7-21-2017

With a Little Help from My Friends: The Contributions of a Peer Language Network on the Conventionalization of Space in an Emerging Language

Deanna L. Gagne
University of Connecticut - Storrs, deanna.gagne@uconn.edu

With a Little Help from My Friends: The Contributions of a Peer Language Network on the Conventionalization of Space in an Emerging Language

Deanna Louise Gagne, PhD

University of Connecticut, 2017

Individual children are able to regularize inconsistent language input; indeed, many consider this ability the driving force for language change and language emergence. Prior work on Nicaraguan Sign Language found that child learners systematized the use of space, creating morphological structure that had not existed previously in the language. First-Cohort signers produced spatial modulations inconsistently, both within and across individuals. However, younger Second-Cohort signers who received this inconsistent input consistently produced spatial modulations reflecting a rotated layout in which a verb's movement to the signer's right consistently mapped to an event and/or referent on the left. Second-Cohort signers benefited from both older-to-younger language learning and peer-to-peer interactions, obscuring the contributions of each. This dissertation disentangles these factors by exploring a rare sociolinguistic context in which children receive inconsistent linguistic input and also lack linguistic peers: the hearing children of First-Cohort signers, known as "Codas," (children of deaf adults).

Three studies investigated patterns in participants' signed *productions, interpretations* of others' productions, and non-linguistic *encoding* of spatial events. Results show that (1) individual children can regularize inconsistent input without the benefit of peer linguistic interaction;

however, (2) the unique sociocommunicative situation faced by Coda children drives them to regularize in unpredicted ways. They produced *unrotated* layouts more often than their First-Cohort parents, despite the strong preference of Second-Cohort signers for *rotated* layouts. Codas assigned flexible interpretations to others' spatial modulations, a potential consequence of the lack of a peer language network. First-Cohort signers showed the weakest abilities to encode spatial relations (e.g., whether someone tapped the person to their right or to their left), which may have led to inconsistent productions and interpretations. Their Coda children may implicitly accommodate this weakness by systematizing the input differently from Second-Cohort signers, reflecting both the Codas' individual learning biases and their unique sociocommunicative pressures.

These results resonate with findings regarding heritage language learners, whose lack of linguistic peers limits their acquisition of their parents' native language. These findings have important implications for Deaf children in mainstreamed educational settings, whose sign language input comes primarily from non-fluent adult signers, and who rarely have signing linguistic peers.

With a Little Help from My Friends: The Contributions of a Peer Language Network on the Conventionalization of Space in an Emerging Language

Deanna Louise Gagne

B.S., Northeastern University, 2000

M.A., University of Connecticut, 2015

A Dissertation

Submitted in Partial Fulfillment of the

Requirements for the Degree of

Doctor of Philosophy

at the

University of Connecticut

2017

APPROVAL PAGE

Doctor of Philosophy Dissertation

With a Little Help from My Friends: The Contributions of a Peer Language Network on the Conventionalization of Space in an Emerging Language

Presented by

Deanna Louise Gagne, B.S., M.A.

Major Advisor

____

Marie E. Coppola

Associate Advisor

____

Letitia R. Naigles

Associate Advisor

____

Jennie E. Pyers

University of Connecticut

2017

Acknowledgements

I can only hope that with the single drop of my pebble, I can send waves to touch every shore.

It is not often that one gets to say that their dreams have come true. I first learned about the emerging sign language in Nicaragua when I was an undergraduate student at Northeastern University, in an American Sign Language Linguistics course with **Dr. Dennis Cokely**. I remember thinking to myself at the time "*How neat, if only I could do something like that myself one day."* The idea of learning about and interacting with signers from a newly-emerged sign language enthralled me, but like many things in life, was overtaken by other things. Ten years later I realized how much I really felt this was my dream – time and time again I kept finding myself devouring any journal articles about language acquisition or language emergence I could get my hands on. Fortunately, luck was on my side and **Dr. Jennie Pyers** put me in touch with **Dr. Marie Coppola,** and my journey finally began. Of course, this has not only been my journey. During all this time, and I'm sure even into the next phase of this journey, I have never worked alone. This body of work is dedicated to those who have helped to mold me into the person I am today and to those who believed in me and my work to help me continue on that path.

First and foremost, I am most grateful to the **Nicaraguan signers** who participated in my study. They have welcomed me into their homes, have given me countless tidbits of advice, have shared their personal experiences as **deaf signers**, have shared experiences as **Codas**, and have given me a broader understanding of what it means to use a language that is deeply enmeshed in the time and place of its birth and is the core of a community that is still growing. It has been

amazing to find so many shared values across cultural lines and to discover nuggets of beautifully different perspectives and experiences.

My international experience and my field work could not have been so fruitful without the contributions of some very special Nicaraguans who are not deaf and otherwise would have gone unnoticed in this body of work. I sincerely thank Dr. Claudia Molina, Leybi del Rosario Tinoco, Raquel de Los Angeles Tercero Fletes, Ana Francisca “Panchita” Fletes, and Jose Antonio Fletes. Their guidance, support and friendship made living and working in a new place feel like home.

I have almost no words for the guidance, coaching, friendship, mentorship and instruction of **Dr. Marie Coppola.** The mere fact that she believed in me and in my ideas and encouraged me to follow my own curiosities without doubting in my abilities is why I am here today. I am sure the mind-meld we have found will continue.

