" use of space within a block was defined in the same way for signers as for hearing gesturers (that is, use of space as using space in the same way in at least 6 (75%) of 8 trials for representing at least the agent and/or patient). I then determined whether each signer used space in a given block the same way they used space in the previous block in which they were the producer.

I calculated the average consistency of space use within producer, across blocks for all four signers. Both members of Pair 1 used space in all 8 blocks in which they produced, and were 100% consistent in their own use of space across blocks. The first member of Pair 2 was 100% consistent in her own use of space across blocks, and the other was 67% consistent in her use of space across blocks. The two members of Pair 2

used space in fewer blocks (4/8 for the first member and 3/8 for the second member), but they did not vacillate in using space consistently. They used space in their agent and/or patient representations consistently for 3 or 4 blocks of trials (in the first half of the experiment), then quickly reduced their use of space in agent/patient representations in favor of using only lexical items and sign ordering (SVO) to identify the agent and/or patient and their respective semantic roles. Thus, both pairs of signers had a consistent strategy in all 16 blocks of the experiment, although that strategy was not necessarily always a spatial strategy.

4.3.4. Across-producer and across-block consistency of space use

In addition to measuring whether producers were internally consistent in their use of space across blocks, I calculated whether both members of a pair used space in the same way as each other. This is a measure of the degree to which a spatial strategy is shared by both members of a pair. For this calculation, I coded whether the use of space in a given block was the same as the use of space in the immediately preceding block. Given that in the first block, there is no "previous" block to compare to, the determination of across-producer consistency across blocks is out of 15 total blocks.

Pair 1 was 100% consistent in their use of space across blocks and across producers. That is to say, both members of this pair used space in the same way in all 16 blocks. Pair 2's consistency of space use across blocks and across producer was 88%. This is because the first producer did not use space in the first block, so Block 2 was coded as "0," and both producers dropped their use of space in the agent and patient

representations in Blocks 8-16[32]. However, across the 7 blocks (Blocks 2-8) in which these signers did use space, they did so consistently.

4.3.5. Summary of ASL signers' use of space

All four signers used space in their representations of the characters and events in the video stimuli, especially in the first half of the experiment. In the second half of the experiment, one pair reduced their use of space in favor of using lexical items alone to represent the agent and patient, but maintained a use of space in their event representations. All four signers used space in the same way—that is, using a spatial layout that matched the spatial layout in the video stimuli. They were also overwhelmingly consistent in their use of space to represent multiple elements within a production.

Signers were also extremely internally consistent and consistent with their partner in how they used space. Although one pair did not initially begin using space, and ceased using space in the second half of the experiment, in all blocks in which signers used space, they were consistent both across their own productions, and across producers. In Chapter 5, I will discuss how hearing gesturers' descriptions of events and uses of space compare to those of ASL signers.

[32] ASL has a variety of linguistic devices for indicating argument structure; in the blocks in which this pair did not use space, they opted instead to use word order to express characters' semantic roles.

Chapter 5: Discussion

Recall that of the total number of pairs who participated in the three studies, 38/60 (63%) did *not* use space as a primary means of expressing argument structure. This fact alone indicates that the use of space, while certainly a strategy that hearing gesturers can capitalize on for expressing argument structure, is not a common or preferred strategy for doing so. The remainder of the discussion focuses on the 22 pairs who did use space as their primary strategy for representing argument structure, and assesses the degree to which their spatial strategies can be considered system-like.

5.1 Element representation and space use

Participants generally produced descriptions that contained at least two elements contained in the stimulus events—namely, the agent and the event (Table 9). Patients were represented less often, but selection of the matching picture from the comprehension array did not depend upon the patient being represented. This indicates that participants understood the goal of the communication task and did attempt to meet this goal.

Participants in Studies 1-3 used space in more than 80% of trials for the agent and the event. Rates of space use for these elements in participant descriptions suggest that the space use for the agent and event did not differ significantly across studies in the first half of the experiment. This was expected, as the stimuli in the first half were identical for Studies 1-3, and confirms that participants across the three studies used space to the same degree in the first half of trials.

Studies 2 and 3 contained manipulations that were designed to affect participants' use of space in some way (see Table 4, in Chapter 2). The second half of Study 2 increased the environmental variability (in terms of characters' spatial locations in the video stimuli and comprehension arrays) in a way that required participants to represent characters' spatial locations. The second half of Study 3 increased this variability to an even greater degree, such that representing the actual spatial location of characters might prove a hindrance to comprehension.

The fact that the rates of space use for the agent and patient did differ significantly across studies in the second half suggests that the manipulations in Studies 2 and 3 had an effect on the rates of space use. In particular, the use of space for the event increased significantly from the first to the second half of Study 2, and the use of space for the agent significantly decreased from the first to the second half of Study 3. The use of space for the agent increased from the first to the second half of Study 2, and the use of space for the event decreased from the first to the second half of Study 3—but these differences did not reach significance.

For those participants who did use space, they used space across the primary elements of their descriptions (the agent and/or event) in a high percentage of trials (63-100% across all elements and all studies, Table 10). Taken together, these findings confirm that the design of the study did encourage space use in the description of the video stimuli. The remainder of the discussion addresses the degree to which participants' use of space could be considered systematic.

5.2 Within-individual and within-trial consistency of space use

Participants used space in representing more than one element of their descriptions in at least half of their productions, on average. When participants used space in more than one element of their descriptions, they always used space with either the agent or patient (or both) and the event. However, the number of trials in which a single participant used space in more than one element of their descriptions varied considerably in the first half of all three studies (between 0 trials and 32 trials, the maximum). This pattern suggests that there is no immediately obvious way to use space with the stimuli that any participant can easily pick up on in the first half of the experiment. Instead, participants ‘try out’ using space to represent one or more elements.

That variability persisted into the second half of Study 3, which reflected the fact that, in that half of the experiment, the use of space was an inconsistent means of communicating about the event. The variability in this measure decreased moderately in Study 1—participants used space in more than one element in between 17 and 32 trials—suggesting that participants’ use of space became more internally consistent when they observed more trials like those they experienced in the first half of the experiment. In the second half of Study 2, the variability in the number of trials in which space was used in more than one element decreased markedly (the range is 5-32 items in the first half, and 29-32 items in the second half; Table 11), reflecting how the ‘environment’ (the video stimuli and the structure of the comprehension arrays) in Study 2 encouraged increased systematic use of space.

When the hearing participants did use space in more than one element of their description, they were overwhelmingly consistent within an utterance in how they used it

(in 93-100% of trials). This rate of within-trial consistency of space use is also much higher than what has been documented in the first cohort of Nicaraguan signers (Senghas et al., 1997)[33]. The fact that hearing gesturers were more consistent in the use of space within their productions than first cohort of NSL signers may be specifically because hearing gesturers have acquired linguistic symbols that help them represent and maintain characters' spatial locations[34]. Several researchers have proposed that spatial language allows for more nuanced, complex, or consistent spatial cognition abilities (e.g. Gentner, Ozyurek, Gurcanli, & Goldin-Meadow, 2013; Pyers, Shusterman, Senghas, Spelke, & Emmorey, 2010; Shusterman & Spelke, 2005; So, Coppola, Licciardello, & Goldin-Meadow, 2005). It may be that hearing gesturers, because they have acquired a language with a rich set of terms for describing spatial relations, have developed the spatial cognition needed to use space for the representation of characters that first-cohort NSL signers lack (Pyers et al., 2010).