I am grateful for the enormous contributions of **Dr. Ann Senghas** and **Dr. Jennie Pyers**. They have been mentors, colleagues, and friends in the field, in the lab and in life. Thank you for welcoming me to the fold.

State-side, this project benefitted immensely from the contributions of **Dr. Diane Lillo-Martin** and **Dr. Letitia Naigles**. Your unique expertise, hours of discussion, and encouragement as I found my own standpoint broadened the reach of this project in ways that I could not have achieved on my own. I also want to thank **Dr. James Magnuson** for believing in me and investing in me through the **UConn IGERT/ Neurobiology of Language program.** The interdisciplinary experiences of the IGERT and the financial support to collect these data can never be repaid; I only hope I can pay it forward.

Of course, many more people during my time at UConn have touched my life and my work in countless ways: **Dr**. **Kaitlin Flannery**, my commisserator in all things grad school; **Dr**. **Emily Carrigan**, **Jessica Contreras**, and **Russell Richie**, my lab "siblings;" and of course the hours and hours of work contributed by the research assistants on this project: **Hayseli Midence**, **Julia Adell**, **Eli Miranda**, **Karianna Montalvo**, and **Therese O'Neill**.

Of course, I am who I am as a scientist because of who I am as a person. And therein lie so many more to thank. First just a few of my friends who have constantly rooted for me as I gave up my previous career for the life of a grad student: **Nathan Fowler**, **Dr**. **Jennifer Hensley**, **Summer Chappell**, **Dr**. **Naomi Caselli**, **Cory Brunner**, and **Kristal Hier** among them.

I am eternally grateful for the support of my in-laws, **Elaine and Gordon Gueutal**, who made grad school possible during a time that I also was growing a family. I sincerely am thankful for having a family to lean on in the tough times and to celebrate with in the good times; the **Ammons**, the **Gagnes** and the **Rocheforts** have populated my island in the storm. Yet my rock, the very shore and stability of that island has been my husband, **Kurt Gagne**. As a friend, as a colleague, as a partner, he has been there for me through thick and thin and I could not have *ever* done this without him.

Finally, I thank those who gave me life, who raised me, and who gave me the gift of not one or two, but three languages and three cultures with which to navigate this world: my parents, **Richard and Maria Ammon**. It has been my greatest pleasure to learn about myself as a heritage speaker and a Coda, and to give a small gift back to the deaf community my parents cherished and to communities the world over.

This research was supported by NSF Graduate Research Fellowship #DGE-1247393 and NSF IGERT Grant 1144399 to the University of Connecticut.

Table of Contents

Chapter 1. Introduction

Children are amazingly good language learners. They are able to acquire their native language quickly and effortlessly in vastly varying contexts, needing little to no explicit instruction. Despite much work in this area, there is not much consensus on exactly which elements of a child's language experience are necessary and sufficient for this universally achieved success. If children are such good language learners, why would it matter the number of language models, or whether they interact with other children? Conversely, if children are not facile at acquiring language in less-than-ideal environments, what can we say about the necessary elements for universal success?

The feat of native language acquisition is particularly remarkable when one considers the vast number of possible grammars that are consistent with the sentences that a given child experiences in their linguistic input. Even in an environment with rich, typical, language models, adults' language productions are insufficient to uniquely identify one grammar, leaving children to generate grammatical rules from a limited set of data. This observation, dubbed the "poverty of the stimulus" argument, lead to Chomsky's (1959) suggestion that an innately available Universal Grammar guides children's language acquisition.

Chomsky's theory (e.g., 1959) spurred several lines of investigation, some supporting (e.g., Fodor, 1983) and some challenging the existence of an innate set of principles and rules that govern language (e.g., Tomasello, 2010). Among these challengers are those who perceive the child as an avid learner, for example, discerning the distributional properties in the language they hear and see and applying that information to the language stream (e.g., Saffran, Aslin & Newport, 1996; Aslin, Saffran & Newport, 1998). However, this line of research, and others like it (e.g., Hudson-Kam & Newport, 2009, Newport & Aslin, 2004) focuses on the child as an

individual learner without considering the sociolinguistic environment in which a child is situated (e.g., Bloom & Tinker, 2001; Hoff, 2006; Tomasello, 2010). The common perspective is that a child's ability to process and expand on the language in her environment is due to the skills and capacities of the child alone. The social context and interaction patterns of the child are rarely considered in systematic studies of the relationship between language input and the child's eventual attainment. Thus, even when such networks vary, the resulting (transformed or regularized) language output is interpreted not a consequence of the child's network but as a result of the capacities brought by individual children. Of course, many social influences could affect the language acquisition process (e.g., Hoff, 2006; Gallaway & Richards, 1994; Hoff-Ginsberg & Shatz, 1982). This dissertation aims to disentangle two particular contributors related to the child as a language learner: (1) the contribution of the child as an individual to his or her own language acquisition, and (2) the contributions of the child as a participant within a network of linguistic peers.

To peer or not to peer

Chomsky's (1959, a.o.) argument of the *poverty of the stimulus* focuses on the typical child learning from fluent models of established languages. The argument pays little attention to possible disfluencies in the input, nor to the larger language-learning environment in which the child exists (e.g., bilingual environments, the contributions of peers who may use the same or a different language, cultural norms, etc.). However ideal the language learning environment may be (and in reality, most language is learned in an "ideal" environment, with input containing many examples of utterances that conform to the target grammar, and with a good number of peers with whom to use the language), variations to the ideal do exist, and research has been conducted to investigate the language acquired by children given those imperfect conditions.

Table 1 presents six potential outcomes framed by the relationship between richness of input provided and the presence of linguistic peers, which will be discussed further below.

	Surfeit of peers (usually assumed, but not usually explicitly explored)	**Scarcity of peers**
Rich language input	• Typical language conditions	• Heritage Language speakers
Inconsistent language input	• Development of Pidgins to Creoles • "Simon"	?
No language input	• Emerging Language, such as Nicaraguan Sign Language, Cohort 1	• Homesigners[1]

Table 1. The six possible combinations of the presence of peers and the richness of the input. This dissertation aims to investigate the cell at the intersection of the scarcity of peers who are provided impoverished language input, indicated by the "?".

Peers all around. Most studies of language acquisition are interested in the richness of the input that the child receives, and they generally ignore the contributions of peers. The existence of peers is usually assumed or overlooked because children rarely grow up without linguistic peers, though it does happen (e.g., Hoff, 2006). Obviously, the typical example of language acquisition is that of the child acquiring an established language. As mentioned earlier, language acquisition studies focus on the fact that even in the most ideal situations, the language input may seem sparse in many aspects of grammar acquisition. One example is the lack of negative evidence for some linguistic structures (Marcus, 1993), which buttressed the case for innate linguistic knowledge (Chomsky, 1959; Fodor, 1983; a.o.), and led to the positing of

---

[1] Homesigners do have peers, or friends and family of a similar age with whom they interact using their idiosyncratic gestural communication systems. However, the homesigner is the *only* person that these others interact with who uses the system as their primary language (i.e., the siblings, parents, or friends do not use homesign with each other), which means these individuals only use the system in limited contexts (Richie, Coppola & Yang, 2014). This asymmetry limits their comprehension of the system once context is removed (Carrigan & Coppola, 2017). These individuals are therefore not considered linguistic peers in the way that would be meaningful in this series of studies.

language learning mechanisms that support rapid and effortless acquisition given limited or inconsistent input (e.g., Newport, 1999; Singleton & Newport, 2004). These theories vary in terms of the generality of those learning mechanisms, i.e., whether they are specifically linguistic or part of our domain-general cognitive abilities. Some researchers suggest highly competent learning abilities that allow a child to discern the distributional properties of the language stream (Aslin, Saffran & Newport, 1998; Saffran, Aslin & Newport, 1996), or later, take advantage of syntactic structures for word learning (i.e., syntactic bootstrapping (e.g., Fisher, Gleitman & Gleitman, 1991; Naigles, 1990)). Some of the efforts to explain language acquisition in terms of learning mechanisms, instead of with respect to an innate language acquisition device, assert that the input is not as sparse as Chomsky and others would suggest, and that there is enough richness in the input enough for children to discern the patterns available and extract rules based on those patterns (e.g., Aslin et al. 1998, Saffran et al., 1996, a.o.).

There are cases, however, of children who do not receive rich input from their language models[2]. Surprisingly, in cases of Pidgins/Creoles, child learners seem to surpass their language models in spite of the impoverished input. In these languages, adult language users who already had acquired a native language come in contact with speakers of language(s) unlike their own. Through their efforts to communicate, elements of each of their (two or more) languages are adopted and thus contribute to a novel language, a pidgin. This language is considered impoverished because many grammatical elements are stripped away and the adult users may exhibit inconsistencies in their productions (e.g., Arends, Muysken & Smith, 1994, Aronoff, Meir & Sandler, 2005, Holm, 1989, Hudson Kam & Newport, 2005, Hymes, 1971; Newport, 1999). This impoverished language production makes up the input to children born in that

[2] While Chomsky's "poverty of the stimulus" theory could seem to apply here, as impoverished or inconsistent input may be by definition, "poor;" it had little to say directly about cases of impoverished or inconsistent input.

language environment, and surprisingly, the children often are *more* consistent in their productions, later adding more grammatical complexity and evolving the language from a pidgin to a creole to a fully-fledged language, a feat the adults speaking the earlier versions never accomplished, even after using the pidgin or creole for many years[3] (e.g., Bickerton, 1981). While this is an astounding accomplishment by the children, it is often overlooked, or just not mentioned either by researchers asserting language learning *or* innate generative abilities, that these children likely interacted with other children who were also acquiring the pidgin or creole – they had a network of linguistic peers with whom to use the language they were evolving.

A similar case is that of *Simon*, a deaf child exposed to inconsistent American Sign Language (ASL) input, who regularized his inconsistent input. His productions resembled more the signing of children acquiring ASL natively from their native-signing parents than that of his own parents' (Singleton & Newport, 2004). Simon was born deaf to parents who, like Simon, were also deaf, but who themselves were born to parents (i.e., Simon's grandparents) who had normal hearing and did not know sign language. Because of this, Simon's parents spent their youth, and importantly, the entirety of their language-sensitive periods[4], in educational programs which did not use sign language, but instead used oral/aural methods of communication (Singleton & Newport, 2004). They later learned ASL in their mid-to-late teens. Given this late exposure to the American signing community, they did not become *natively* fluent in ASL. Their

---

[3] One exception may be Tok Pisin, a pidgin spoken by over 1,500,000 people in Papua New Guinea, and a native language to over 20,000 children (Levey, 2001, citing Todd, 1994, p. 251). Interestingly, Tok Pisin is still heavily influenced by English, one of the languages from which it was originally derived, lending a layer of complexity to the emergence of "new" structures in Tok Pisin. Specifically, native Tok Pisin-speaking children often attend school where they are exposed to English; they then have been shown to incorporate further English structures into their spoken Tok Pisin (Romaine, 1992). Further, the pressure of creating a written form of the language for adult use (i.e., newspaper media) also invited the creation of English-based relative clause markers (Levey, 2001). Whether these innovations are mere borrowings from English or novel innovations by (child or adult) speakers of the language is still debated (Levey, 2001).