Participants could adopt either a "matching" on "non-matching" spatial layout (relative to the video stimuli) to represent the characters in space (described in Chapter 3). A matching layout was preferred by participants in all studies, and was used in 60-97% of trials. This is unlike the pattern in the descriptions produced by the second cohort of Nicaraguan signers, who primarily use a non-matching ('rotated') layout (A. Senghas,

[33] The measure used in Senghas et al. (1997) is not completely analogous to the within-trial consistency measure used here. Because the signers who provided those data at that time rarely produced spatially modulated gestures referring to characters, the same type of analysis was not possible. Instead, the authors examined the degree to which the spatial layout used with multiple predicates was consistent (that is, the same when referring to the same character, or contrastive when referring to different characters). Nevertheless, these two measures are comparable insofar as they both indicate the degree to which participants are keeping track of and maintaining consistent and contrastive locations for referring to particular characters.

[34] Hearing gesturers also differ from NSL cohort 1 signers in socioeconomic status and education levels. However, these differences also exist between hearing gesturers and early-exposed cohort 2 signers, who *do* use space systematically; therefore, these differences do not explain the fact that hearing gesturers seem to be more internally consistent in their use of space than NSL cohort 1 signers.

2003). Given the cognitive challenges associated with mental rotation (Shepard & Metzler, 1971), the fact that a matching spatial layout is preferred by hearing gesturers *might* be a sign that they are using space to represent "where" rather than "who." Rather than using space in an abstract way to represent the characters (which could be done as easily using a non-matching layout as with a matching layout), participants may simply be encoding something akin to "the person on the left pushes the person on the right" and representing that using a matching spatial layout[35]. This is certainly true for participants in Study 2, where they are required in the second half of the study to represent characters' spatial locations.

5.3 Use of spatial strategies versus non-spatial strategies

In order to examine whether participants' uses of space constituted a linguistic device for expressing argument structure, I first quantified the prevalence of participants' attempted strategies for distinguishing the two characters in a stimulus video and indicating their respective semantic roles. The strategies are designated "attempted" because they do not take into account whether participants used those strategies consistently within blocks. These analyses provide a baseline measure of how often participants used spatial and/or non-spatial strategies in describing the stimulus videos.

Because the 23 pairs selected for further analysis had been designated as "space-using" pairs by the primary research assistant (see Section 4.1.1), I expected that their uses of space would be substantial. Analysis of the proportion of blocks in which

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[35] The fact that signers can ignore characters' spatial locations and focus solely on their semantic roles (likely encoding "the man pushed the woman") is evidenced in different ways by the performance of each pair of ASL signers in the second half of the study. Pair 1 continued to encode characters' spatial locations in production, but ignored this information in selecting a matching picture from the comprehension array. Pair 2 opted not to encode characters' spatial locations at all in their productions, and in fact only explicitly encoded "the man pushed" in the linguistic signal.

participants used a spatial strategy confirmed this: in the first half of each Study, participants attempted to use spatial strategies 80-88% of the time. I did not expect to find differences across studies in the use of attempted spatial strategies in the first half of the experiment, and the results again confirmed this prediction.

5.3.1 First versus second half: did the manipulations affect the use of spatial strategies?

Within-study analyses comparing rates of attempted spatial strategy use in the first versus second half of the experiment indicated that the changes in study conditions in studies 2 and 3 influenced participants' attempts at using spatial strategies. When environment remained consistent from the first to the second half of the experiment (Study 1), participants' use of space to represent the events did not change (nor did their use of non-spatial strategies).

In the second half of Study 3, the spatial location of characters was variable, and using space to represent characters' locations (use of space for "where") actually provided conflicting information on some of the trials. Accordingly, participants' use of attempted spatial strategies dropped somewhat, and their use of attempted non-spatial strategies increased significantly. This indicates that participants recognized that trying to use *where* characters are as proxy for indicating *who* they are was unsuccessful when the environment is variable (as it is in real life).

One possible way to solve the problem would be to use space in a way that abstracted away from characters' actual spatial locations—that is, to use space for "who" rather than for "where." Participants in Study 3 could have continued to use the same conventions of form they had developed in the first half—STAND-LEFT and STAND-RIGHT—but update the meaning associated with these forms such that they meant "male character"

and “female character,” respectively, rather than referring to the actual spatial locations. This would be analogous to the “reanalysis” of form-meaning mappings that Senghas (2010) suggested may happen between the first and second cohorts of NSL signers.

However, rather than reanalyzing their form-meaning mappings, participants in Study 3 most often invented an additional, non-spatial means of distinguishing the characters. These non-spatial strategies fell into three categories, each of which also appeared in Studies 1 and 2. The first type of non-spatial strategy, described briefly in Chapter 3, was using the hands to represent some feature of the character (e.g. a “short-hair” gesture to indicate the male character, or a “glasses” gesture to indicate the girl, who wore glasses in the stimulus videos). This was termed a “lexical” strategy. The second type of strategy involved using the whole body to represent another physical feature of the character: height. Participants would crouch to indicate the shorter character, and either stand normally or stand on tip-toes to represent the taller character. This type of representation had more overlapping form-meaning mappings than those in the ‘lexical’ strategy: a gesture for “short one” could refer to three out of four characters, depending on the specific characters involved in the event, whereas the lexical gestures participants used (e.g. “short hair”) could only ever refer to two out of 4 characters. Although this strategy also uses contrastive physical features to identify characters, because of the nature of the form-meaning mappings this strategy involved, and because the whole body was used (rather than the manual articulators alone), this strategy was considered distinct from ‘lexical’ strategies.

The third type of representation was perhaps the closest to a spatial strategy. This strategy was referred to as a “self-as-character” strategy, and involved the producer

adopting the role of a single character in the stimulus videos (typically the male or the female character), and only acting out the actions performed by that character. This sometimes engendered confusion for individual productions in which the character represented by the producer was in the semantic role of patient, and thus stationary in the event. However, receivers were remarkably quick to pick up on this strategy. Producers who used this strategy also sometimes used points to themselves or the receiver to indicate the character undertaking the action (so receivers were sometimes made to represent the other character in the event). Event gestures produced in the context of this strategy were typically directed at either the producer themselves or at the receiver (in a more obvious way than producers who used spatial strategies might direct an event gesture toward the space to their right, where the receiver happened to be standing). Participants who used this strategy also typically depicted the action themselves, regardless of whether they had taken on the role of the agent or the patient in that specific production. They did not contrastively and/or consistently locate different characters in either their agent/patient or event representations. This was therefore not considered a spatial strategy.

It was possible for participants to use multiple strategies within the same production, and they did do so. For instance, the participants in Study 3 who continued to use space in their productions in the second half of the experiment, despite the potential confusion this strategy might have engendered, almost always added an additional strategy to help disambiguate characters and semantic roles. They produced both strategies together, resulting in productions like CROUCH-L (crouching to mean "the boy" while stepping to

their left side) or GLASSES-R (stepping to their right while gesturally representing glasses to mean "the girl").

In the second half of Study 2, where the use of space to represent characters' relative locations was required to ensure successful comprehension by receivers, participants did increase their use of attempted spatial strategies to almost 100% of the blocks. Because the comprehension arrays in the second half of Study 2 also required producers to identify who the characters were independently from where the characters where, participants' use of non-spatial strategies also increased significantly from the first to the second half.