[4] The critical, or sensitive period of language acquisition is believed to be between birth and 12 years of age, depending on the age of first exposure and intensity of exposure (Bylund, 2009; Fromkin, Krashen, Curtiss, Rigler, & Rigler, 1974; Köpke, 2004; Lenneberg, 1967).

late-learned, nonfluent ASL productions thus formed the majority of Simon's ASL input. When tested, however, instead of producing language like his input (his parents), Simon outperformed his parents on tests of ASL production, producing signed utterances which looked more like those produced by children who had the benefit of fluent ASL from their language models, in spite of the fact that no one in his home or school environment used fluent ASL.

Singleton and Newport (2004) focused on the inconsistent ASL input provided by Simon's parents. However, they note and clearly support their claim that Simon received *no other ASL input* because he attended a self-contained classroom for deaf children where the teachers used "Total Communication," a manual code for English that aims to make English word order more "visible" to deaf children by borrowing lexical signs from ASL while discarding the morphology of ASL (Supalla, 1991). Obviously, then, there was no native ASL in Simon's input, either from his parents, or from his teachers (who used speech and manually coded English), or from his deaf classmates, who were all deaf children born to hearing parents who likely knew little sign language[5]. However, just as in the case of Pidgins and Creoles, where *all* the children are receiving impoverished input and eventually introduce more grammatical regularity, Supalla (1991) has shown that deaf children in environments using Manually Coded English as the sole means of communication will begin to impose ASL-like morphology. Thus Simon's peer network was a group of children exposed to inconsistent sign input (in the form of manually coded English); Simon had a network with whom to strengthen the seeds of ASL grammar that his parents may have planted via their inconsistent input.

Most recently, the *de novo* emergence of Nicaraguan Sign Language (NSL) stands as an example of how language can emerge, without any linguistic input, among a group of peers. The

[5] Approximately 90 to 95 percent of deaf children are born to parents who can hear and do not know a sign language (Mitchell & Karchmer, 2004).

history of Nicaraguan Sign Language will be discussed in a little more detail in section 1.3, but for our current comparison of the richness of language input and the availability of linguistic peers, we look to NSL as an example of how a peer network alone can give rise to the beginning stages of a language. The first wave of Nicaraguan deaf children to come together in a meaningful way (linguistically speaking) is considered the first cohort of the language ("Cohort 1," Senghas, 1995; Senghas & Coppola, 2001; Senghas 2003, Senghas, Senghas & Pyers, 2005). Cohort 1 signers, coming from households that did not know any sign language, were brought together at a school for special education in the late 1970s where no teacher knew sign language either. The teachers spoke Spanish to these deaf children (who could not hear the Spanish, and thus could not acquire it), and the children gestured with each other using their own idiosyncratic homesigns (Also see the next section for a description of homesign/homesigners). These children developed a stable core lexicon[6] (Polich, 2005), some stable word orders (Senghas, Coppola, Supalla & Newport, 1997), and combinatorial properties (Senghas, Kita, & Özyürek, 2004) over approximately a 10 year span, an incredibly short period of time considering the age of most established languages. However, after about these ten years, Cohort 1's ability to continue evolving the language dissipated as the children entered early adolescence. It is likely that the limitation to Cohort 1's abilities to continue contributing to the emergence of the language is the fact that they aged beyond the sensitive, or critical period of language acquisition (Senghas, 1995; Senghas & Coppola 2001), the very same factor that limits native-like acquisition of any language later in life (e.g., Lenneberg, 1967; Newport, 1990). This rapid emergence of NSL in Cohort 1 is often cited as evidence for an innate ability to create language (e.g., Siegler,

[6] Here I am considering the core lexicon to be lexical items for most concrete things such as people, animals, objects, and most action verbs. It is noted, however, that more abstract concepts, such as mental state verbs, were not used frequently by most Cohort 1 signers as compared to Cohort 2 signers, possibly calling in to question the time at which they appear in the history of the language (Pyers & Senghas, 2009).

Deloache, Eisenberg & Saffran, 2014). Here again, however, NSL represents language emergence among a *group* of deaf children. What if each of those children had been alone, without the others? How far could one child go, linguistically speaking, without language input and without peers? This is the situation experienced by *homesigners*, who are discussed in the next section.

No friends to talk to. I have described three examples of children (in groups) acquiring language with three types of input: rich input, impoverished input, and none. The constant factor across the three examples (Table 1) is the fact that these children were able to either (a) acquire language completely (typical language acquisition), (b) surpass their language models (impoverished input), or (c) create a new language (no language Input) in the presence of peers. If we ignore the presence of peers, we could assume then that children, as individuals, have a strong bias to acquiring (or developing) language, and that the output somehow depends on the input. At each of these levels, the children produced something equal to or *better* than what they received as input from adults.

What if these children had no peers? What would happen at each of these levels of input? How important are linguistic peers (peers who use, and importantly, *rely on*) a common language as the child? In Nicaragua, individuals exist who can serve as a direct comparison to Cohort 1 signers of NSL in terms of the presence (or not) of linguistic peers. *Homesigners* are deaf individuals who, by virtue of their deafness, cannot access the spoken language around them and who create idiosyncratic gestural systems that they use regularly with the people (friends, family) around them (Carrigan & Coppola, 2017; Coppola & Newport, 2005; Goldin-Meadow, 2005; Richie, Yang, & Coppola, 2014). In Nicaragua, due to financial or geographical barriers,

not every child has the means to attend a school for the deaf[7] – these children are *homesigners*[8]. For our purposes, then, homesigners are deaf individuals who have no language input (no one has taught them a sign language) and no linguistic peers: all their peers (siblings, friends) are hearing individuals who do not rely on the homesign system to communicate with anyone other than the homesigner themselves (Richie et al., 2014). Incredibly, homesigners *do* create language-like systems with no direct language models and no linguistic peers. These systems include the grammatical relation of subject (Coppola & Newport, 2005) and the innovation of morphological forms marking plurality (Coppola et al., 2013), both of which suggest that children have some innate ability to create linguistic structure. Unfortunately, however, homesign systems are linguistically limited. In most instances, when homesigners are compared to Cohort 1 signers (deaf individuals who also have no adult language models, who live in the same culture, and are roughly the same age), Cohort 1 signers' productions often show more regularity and innovation, for instance in the conventionalization of a lexicon (Richie et al., 2014), or the pronominal uses of pointing (Coppola & Senghas, 2010). In some instances, homesigns and Cohort 1's productions are indistinguishable, which speaks to either the limitations on Cohort 1's ability to continue regularizing due to the close of their sensitive period, or to the contribution (or lack thereof) of the input. Either way, we note that homesigners give us a peek into the language abilities of individuals with no input and no linguistic peers.

---

[7] While the reach of NSL has spread, it is still an emerging language and an emerging community. Few schools exist outside of the capital city of Managua, and even they are difficult to get to or only provide sporadic meeting times and resources for children and families to become fluent in NSL (Labato, 2017).

[8] Note that some homesigners do attend hearing schools – schools with no accommodations for the profoundly deaf child other than placing them at the front of the room to copy what is written/drawn on the board. While there may be some benefit to the homesigning child from attending a hearing school in this way, such as in areas of executive functioning, there is still no direct language benefit. Therefore these children are still considered *homesigners*. What is still unclear is whether *every* deaf child born to a family who doesn't know sign becomes a homesigner, but that question is beyond the scope of the current project.

If children with no linguistic input who also lack linguistic peers can begin to create systematic communication systems, then what of children *with* linguistic input? Heritage Language Speakers are children who receive rich linguistic input, but have few or no peers with whom to use that language (e.g., Benmamoun, Montrul, & Polinsky, 2013; He, 2010; See Table 1). *Heritage speakers* of a language are individuals who learn a language natively (from birth), from parents and other adult family members who provide fluent, native language models. Notably, the use of said language is usually confined to the home environment or other limited settings and is not used in the surrounding community, such as in the child's educational setting or at the local market (e.g., Benmamoun et al., 2013, Kagan, 2005). This situation captures the experience of the theoretical child of Hindi-speaking immigrants who do not speak English but have moved to an English-dominant area of the United States. Hindi is the language of the child's home, and in fact, is the only language that the child has been exposed to from birth. But over time, as the child enters school and is exposed to English from his teachers and peers, his fluency in English (technically a second language) will likely exceed his fluency in Hindi, which may never be as fluent as his parents'. Note that unlike for children of pidgin-speakers, or Simon's case, heritage speakers' language models are usually <u>fluent, native models of the target language</u>. The literature characterizes two kinds of heritage language speakers. First, there are those who grow up primarily in a monolingual L1 (in the above case, a monolingual Hindi environment) and then immigrate to a new country during his childhood where the dominant language in school and social environments is the L2. In this case, depending on the child's age at the time of the move, there is likely to be attrition of the L1 (e.g., Montrul, 2004). The second type is the child of L1-dominant parents (e.g., Hindi-speaking parents) who is born into an environment where the L1 is not the dominant language of the greater linguistic sphere. In this

case, there are several possibilities depending on the language environment of the home and childcare choices of the parent. These children may be shielded from much of the culturally-dominant L2 for several reasons: his parents watch Hindi TV, listen to Hindi music, and he does not attend school in the dominant language. Thus, the child spends time only with his Hindi-speaking parents and their Hindi-speaking friends. This child, upon entering the greater public school environment, may experience attrition like the first type of heritage speaker. But there is another extreme to the spectrum of experiences of heritage speakers – that is, the heritage speaker who is exposed to both languages from birth. Perhaps in this case of Hindi, there is an older sibling already in the school environment and who brings the culturally-dominant L2 home, or the parents are learning the L2 themselves and therefore expose their children to the L2, or the parents choose early childcare environments where the L2 is the dominant language. In these cases, we don't necessarily expect attrition of the L1, but possibly incomplete acquisition of the L1.