In the next section I discuss the degree to which participants' uses of spatial strategies were consistent, and how that informs the question of whether hearing gesturers in this task can develop linguistic spatial devices for expressing argument structure.

5.4 Within-individual and across-block consistency of space use

To ensure that one study wasn't inherently more difficult than the others, I also analyzed the proportion of blocks in which participants used *some* consistent strategy (spatial or non-spatial). The three studies did not differ significantly, confirming that the three studies did not differ overall in the challenge they posed to participants in developing any kind of consistent strategy. On average, participants used a consistent strategy for a large portion of the task (87-95% of blocks). However, having a consistent strategy *within* blocks did not always translate to *across*-block consistency in the use of spatial strategies.

Hearing gesturers were fairly internally consistent in their use of spatial strategies across trials and across blocks in which they produced, but the average internal

consistency for participants in any study never reached 100%. In Study 1, participants were, on average, 71% (ranging between 0% consistent to 100% consistent) internally consistent in their use of space in the first half of the experiment, and 80% internally consistent (ranging from 25-100%) in their use of space in the second half.

Because the environment—that is, the spatial location of characters in the video stimuli and the comprehension arrays—in Study 1 was consistent, participants were not necessarily encouraged or required to be extremely consistent, or to become more consistent over the course of the experiment. They did not have to communicate anything about the spatial location of the characters—their consistent spatial location merely served as a source of stability in the environment on which participants could (and did, to some degree) capitalize on. However, participants in Study 1 could be equally successful in the task using other strategies. Two main findings emerged: First, participants in Study 1 attempted non-spatial strategies in both the first and the second half. In addition, the average percentage of blocks in which participants used *some* consistent strategy was higher than the average rates of consistent spatial strategy use, indicating that participants in Study 1 also occasionally used consistent strategies that were non-spatial.

In the second half of Study 2, the inconsistent environmental conditions—the fact that characters' spatial locations become variable in both the stimulus videos and the comprehension arrays—should have led participants to increase the consistency of their use of space. The data showed that the average internal consistency of spatial strategies went down slightly in the second half of Study 2, although this decrease was not statistically significant. This apparent slight decrease might be explained by the fact that

the total number of blocks in which participants used space (the denominator for this measure) increased quite a bit from the first to the second half (from 37 to 55 blocks). This increase in the denominator out of which participants' consistency was calculated resulted in part from an increase in the number of blocks in which two participants actually attempted any spatial strategy at all, and was partly an artefact of the way the consistency measure was calculated for the first half of the experiment (see Section 4.3.3). One other measure that suggests that participants became generally more consistent in their use of spatial strategies in the second half of Study 2 is that the range decreased, from 33-100% in the first half to 50-100% in the second half.

Participants' use of space became less consistent in the second half of Study 3, which further supports my conclusion from the previous section that they were using space for "where" rather than for "who." The use of space for "where" provided conflicting information for trials in which the target picture in the comprehension array showed participants in reversed spatial locations relative to the original stimulus event. It therefore makes sense that participants' use of space for "where" would become less consistent as they struggled to adapt to this change in the environment. Participants typically adapted by innovating new, non-spatial strategies that took on the bulk of the referential content with respect to identification of the characters, and using these with (slightly less consistent) spatial strategies, or switching entirely to using these new non-spatial strategies. In sum, within-participant, across-block use of space, while not wholly inconsistent, was nevertheless not as consistent as we might expect if it were a linguistic device (also see comparison to ASL signers' consistency in Section 5.7).

5.5 Across-individual and across-block consistency of space use

Conventionalization of spatial strategy use showed the same general pattern that internal consistency of spatial strategy showed. When they used space in the first half of the experiment, both members of a pair in all three studies used space fairly consistently (in 79-83% of blocks). This suggests that the members of a single pair were able to conventionalize their use of space to a relatively high degree in the first 64 trials. The fairly high rates of conventionalization of spatial strategies indicate that, when the environment is stable, it is not inherently difficult to develop a conventionalized spatial strategy.

5.5.1 Study 1

In Study 1, the rates of consistent spatial strategy use across members of a pair did not change from the first to the second half. This indicates that the additional 64 trials in the second half did not encourage increased conventionalization across members of a pair, despite conventionalization not having reached 100% in the first half of the study. The lack of full conventionalization may be explained in a few ways. Different members of some pairs used distinct, mutually intelligible strategies throughout the task (often one participant would use a spatial strategy and the other participant would use a non-spatial strategy). This suggests that the conditions of the experiment did not encourage participants to conventionalize fully; I discuss five possible reasons this might be so.

1. One possibility was that the **number of trials was too low** to allow for full conventionalization, but the fact that participants reached approximately 80% conventionalization in the first half and then remained at that level throughout the second half discredits that hypothesis.

2. As discussed in the previous section, perhaps the fact that **selecting the matching picture did not depend on producers' spatial consistency** also allowed conventionalization rates to remain relatively low.
3. The **meaning space in these studies was intentionally restricted** so as to limit the cognitive burden placed on participants. However, this restriction may have unintentionally reduced the need for conventionalization by allowing participants to hold the entire meaning space in their working memory during the task. This may be particularly true because the participants were all adults who were able to use their early-acquired native languages to mentally represent the events. de Villiers (2014) showed adults and children pictorial scenes containing 2-argument events (similar to those used in the present studies), and asked participants to select a matching scene from an array similar in structure to the comprehension arrays in the present studies. She found that both adults and children who were permitted to use or provided with linguistic descriptions of target scenes performed better on the task than adults who were prevented from using their i-language (via verbal shadowing) or children who did not receive linguistic descriptions of the scenes. Future work should examine whether the size of the meaning space affects the development and conventionalization of linguistic devices for children versus adults.
4. The fourth potential reason for participants' stalled conventionalization in Study 1 has to do with the **limited variability of the semantic 'environment'** provided in the study. Participants were required to describe 4 different characters engaged in 8 different actions involving transfer (which could all have been described using

similar syntactic or semantic sentence frames). Perhaps this did not provide sufficient variability to encourage conventionalization. In the domain of acquisition, for example, Naigles & Hoff-Ginsberg (1998) found that the variety of syntactic frames in which children heard verbs predicted how early children acquired those verbs. In the same way that hearing verbs in a greater variety of syntactic frames allows children to develop the internal grammatical structure to support the understanding and productive use of those verbs, perhaps requiring participants to describe events that recalled a greater variety of syntactic or semantic structures would have further encouraged the development of structure within this task. However, data from Nicaraguan Sign Language suggests that having the opportunity to describe more types of events does not necessarily help in the conventionalization of spatial devices for argument structure. First-cohort signers have had plenty of opportunity to describe events of varying types (those they encounter in their daily lives), and they did in fact develop a variety of word orders to represent these different event types, but they still did not conventionalize the use of space for argument structure (A. Senghas et al., 1997).

5. The final hypothesis regarding Study 1 participants' incomplete conventionalization is one that can be addressed by examining rates of consistency in Studies 2 and 3. It may be that the **lack of variability in** a different aspect of the environment—**characters' relative spatial locations** across stimulus events—precluded full conventionalization in Study 1. If this was the case, we should observe higher conventionalization in the second half of

either Study 2 or Study 3, in which participants' locations varied both in the stimulus videos and in the comprehension arrays.