What is most interesting for our purposes is that either type of heritage speaker is an individual who, given the fluent native models in their home, still seem to fall short of acquiring that language fluently (e.g., Benmamoun et al., 2013; Montrul, 2012; Van Deusen-Scholl, 2003), when we (theoretically) expect that all a child needs is a few good language models to demonstrate how the language works. Another interesting factor is that this "falling short" is not exactly like the way that second language learners fall short of native language acquisition. For heritage speakers, some aspects of their production and comprehension are indistinguishable from those of native speakers and are often better than those of second language learners. Other aspects – often those that are typically acquired later, such as complex morphology, fall short of native-like fluency and pattern differently even from second language learners (e.g., Lynch,

2008; Montrul, 2010, 2011, 2012). Some language outcomes in heritage speakers have been tracked longitudinally, showing attrition from 100 percent accuracy in gender agreement for Spanish L1, English-L2 children who are immersed in English-dominant environments (Montrul, 2004). As an example of one of these children, a child raised in a Spanish-dominant environment then moved to an English-dominant environment. She later showed a decrease in accuracy (attrition) for gender marking from age 6:7, when she scored 100 percent, to two years later, at age 8:5, when she scored 94.2 percent (ibid). Of course, this describes the attrition of a sequential heritage speaker (one who was exposed exclusively to the L1 and then later to the L2). In theory many heritage speakers, even those exposed to the home and socioculturally dominant language from birth, experience some sequential effects given typical ages at which children start schooling in the dominant language. However, what is most interesting is that in every case discussed here (with the exception of international adoptees who are completely immersed in the new dominant language) the heritage-language speaking child still encounters rich language models in the home. However, this rich language model is not enough to scaffold fluent native language acquisition, and as shown in the example of the sequential heritage speaker, is not enough to maintain heritage language fluency.

Why does this happen? What makes all this especially surprising is exactly what has been reviewed so far: (1) children given rich input in typical environments acquire their native language fluently, effortlessly, and completely, even when it could be argued that the amount of information provided by any language model, even in typical environments is not enough to support the complete acquisition universally observed (Chomsky, 1959). Therefore, children must be going beyond what even typical input offers, and (2) children provided with

impoverished language input also seem to take that input and improve on it[9]. These two factors lead to a virtual impossibility that heritage speakers as a group could exist- all around we see cases of children going beyond their input, and that very little input is necessary to scaffold a richer result when in the hands of children.

However, a paradox arises when one considers the divergent outcomes observed among heritage language speakers who are, by definition, raised with rich adult-to-child input and virtually no peers with whom they use their heritage language, and the suggestion from other literature that the sociolinguistic contributions of a peer network are necessary for complete language acquisition. Sociolinguistic contributions may include things like the ability to "hash out" differences with perceived peers (as opposed to accommodating those who are higher in status), the need to explain things more clearly to peers who may not have as large a scope of knowledge, less shared home context, and so on (e.g., Pellegrini, Galda, Flor, Bartini, & Charak, 1997; Kuntay & Senay, 2003; Pesco & Crago, 1996; Preece, 1992; Sheldon, 1996). This dissertation cannot disentangle all the potential mechanisms or contributions of having a network of linguistic peers, but focuses on whether peers are a necessary (or even sufficient) for fluent native language acquisition.

The central question I pose is the following: what if a heritage language learner (a child with no language peers) was not provided a fully-established language, but an emerging, inconsistent language? Heritage language learners are typically provided rich input from an established language and are thus compared to native fluent speakers of that established language. What if we changed the benchmark? What if the input was impoverished enough such that the individual child, in theory, could improve on the input (like children learning creoles do),

---

[9] Here *No Language Input* is arguably *impoverished* in that the input provided the child is (1) less than *Rich* and that the child still creates language/ communication that goes beyond that (lack of) input.

regardless of the presence of linguistic peers? This language experience would complete Table 1. What is left to be seen is whether such a child could improve on their input without linguistic peers or would fall short, as heritage speakers do?

Statement of the Problem

The evidence so far suggests that children *can* acquire language, and even improve on inconsistent or an emerging language when in the presence of peers (e.g., Oller & Eilers, 2002). However, when children receive fluent, native language models but do not have the benefit of using that language in a community setting (i.e., with peers), they do not always achieve fluent mastery of their home language; this may be attributable to pressures from the dominant language used by the peers they encounter, for instance, in educational settings (Benmamoun, 2013, Kagan 2005), or as an effect of number-of-interlocutors having varied peer interactions may bring (Gollan, Starr, & Ferreira, 2015).

These findings suggest that the presence of language peers is a likely factor underlying the observed regularization of language in children, and that this process is not necessarily driven by an individual child, but is at least triggered, if not driven by, environmental factors. However, this interim conclusion usually relies on studies comparing heritage language speaking children as compared to native monolingual speakers of that established language, leaving the possibility that other language-specific factors may come into play beyond the contributions of the transmission conditions. No studies have explored this question using an emerging language (providing inconsistent input) to compare children with varying degrees of linguistic peer networks, thus leaving a gap in the literature regarding (1) the ability of individual children to regularize inconsistent input, and (2) the relative benefit of having a peer community with whom to use said emerging language in order to regularize that language (i.e., improve upon the input).

The current study addresses that gap by investigating the potential contributions of the presence of a peer network on the regularization of language given the same inconsistent language model. Here we investigate two groups of individuals, one with access to a peer-based linguistic community, and one without, both in the context of the same emerging language, Nicaraguan Sign Language (NSL), and broader culture (the city of Managua, Nicaragua). An emerging language, rather than an established language, is considered to be ideal for the observation of regularization, given the greater opportunities for regularization to occur in a context where inconsistent input is prevalent[10], and the vanishingly rare opportunity to observe a language emerging in real time.