5.5.2 Study 2

Participants in Study 2 did not show a significant increase in conventionalization of spatial strategy use from the first to the second half of the experiment, although the range in percentage of blocks for which participants demonstrated a conventionalized use of space did decrease from the first half (25-100%) to the second half (75-100%). This provides some support for the hypothesis that increased variability in characters' spatial locations encouraged participants to be more spatially consistent (both internally and across members of a pair).

However, participants' (slightly) increased conventionalization in the second half of Study 2 does not necessarily indicate that they had generated linguistic spatial devices for expressing argument structure similar to those of established sign languages. The comprehension arrays in Study 2 required participants to exactly represent characters' spatial locations, and contained a target picture that exactly matched the stimulus video in terms of characters' semantic roles and spatial locations. It is possible that, rather than having spatial devices for argument structure, participants were simply modifying their strategies to match the task demands. A linguistic device should be stable under a variety of environmental conditions, and should be robust to a variety of environmental perturbations.

5.5.3 Study 3

How participants' rates of conventionalization of spatial strategies changed from the first to the second half of Study 3 tells us whether participants' spatial strategies were in

fact more like spatial argument structure devices. If participants' spatial strategies were more like a linguistic device from the first half of Study 3, their rates of conventionalization should remain constant in the second half of the study. The manipulation in the second half of Study 3 might also have encouraged abstraction of participants' spatial strategies to make them more like linguistic devices—if this were the case, we might expect to see an increase in the conventionalization of spatial strategies. It is also possible that conventionalization and abstraction are *not* causally linked, and therefore no change in conventionalization would be expected as a result of abstraction—I examine this further in the general discussion. However, if participants' use of space was a strategy based on the environmental regularity (in the stimuli) rather than a linguistic device, I would expect the variability and inconsistency of spatial information in the second half of Study 3 to decrease participants' internal consistency and therefore also decrease their conventionalization of spatial strategies.

The results from the across-individual, across pair analysis of spatial strategy use in the second half of Study 3 shows that the manipulation in study 3 actually *decreased* the degree to which members of a pair used space in the same way (from 85% in the first half to 45% in the second half). The almost 40% drop in the conventional use of spatial strategies was only marginally significant, but this is likely a power issue. In the paired-sample t-tests comparing the first and second halves of the study, I was required to exclude pairs in which one member did not use space in either the first or second half (or both); this left me with only 13 data points. This result suggests that the conventionalization of spatial strategy use decreased when space in the environment

became variable or inconsistent. This further underscores my conclusion that participants in these studies did not develop a spatial devices for representing argument structure.

5.6 Is consistency of spatial strategy use related to comprehension?

In determining whether some observed communication phenomenon constitutes a linguistic device or a strategy, it is important to measure not only the degree to which individuals converge in their productions, but also whether such productions are mutually intelligible (e.g., Senghas, 2003). I therefore calculated whether participants' consistency in their strategy use within trials (both spatial and overall) correlated with their partner's comprehension in those blocks.

If participants' spatial strategies became more systematic over the course of the study (either in terms of their consistency or in some other way that the current consistency measure did not capture), I would expect comprehension rates to go up accordingly in the second half. Another piece of the relationship between consistency and comprehension is whether the consistent spatial strategies participants develop early in the study are systematic in a way that supports comprehension even in the face of environmental perturbation (like the manipulations in the second half of Studies 2 and 3). If this is the case, I would expect the relationship between consistency and comprehension to increase from part 1 to part 2, as producers' increasingly systematic use of space allowed participants to use it for comprehension to a greater degree

Comprehension was significantly related to consistency of overall strategy, which suggests that participants' strategies (and specifically the rates of consistency of those strategies) were the basis for receivers' comprehension. In short, participants successfully completed the communication task we set them.

Collapsing the data from all three studies, I found that participants' consistency in their use of spatial strategies was not significantly related to receivers' comprehension in the first half of the studies, but consistency was related to comprehension in the second half of the studies. The second half of the studies provides the most focused evidence for whether participants' uses of space can be termed a linguistic device: if participants' consistency remains highly correlated with receivers' comprehension when the environment is variable, that suggests that the consistency might be doing the communicative work associated with linguistic devices. In the second half of Study 1, the correlation between participants' consistency of spatial strategy use and receivers' comprehension was $r_s(10) = .76$. The same correlation was $r_s(12) = .47$ in Study 2, and $r_s(12) = .25$ in Study 3, then. The correlation was statistically significant for Study 1 ($p = .004$), marginally significant for Study 2 ($p = .09$), but not significant for Study 3.

5.6.1 Study 1

Although neither average consistency nor average comprehension changed much from the first to the second half of Study 1, the relationship between the two was stronger in the second half. It may be that although the mean consistency and comprehension did not change, participants separated into two approximate groups: one who was consistent in production of spatial strategies and showed high comprehension, and one who was less consistent in production and showed lower comprehension.

5.6.2 Study 2

The fact that the correlation between spatial strategy consistency and receiver comprehension remained stable from the first to the second half of Study 2, rather than increasing as in Study 1 is likely due to the fact that successful comprehension in this half

did not depend only on understanding character's spatial locations. Although producers' use of space in Study 2 became more consistent (both in terms of a higher mean and decreased range), receivers also needed to understand how producers separately represented of characters' identities. Comprehension was therefore less dependent in the second half on the consistency of the spatial strategy alone, and likely more closely related to the consistency of both spatial and non-spatial strategies.

5.6.3 Study 3

Within-block consistency of spatial strategy use was not related to comprehension in either half of Study 3. In general, participants in the second half of study three were less internally consistent across blocks in their spatial strategy use, and converged to a lesser degree with their partners in terms of production. From the first to the second half of the study, participants' overall attempts to use spatial strategies (whether consistent or not) decreased by 11%, and their rates of non-spatial strategy use increased by 50%. This suggests that receivers' comprehension may have depended more on the consistency of those non-spatial strategies and less on spatial strategy consistency.

Taken together, the relationships between consistency of spatial strategy use and receivers' comprehension do not unambiguously indicate that participants' spatial strategies became more systematic over the course of the task[36], for any study. It is true that the consistency of spatial strategies was related to comprehension overall, but this relationship was not the same (in its degree or its nature) in all three studies. Furthermore, the changes in correlations from the first to the second half in each study

[36] It is, of course, possible that the evolution of the types of systematicity I measure in this study require lengthier periods of time to develop. However, recall that in Study 1 a relatively high level of consistency and convergence were reached very early on in the first half of the study (on average), and those levels remained consistent throughout the second half of the study, It is not clear how much more time would be needed to observe increased systematicity, but this is a potential avenue for future research,

suggest two things. First, that participants did not start out with systematic uses of space that were robust to environmental perturbations. Second, that participants probably did *not* systematize their spatial strategies as a result of the increase in environmental variability increased, but instead relied on other non-spatial strategies that they innovated to carry the bulk of the expression of argument structure.

5.7 ASL Signers

To confirm that these features of a linguistic device are in fact observed in users of a language with an established spatial agreement system (and are possible within the context of my task), I asked native users of American Sign Language to complete in the same task hearing gesturers completed. In order to see whether ASL signers' uses of space were in fact robust to environmental variability, I asked them to complete Study 3, in which the variability of characters' spatial locations in the stimulus videos and comprehension arrays is the highest.