In an emerging language, as it is in pidgins and creoles, we are much more likely to be able to identify cases of language regularization over short time spans, given the low prevalence of already-regularized grammatical structures. Therefore, regularization could be gauged by measuring the rate of consistency of grammatical forms in the productions of children as compared to their adult models, who are alive at the time of testing but because of critical period effects, represent the language as it was when their critical period closed. Because of this, most researchers consider the language productions of Cohort 1 signers to reflect an earlier version of the language than Cohort 2 signers, even when tested at the same current time. Rarely do we have such an opportunity, where there is an advantageous (for our purposes) interaction between an emerging language (like the pidgins and creoles) with the sociolinguistic context of the samples of interest, one deaf with a peer network, and one hearing sample, born to deaf parents and who use the signed language at home, but not with peers, which disambiguates the possible

[10] Language change can indeed be measured in established languages, though it requires much more historical data, often spanning hundreds of years' of language documentation. This type of historical data also confounds the two transmission types we are interested in here, that is, over hundreds of years, we can be certain that both horizontal (peer-based) and vertical (adult-to-child) transmission environments played part in the evolution/ regularization of the language.

contribution of the individual learning from the input alone from the individual nested within a peer network.

History of Nicaraguan Sign Language

In order to describe the current study, a clearer picture of the sociolinguistic history and context of the intended participants is warranted. Here I begin with a description of the emergence of Nicaraguan Sign Language (NSL) and previous work with the language as it pertains to this study, along with specific terminology, including the concepts of Vertical vs. Horizontal Language Transmission, the use of space (Rotated vs. Unrotated Space), and "Codas" (children of deaf adults).

The emergence of Nicaraguan Sign Language (NSL) and the regularization of signing space. The history of NSL has been described in fair detail previously (e.g., Polich, 2005; Senghas, 2003, Senghas, Senghas, & Pyers, 2005); thus, I will only highlight the factors relevant for the current study. NSL is a language that emerged *de novo*, that is, no other previously-existing language contributed to the roots of NSL, or provided any target language or language model. Rather, the roots of NSL are homesign systems - idiosyncratic gestural communication systems created by individual deaf children for use with their own family members and friends (Carrigan & Coppola, 2017; Coppola & Newport, 2005; Goldin-Meadow, 2005). Beginning in the mid-to-late 1970s, deaf children and adolescents using homesign systems were brought together in the first and subsequent cohorts of students attending a center for special education in the capital city of Managua, Nicaragua. The first cohort of signers to arrive had *no* sign language education or input – the school employed an oral/aural education method and thus the teachers used spoken Spanish with their deaf students. Importantly, the teachers did not systematically discourage the use of gestures or homesign among the children as

they conversed with each other. Thus, the first cohort of NSL signers experienced *horizontal* language transmission/ input (with each other) but no *vertical* language transmission (no language model) (Senghas, 2003) (Figure 1).

Vertical language transmission occurs among users of varying language fluency and experience, where the more experienced and fluent speaker of the language models the target language for the lesser-experienced speaker. An example of this is parent-to-child vertical language transmission, but this also happens between teachers and students, older siblings or students to younger siblings or students, etc. (1a).

Horizontal language transmission occurs among users of roughly the *same* language fluency and experience. This occurs, for instance, between siblings close in age or among classmates (1b).

Most typically developing children experience *both* vertical and horizontal language transmission simultaneously (1c). That is, their daily lives include interactions with older language models (who have their own peer language community) as well as with language peers who are also acquiring the same language with similar vertical models.

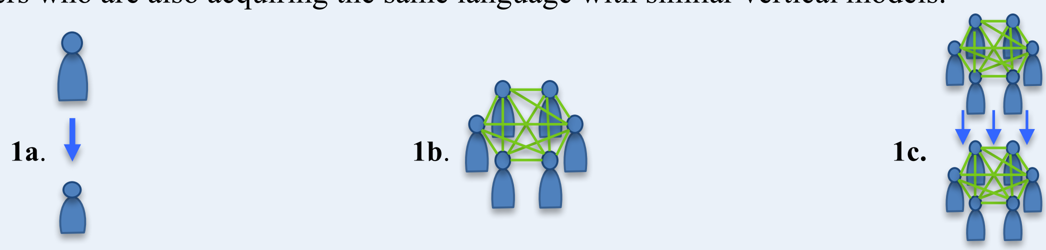


Figure 1. Vertical vs. Horizontal Language Transmission

The second cohort of NSL signers is comprised of children who arrived at the school approximately ten years after the first cohort – in the mid 1980s. Importantly, second cohort signers were (a) still child homesigners themselves, as they were not exposed to sign in the home and thus had likely developed gestural communication with their families before arriving at the school[11], and (b) were subsequently exposed to the productions of the first cohort signers who had been at the school already for upwards of ten years. Thus, these second cohort signers

[11] Note that child homesigners, despite their young age, have very productive communication systems; Susan Goldin-Meadow's work with child homesigners included children as young as 1;6 (Goldin-Meadow, 2005).

experienced both *vertical* language input from first cohort signers, as well as *horizontal* language input from their second cohort peers (Figure 1) (Senghas, 2003).