5.7.1 Rates and consistency of space use

ASL signers' performance in the task confirmed the systematicity of their uses of space for argument structure. One pair used space in almost every trial across the entire study (between 91-100%) in the representation of some element of their description (typically the agent and event). The second pair had a lower overall use of space that was impacted specifically by the manipulation in the second half of Study 3.

In the first half of the study, this pair used space a high proportion of the time (94-100% of the time) for elements that were necessary to represent (the agent and event). In the second half of the study, one pair dropped the use of space for the agent and patient after realizing that doing so constituted a conflicting piece of information for their partner

in selecting the intended target picture from the comprehension array. This pair had used space on an average of 95% of trials in the first half, however. When they reached the second half, the first producer vociferously expressed the opinion that there was no matching picture for trials in which the intended target picture showed characters in reversed spatial locations relative to the stimulus video. The second producer ratified this declaration in the next production block. These participants had clearly encoded the spatial location of the characters as a relevant feature of the stimuli, and were both representing the information in their productions and intending that their partner use it for comprehension.

Looking only at the trials on which signers did use space, all signers' use of space was consistent within trials between 92-100% of the time. Furthermore, when signers did use space in their descriptions, they did so in ways that were overwhelmingly internally consistent and shared by both members of the pair. As has been described in previous literature, the signers in this study 'set up' characters in space using lexical items and classifier constructions or torso shifting, and then spatially modulated their verbs in a way that clearly indicated the semantic role of one or both characters. Comprehension was also extremely high (averaging 95%) for all four signers.

5.7.2 Did the manipulation affect signers' performance? (First versus second half contrasts)

One pair of signers continued to use space in the second half of the study the same way they had used space in the first half of the study, despite the fact that the spatial information provided in the productions might have on the surface conflicted with the spatial location of characters in the intended target picture in the comprehension array.

For instance, if a signer established the man to her left, but the intended target picture showed the man on the right, it might seem that the use of space here would be confusing for the receiver. However, comprehension did not change significantly for this pair from the first to the second half of the experiment.

The second pair of signers dropped the use of space in the second half of the experiment, and, as described above, clearly noted that the stability of space in the 'environment' (that is, the rate of matching between characters' spatial locations in the stimulus videos and the comprehension arrays) had changed. However, neither this environmental change nor these signers' response to it influenced their comprehension significantly. This was largely because they continued to represent characters using lexical items, as they had been doing throughout the first half of the experiment (simultaneously with the use of space). The bulk of the referential information regarding argument structure simply shifted to being expressed using a word order device—participants produced mainly SVO sentences. This was in fact also highly similar to a portion of the word order used in the first half—signers would produce something like MAN-L [prosodic break] WOMAN-R [prosodic break] MAN-L PUSH-R (S, O, SVO). There were clear prosodic breaks between the two nominal establishments (setting up the man and woman in contrastive space), so the portion of their productions containing the event representation used the same word order that they used in the second half of the experiment.

Further discussion of how ASL signers used space in this task are included in Chapter 6 (the General Discussion). I discuss how ASL signers' uses of space constitute linguistic devices according to the criteria enumerated in Chapter 2, and how hearing

signers' performance on these criteria differs. I then describe how that disparity supports my conclusion that hearing gesturers were unable to develop linguistic spatial devices for expressing argument structure in the course of this task, and what implications that has for how such devices emerge or are acquired.

Chapter 6: General Discussion

This dissertation tested whether interacting hearing adults could innovate linguistic spatial devices for expressing argument structure in the gestural modality. In three studies, I tested the effects of different environmental manipulations on participants' ability to use space in gestural descriptions of simple events. I found that although participants in all three studies did use spatial strategies to express argument structure (and receivers understood those uses of space), no hearing participants developed robust spatial devices for expressing argument structure according to the criteria laid out in Chapter 2. These findings suggest that the conditions of the present studies did not allow for the innovation of spatial devices for argument structure within a single 'generation' of interacting adults, and lend support to the proposal of Senghas and colleagues (e.g. Senghas, 2003; Senghas & Coppola, 2001) that intergenerational transfer, combined with the language acquisition mechanisms of children, are critical ingredients in language change and language genesis[37].

In the following sections, I discuss how the findings from the studies in this dissertation further inform our understanding of the features of spatial devices for argument structure and how such devices are acquired or generated *de novo*. I summarize hearing gesturers' use of space in terms of the components of systematicity by which I measured their productions. I speculate about how the characteristics of my study influenced hearing gesturers' ability to develop fully linguistic spatial devices for

[37] An additional possibility is that child learners per-se are not necessary, but that having *some* early structured input is the key to being able to systematize the use of space for argument structure. Both the hearing gesturers in the present studies and the second cohort signers who were exposed to NSL before age 10 experienced early and at least somewhat structured input, but neither first cohort signers nor later-exposed second cohort signers did.

expressing argument structure. I then compare the behavior of these participants to the uses of space observed in signers of Nicaraguan Sign Language, and discuss similarities and differences between characteristics of the 'environment' in the present studies and those in which Nicaraguan signers are interacting. Finally, I discuss cognitive skills that support the components of spatial devices for expressing argument structure, and integrate this with my findings and those of Senghas and colleagues. The product of this discussion will provide a better understanding of the roles of children's learning mechanisms in the development of linguistic structure.

6.1 Did participants generate a linguistic device or a communication strategy?

The exact point at which communication becomes language is ill-defined. For the purposes of answering the questions posed in this dissertation, I laid out criteria in Chapter 2 that distinguish a linguistic device for a particular function, from a context-dependent strategy that serves the same function. The basics features of a linguistic device that I measure in the present work are:

1. internal consistency (both at the level of a single utterance and across utterances)
2. across-individual convergence of form in production
3. across-individual convergence of understanding (mutual comprehensibility)

6.1.1 ASL signers' use of space

ASL signers were internally consistent in their uses of space, and both members of a pair (in fact all four signers) converged on the same general device for using space (establishing R-loci and moving verbs between them). Comprehension was also

extremely high for all receivers. One pair of signers opted not to use space in their agent and patient representations in the second half of the study, but continued to use space in their event representations. This change in the use of space did not impact receivers' comprehension, however, because both participants continued to rely on one aspect of their spatial devices for expressing argument structure that was present in their productions from the beginning of the experiment: using lexical items to establish the characters. This allowed for a fairly seamless transition for this pair between the first and second halves of the experiment (beyond their observations that the intended target pictures did not 'match' the video stimuli). Taken together, these findings confirm the systematic nature of the use of space in ASL for expressing argument structure[38].

6.1.2 Hearing gesturers' use of space

The summary of hearing gesturers' performance in the three studies indicates that *their uses of space did not constitute a linguistic device*, at least not to the same degree that ASL signers' uses of space did. Hearing gesturers in this task did use space to express argument structure, indicating that the use of space for argument structure alone is not necessarily a privileged or cognitively difficult-to-generate feature when supported by environmental conditions. However, despite the study being specifically designed to encourage its use, space was not the majority strategy choice of the 48 pairs who participated in the studies. This may have been a result of biases from participants' native languages, which could have tended more toward the use of word order as a device

[38] The fact that one pair of ASL signers dropped the use of space in the second half of the study does not undermine the systematicity of their use of space for expressing argument structure. Instead, it highlights the way in which this linguistic device participates in a larger system that has multiple means of expressing argument structure (including word order). The fact that this transition was seamless for ASL signers, but required a period of renegotiation, on average, for hearing gesturers, underscores this point.

for marking argument structure over morphological markings (though I did not collect data on participants' native languages).

Furthermore, hearing gesturers' uses of space did not satisfy any of the criteria for systematicity to the same degree that ASL signers' uses of space did. This may indicate that although the use of space is a *possible* means for expressing argument structure, doing so in a way that is systematic—in terms of internal consistency and convergence across individuals in both production and comprehension—poses a greater challenge. In the next few paragraphs I summarize hearing gesturers' performance on the different measures of systematicity, and discuss what their shortcomings tell us about the function and cognitive difficulty of different elements of using space for argument structure.

6.1.2.1 Internal consistency at the item level

Hearing gesturers were highly consistent in their use of space within productions. This could be because their uses of space were part of a linguistic system, but their consistency is more likely a result of cognitive representation and memory. Participants were consistent in their pantomimic representations of events because it was the easiest way to encode and reproduce the event they had watched. Participants who had trouble using space frequently looked back at the video screen (where the final frame of the stimulus video remained visible) to confirm characters' locations. Additionally, some participants rarely used space in multiple elements of their productions, which accords with the idea that the use of space supported cognitive representation for the producer rather than serving as a means for communicating argument structure.

6.1.2.2 Internal consistency across utterances

Hearing gesturers were also reasonably internally consistent (across trials and across blocks) in their use of spatial strategies, but they were not 100% consistent in their uses of space, nor as internally consistent as ASL signers were. Following the manipulations at the beginning of the second half of Studies 2 and 3, participants exhibited changes in their strategies for expressing argument structure, and slight (on average) decreases in comprehension as they renegotiated the changed form-meaning space. The changes in consistency (in terms of means and variability) of space use and the slight decreases in comprehension between the first and the second halves of Studies 2 and 3 suggest that participants' uses of space were not linguistic devices.

6.1.2.3 Convergence and comprehension

The manipulations in the second halves of Studies 2 and 3 changed rates of convergence between the two members of a pair, which I would not expect if their uses of space were linguistic devices. The changes in convergence and the relationship between consistency of spatial strategy use and comprehension in the second half of Study 3 particularly underscore this point. When ASL signers encountered the change in the second half of Study 3, their productions remained more stable than those of participants in Study 3. Even though one pair of signers did drop the use of space, they maintained the use of a secondary mechanism for expressing argument structure that they had previously used in conjunction with the use of space. Correspondingly, ASL signers' comprehension remained steadily high. The manipulations did not perturb ASL signers' performance in the task because their spatial devices were robust to such perturbations. Hearing gesturers' spatial strategies, in contrast, were not similarly robust.

6.2 The effect of learner-internal and learner-external (environmental) factors on systematicity

Whether interacting adults in a single ‘generation’ can generate a linguistic spatial devices for expressing argument structure depends on two factors: learner-internal factors, and learner-external factors (the environment). Senghas and colleagues suggest that the interaction of an environmental (intergenerational transfer) and a learner-internal factor (children’s language acquisition mechanisms) are at the heart of the development of such spatial devices in Nicaraguan Sign Language. Crucially, however, Senghas and Coppola (2001) finds that intergenerational transfer only results in increased systematic use of space for individuals who were exposed to NSL before the age of 10. Thus, they conclude that learner-internal factors—*children’s* language acquisition mechanisms—are the key ingredient in the emergence of the spatial devices in NSL.

However, the nature of field work and the retroactive examination of language emergence is such that researchers are unable to control or observe all the environmental factors at play. The present work tested whether child language acquisition mechanisms operating via intergenerational transfer must necessarily be the key ingredient in the emergence of linguistic spatial devices to express argument structure. I examined this by manipulating participants’ environment to see whether these differences in learner-external factors can encourage the genesis of spatial devices to express argument structure independently of child language learning mechanisms.

6.2.1 What environmental factors influenced hearing gesturers' use of space?

The primary manipulation of the environment in the three studies was the stability of characters' respective spatial locations in the stimuli and comprehension arrays. In Study 1, that stability was high throughout the trials. In Studies 2 and 3, the stability was high in the first half of the experiment in order to encourage participants to notice and capitalize on that stability in their productions (by using space to represent argument structure, which they did). However, the stability decreased, and variability increased, in the second half of both studies. The characters' spatial locations were unpredictable in the video stimuli, and the comprehension arrays either encouraged participants to focus explicitly on (Study 2) or ignore (Study 3) the actual spatial location of characters.

Internal consistency of space use decreased in the second half of Study 2, but the average convergence across members of a pair was not affected. For Study 3, both internal consistency and convergence decreased. Both of these patterns suggest that the participants' uses of space relied on the consistency of space in the environment (the stimuli). When that variability in the environment increased in different ways, participants were required to modify their strategies accordingly. In both cases participants responded to this variability by developing an additional means for representing argument structure (and for some participants in Study 3, dropping the use of space altogether).

The general lack of change in consistency of space use in Studies 1 and 2 between the first and second halves further suggests that a lack of variability in the environment hinders development of a robust spatial system. This accords with work by Hudson Kam and Newport (2005, 2009) showing that adults acquire more veridically the levels of

variability of forms present in their input (though adults will regularize highly inconsistent input). The participants in the present studies in some senses reproduced the reliability of space in the stimuli in their own productions. The present work extends the findings of Hudson Kam and Newport to suggest that **when low levels of variability are present in the meaning space, singular, systematic forms do not emerge**. Even when variability in the meaning space (the spatial locations of characters) increased in the second half of Study 3, participants were unable to regularize their use of space in a way that resulted in a system. Instead, they continued to reproduce the reliability of characters' spatial locations in the stimuli, such that when that environmental reliability decreased, so did their consistent use of space.

6.2.2 What learner-internal factors influenced hearing gesturers use of space?

Work by Fedzechkina, Jaeger, and Newport (2012) asked adults to learn an artificial language in multiple sessions over the course of a few days. Although participants completed the study independently (that is, without interaction with other individuals), they completed both comprehension and production tasks. What adult learners acquired (as demonstrated by their productions) differed from the input in ways that the authors concluded would "facilitate efficient information transfer compared with the input language" (6). Taken together with the results of the present work, this suggests that adult learners may prioritize communicative robustness and efficiency over long-term systematicity of a particular structure. The participants in Study 3 developed and preferentially used a different means of representing characters and expressing argument structure: lexical items and gesture order.

The new strategy that emerged in the second half of Study 3 likely had two advantages over the previous spatial strategy. First, it was more robust in terms of communication against the particular type of manipulation—the changing locations of characters in the stimuli. It may also have been more cognitively efficient to produce, since participants already knew a system (English) that uses lexical items and word order for expressing argument structure.

6.3 Important components of spatial devices to express argument structure

In this section I discuss how the comparison between hearing gesturers' uses of space and ASL signers' uses of space inform our understanding of the components of spatial devices to express argument structure, and how these comparisons inform theories on whether uses of space in established languages are linguistic or gestural.

6.3.1 Cognitive and linguistic foundations necessary to use space for argument structure

Spatial devices for expressing argument structure in established sign languages are robust to the type of environmental variability present in Study 3 (and in the real world). They do this by means of anaphoric redundancy. The process of nominal establishment involves linking a referent to a location in space via use of a lexical item and a point to that location; once the link has been established, participants can then hold both the space and its referent in mind and thereby use that space consistently both internally and across utterances. The signers in my task certainly attended both to the spatial location of the characters and to their identities—when the intentional mismatch (of spatial location) arose in the comprehension arrays, both pairs noticed and commented, and one pair communicated that the event depicted in the comprehension array no longer exactly matched the event in the stimulus video.

Using one's hands or body to represent characters' spatial locations does not seem to be a difficult thing for non-signing individuals to do, once they are given the opportunity to do so. Approximately half of the total number of participants tested used spatial strategies in the first half of the experiment, and they did so in ways that were internally consistent. Hearing gesturers' spatial strategies may have facilitated adults' memory for and reproduction of the events, and they did facilitate comprehension. However, the success of the strategies depended on the environment being consistent; when the environmental variability increased, participants' uses of space for argument structure deteriorated or changed in a variety of ways.

Using space to represent characters requires, of course, the capacity for representation and some degree of spatial memory (Emmorey, 2002). The movement of event gestures between spaces requires the capacity for analogical reasoning (Taub, 2001) and anaphoric reference (Bellugi et al., 1987). Hearing gesturers clearly had the capacity for representation, analogical reasoning, and anaphoric reference, as they all had a native language, and they were able to apply these respective cognitive and linguistic skills to the task of using space for argument structure. Although I did not test this specifically, observations of how participants interacted with the computer on which they watched the video stimulus suggested that spatial memory varied. Some participants needed to check the computer screen again after beginning a production to confirm that they had correctly represented the space in the stimulus. However, participants must have generally had adequate spatial memory, as they were able to represent the space in the stimulus event consistently to some degree.

The cognitive and linguistic skills above are important foundational capacities for using a spatial agreement system. However, despite having all of these, hearing gesturers did not successfully generate such a system. This is very likely because their initially-generated spatial strategies lacked a critical element that helps generate anaphoric redundancy and thus makes the linguistic device robust in the face of environmental changes or variability.

To achieve this anaphoric redundancy, individuals also need a means of representing the characters that is independent of their spatial location as well as shared by a community of users—that is, they need conventionalized lexical items. As we saw in Study 2, hearing gesturers did use space consistently in the first half of the study, but did not do so in a way that identified the characters independently of their spatial location. When required to represent *both* these pieces of information separately in the same production, they adapted their strategy by adding lexical items.

The strategies generated by participants in Study 2 were the most similar to the specific use of a spatial agreement system by ASL signers. However, their levels of consistency and convergence with either spatial or non-spatial strategies still only approximated that of ASL signers (who were nearly 100% consistent and convergent in their use of both). Future work should examine whether, with additional manipulations—such as having participants do the second halves of Studies 2 and 3 sequentially, or introducing new, naïve participants with whom original pairs must then also communicate—participants can continue to conventionalize their lexical items, and further systematize the use of space for argument structure.

6.3.2 How the present data inform the question of the linguistic status of "directionality"

Liddell (2000, 2003) argues that the use of space to express argument structure (which is often referred to in the literature as "directionality") in established sign languages is a gestural feature of the language that he terms "mental space mapping" (410). He maintains that signers' uses of space to express argument structure enable the construction of a mental 'chessboard' of entities and the semantic relationships between them (the nature of the relationship is specific by the lexical forms of the verbs produced). Under this account, both producers and receivers have particular semantic relationships available in their mental grammars (e.g. X-HIT-Y, meaning "one entity hits another"). The producer's association of locations with referents and the movement of verbs between those locations serves to instruct the receiver in how to construct, select, or specify the producer's intended semantic relationship in the receiver's own mental grammar.

Although Liddell's analysis of the use of space to express argument structure is compatible with the way in which directionality is expressed, his classification of the phenomenon in sign languages as gestural rather than linguistic leaves out two important characteristics. The first has to do with how directionality participates in the grammar of different sign languages, according to our definitions of how linguistic devices should behave with respect to other linguistic devices. Lillo-Martin and Meier (2011) examine how the use of space to express argument structure behaves within the grammar of ASL (and some other sign languages). They examine rules governing the use of space in different contexts (using space with present versus non-present referents), and how the use of space interacts with other linguistic devices (e.g. number-marking). They

conclude that directionality is in fact a linguistic device (indication of referents or thematic/syntactic roles) that is expressed with an additional specification made using gesture (the specific identity—understood via the location in signing space—of those referents or syntactic/thematic roles).

The second piece missing from Liddell's analysis of directionality has to do with the criteria I presented in Section 2.6.2 (consistency, sharedness, and comprehensibility). In a chapter addressing the debate on this topic, Okrent (2002) suggests that researchers consider three criteria in determining whether some feature of language is linguistic or gestural. One, "restriction on combination" refers to what Lillo-Martin and Meier assessed in their 2011 paper (described above). In this dissertation, I was focused solely on the use of space for argument structure, and did not assess whether participants' uses of space interacted with any other potentially systematic elements (something akin to a larger 'grammar,' perhaps).

The other two criteria Okrent discusses have to do with what she terms "conventionalization." First, researchers must specify what particular aspect of a prospective linguistic device is being assessed for conventionalization (Okrent calls this the 'site of conventionalization'). I was intentionally vague about this in the present work, as I wanted to leave open the possibility of conventionalization in one or more potential aspects of the use of space (e.g. which articulator is moved in space, or the spatial layout used). Okrent's second criterion, 'degree of conventionalization,' I have enumerated in the present work as having three sub-components. In order to be considered conventionalized, and thus linguistic, a use of space must: (1) be consistent within individuals, within- and across-trials; (2) be consistent across members of a pair

(that is, be shared in terms of being produced by both members); (3) facilitate comprehension (that is, be shared in terms of being mutually comprehensible).

Okrent notes that conventionalization falls on a continuum, and it is difficult to designate a specific point on the continuum that distinguishes gesture from language. I have made some decisions within the dissertation regarding what constitutes systematic (e.g. the use of space in 75%, or 6/8 trials, for the use of space within in a block to be deemed “consistent”). However, comparing hearing gesturers’ uses of space to those of ASL signers reduces the degree to which I rely on (somewhat) arbitrary designations of “consistent” versus “inconsistent.”

I find the arguments put forth by Lillo-Martin and Meier (2011) that ASL signers’ uses of space to be linguistic (with the gestural overlay they describe) to be convincing. However, regardless of where one wishes to draw the exact distinction between language and gesture in the ‘degree of conventionalization’ continuum, I can nevertheless assert definitively that in this task, hearing gesturers’ uses of space for argument structure were less consistent and more susceptible in both production and comprehension to the manipulations in Studies 2 and 3 than ASL signers’ uses of space. I can then conclude that ASL signers’ use of space is *more linguistic* (in terms of the conventionalization sub-criteria) than that of hearing gesturers. Additional data collected from more ASL signers would allow for a statistical comparison of these criteria in ASL signers versus hearing gesturers, which would bolster this conclusion. Regardless, the present work provides both an important operationalization of Okrent’s ‘conventionalization’ criterion, and initial data that add to the literature on the linguistic status of directionality in established sign languages.

6.4 Spatial agreement in Nicaraguan Sign Language

6.4.1 Why does a spatial agreement system in Nicaraguan Sign Language not emerge in the first cohort?

Given the linguistic and cognitive skills or elements identified above, why does the first cohort of Nicaraguan signers not demonstrate a spatial agreement system while the second cohort does?

First cohort signers certainly have the capacity for representation, as they use symbols (signs) to refer to real-world entities, events, and feelings. Some individuals of the first cohort show some degree of spatial memory, as they do spatially modulate signs in ways that are systematically related to the spatial configurations of their referents (Senghas, 2003). However, it is not clear whether the cohort as a whole has sufficient spatial memory to recognize what spatial regularities do exist in the environment and capitalize on those in their language productions.

Members of the first cohort do not seem to have solid command of anaphoric reference. Kocab and colleagues (Kocab et al., 2015) found that first cohort signers were less clear than second cohort signers about marking changes in perspective in their narratives (referential shift). When they did mark referential shift, they used fewer spatial devices to do so than did first cohort signers. In work examining the development of deixis in Nicaraguan Sign Language, Coppola and Senghas (2010) found that first cohort signers used what the authors term "nominal deictics," or points to empty space that refer to entities, less often than second cohort signers (these deictic gestures functions as anaphora in established sign languages). Additionally, Coppola and colleagues found that first cohort signers explicitly identified characters in stories less often than second

cohort signers (whether using spatial or non-spatial devices), and that earlier cohorts less clearly maintained references throughout the course of their narratives (Coppola, Gagne, & Senghas, 2013). These findings suggest cohort one signers may lack sufficient linguistic or cognitive skill to establish, track, and refer to entities using lexical items, let alone using more abstract spatial reference devices.

The use of verbs in general requires analogical reasoning skills, as verbs encapsulate relations between entities (e.g. Gentner, 1978, 2006). Additionally, Taub (2001) argues that the movement of verbs in spatial agreement contexts metaphorically represent real-world transfers. Thus, analogical reasoning skills likely provide support for the development of spatial agreement systems. There does not currently exist any literature examining analogical reasoning skills in users of Nicaraguan Sign Language, but there is some evidence that exposure to a full, accessible language is necessary for certain aspects of analogical reasoning to develop.

Coppola and Henner (in prep) examined performance on Raven's Progressive Matrices (a non-verbal reasoning task, Raven, 1989) by deaf child and adult homesigners in Nicaragua and unschooled hearing Spanish speakers. They found that both groups performed poorly on items that required relational reasoning, suggesting that both language access and schooling may be critical in the development of analogical reasoning skills. Henner (2016) conducted the largest-scale analysis to date on the relationship between deaf children's vocabulary knowledge and performance on language-based analogies tasks. He found that American Sign Language (ASL) vocabulary knowledge was crucial for the development of language based analogical reasoning skills, and that earlier exposure to accessible linguistic input (ASL, from parents who sign) predicted

better vocabulary knowledge and performance on the analogies tasks. First cohort users of Nicaraguan Sign Language may have reduced analogical reasoning skills as a result of not having a language model; this, in turn, could impede their ability to use space in a systematic way in representing events. Future research should assess whether first cohort Nicaraguan signers' analogical reasoning skills relate to their use of different verbs, and the spatial modulation of verbs in agreement contexts.

Finally, the lexical items in NSL were generated by the members of the first cohort of signers in the first ten years of the language's history. It may be that the array of lexical items had not stabilized to the degree necessary for them play a part in use of space for argument structure. Without conventionalized lexical items and a conventionalized means for nominal establishment, any use of space that did appear in members of the first cohort would not have been communicatively robust.

Overall, the patterns of use of space for argument structure in first cohort Nicaraguan signers align with the hypothesized necessary cognitive and linguistic underpinnings of use of a spatial agreement system. It seems that, although we see some of the components of spatial grammar present in members of the first cohort, the lack (or potential lack) of certain important competencies in the linguistic and cognitive competencies of the first cohort signers prohibits their systematic use of space for argument structure.

6.4.2 Why and how does the use of space for argument structure become systematic in the second cohort?

Despite not using space for argument structure as frequently or consistently as later cohorts, the first cohort nevertheless does have a system for representing argument

structure. One question, then, is why the second cohort would conventionalize a novel device for representing argument structure when they already had a functioning device. The second cohort of signers almost certainly did not consciously conventionalize the use of space for argument structure, but what unconscious factors might have influenced its conventionalization?

Kirby and colleagues (Kirby et al., 2008; Kirby & Hurford, James, 2002; Scott-Phillips & Kirby, 2010) propose that iterated learning—the transmission of a system between 'generations' of learners—is responsible for the evolution of linguistic structure. However, if that were true in the case of spatial agreement in Nicaraguan Sign Language, we would not observe the difference between early- and later-exposed second cohort signers in the consistency of space use for argument structure (Senghas & Coppola, 2001). Senghas (under review) writes that while intergenerational transfer is a necessary component of language change, it is not in itself sufficient to effect that change.

As mentioned previously, Senghas and Coppola (2001) argue that is it specifically the age of learner that is crucial in this linguistic change. Senghas (2010) suggests that the language acquisition mechanisms of the early-exposed second cohort signers allowed them to "reanalyze" the inconsistent uses of space in their input from the first cohort such that they generated a spatial agreement system. This argument is certainly consistent with work showing that children regularize inconsistent input (Hudson Kam & Newport, 2005; Singleton & Newport, 2004).

The internal pressures and goals of younger learners may differ from those of older learners, and young learners' cognitive (e.g. memory) and language-learning skills certainly do differ from those of older learners. Children are, like adults, subject to the

pressure of achieving cognitive efficiency when they learn and communicate, but possess more limited memory and processing capacities than adults. Hudson Kam and Newport (2009) posit that regularization is a result of the “less-is-more” tendency of children to reduce variability in order to reduce cognitive load (Newport, 1990).

It might be that both first and second cohort signers can capitalize on the use of space for expressing events, in the same way adult hearing gesturers in the present work did. But early learners in the second cohort, because they had acquired conventionalized lexical items from the first cohort, and they had child-level memory and processing capacity, were able to regularize the form so that the use of space became internally consistent (using a rotated perspective), and conventionalized across users in both production and comprehension.

The use of space in the first cohort of NSL has been documented to be highly variable (both within and across users)—perhaps this variability is like the high levels of ‘scatter’ in Hudson Kam and Newport (2009), resulting in regularization of the input by the children of the second cohort and a conventionalized use of space. Future experimental work should test whether, given highly variable input in form-meaning pairings (of the sort produced by the first cohort), children will be more likely to regularize that variable input than adults.

6.5 Conclusions

The results of the studies presented in this dissertation indicate that, even when environmental conditions encourage its use, hearing adult gesturers are unable to develop a spatial agreement system within a single ‘generation.’ This finding is the first step in experimentally confirming whether vertical transmission and crucially child learners are

necessary for the emergence of a spatial agreement system. The work lays out specific cognitive and linguistic skills and features necessary to support the use of a spatial agreement system, and assesses the first cohort of Nicaraguan signers and their language system with respect to these skills and features. Finally, I speculate about the specific ways that environmental factors (the nature of the input received by the second cohort) and certain learner-internal factors (regularization in the face of inconsistent input) could have supported the systematization of the use of space for argument structure by early-exposed second cohort signers.

The evolution of Nicaraguan Sign Language in general, and the specific evolution of a spatial agreement system in the language, provides a unique opportunity to unpack the influences of learner-internal and learner-external factors on the development of linguistic structure. Continuing work on this question and questions like it should aim to integrate data from multiple research methodologies (e.g. naturalistic data, experimental work, and computational modeling) in order to arrive at well-substantiated and comprehensive answers.

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