The distinction between vertical and horizontal language input becomes relevant given previous work on the regularization of language in Nicaragua which found that the first cohort of NSL signers (who had only experienced *horizontal* language exposure) were inconsistent in their use of spatial layouts to describe the thematic roles within transitive and di-transitive events (Senghas & Coppola, 2001, Senghas, 2003). Section 1.5 reviews the use of space in sign language structure, but I describe a simple example here. To describe an event in which one person gives an object to a person to their right, Cohort 1 signers responded in a number of ways: (1) some showed a preference in producing a *rotated* layout (signing GIVE[12] to their own right); (2) others preferred an *unrotated* layout (they signed give to their left, mirroring the video); (3) however, the majority of Cohort 1 signers did not show a preference for either of these spatial layouts, and inconsistently produced either layout. In other words, Cohort 1 was inconsistent overall in their productions of spatial modulations, showing inconsistency both within signers and across the cohort.

When Cohort 2 signers (signers who arrived at the school after 1983 and who had Cohort 1 signers as their input) were tested on the same task, they had not only regularized the language within each signer -- more individual signers showed consistency from one event to the next— but also that signers <u>across the cohort</u> preferred *rotated* layouts. This observation was later supported with interpretation data (Senghas, 2003), where signers watched videos of others signing and selected the corresponding image(s) that represented a rotated layout.

---

[12] Because most sign languages do not have orthographic forms, it is convention to use a *glossing* system to write about a sign or sign sentence. When *glossing*, one applies the most readily available conceptual meaning in the local dominant language (e.g., GIVE, using English for the act of giving) notated in all caps to indicate that the production is a sign and not the English word.

In sum, those who produced inconsistent layouts also had inconsistent interpretations (Cohort 1), and those who had consistent productions had consistent interpretations (Cohort 2). Senghas (2003, p. 526) provides an excellent example of how this regularization in both the production and interpretation of others amounts to the innovation of a new morphosyntactic structure in NSL:

> "For example, consider a sentence in which *see* and *pay* are both produced to the left. To signers who don't have the new structure in their language, the sentence could mean that one person was seen and another paid, or that a single person was both seen and paid. Signers [i.e., Cohort 2 signers] who have the structure accept only the second, more restricted interpretation. For them, the first reading is not merely unlikely, it is also ungrammatical." (p. 526*, Bracket added for clarity*)

Senghas (2003) concluded that the changes observed from Cohort 1 to Cohort 2 were due to the ontogenetic ability specific to children, to improve on linguistic input and to converge on regular language structures in spite of inconsistent or insufficient input (e.g., Singleton & Newport, 2004).

Senghas (2003) suggests the appropriate sociocultural conditions for language emergence include that children need to be in contact with both other children and adults (both peer (horizontal) and intergenerational (vertical) contact). At this point, however, we cannot identify which- the vertical or horizontal input was the primary driving factor for the regularization of this use of space in NSL. Essentially, we can now ask whether each child as an individual learner was able to regularize based on the vertical input they received from Cohort 1 or whether the horizontal language input (the peer-level interactions) that Cohort 2 experienced was necessary for the regularization exhibited by these individuals, given the inconsistent input. The current series of studies aims to extend this work by introducing another group of signers who also received inconsistent input from Cohort 1, but did not have the benefit of using the language

with peers, as did Cohort 2. These individuals are the hearing, natively signing children of Cohort 1, also known as "Codas," or "Children of Deaf Adults," described below and depicted in Figure 2.

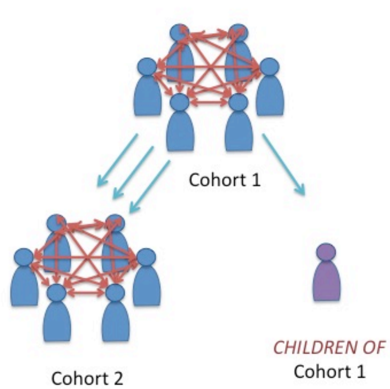


Figure 2. Depiction of the horizontal (red arrows) and vertical (blue arrows) language transmission relationships among the three populations of interest using Nicaraguan Sign Language (NSL). Cohort 1, as the first cohort of signers using NSL, did not receive any vertical input (they had no language models), but benefitted from horizontal input from each other. Cohort 1 served as the language model for two subsequent groups, Cohort 2 signers, who had the benefit of vertical input (from Cohort 1) and horizontal input (from each other), and the hearing children of Cohort 1, who received vertical input from their parents and parents' friends (all from Cohort 1), but who did not experience horizontal language input from any deaf or hearing signing peers.

Children of Deaf Adults (Codas)

Children of Deaf Adults, henceforth *Codas*[13]*,* are individuals who have typical hearing and have at least one deaf parent (usually a signing deaf parent; Bull, 1998). Codas are considered "circumstantial bilinguals," that is, they are bilingual not from the choice of learning a second language, but by the linguistic circumstances of their lives (Williamson, 2015). Additionally, they are *bimodal bilinguals:* they are bilinguals of two languages in two different modalities (one oral/aural and one visual/manual; e.g., Emmorey, 2008; Williamson, 2015). It is

[13] Here we differentiate the acronym for the international organization for Children of Deaf Adults (CODA) and the concept of a hearing offspring of at least one deaf parent by using a capital C and lowercase letters for the rest of the acronym in "Coda." For this series of studies, then, the hearing children of Cohort 1 will be referred to as "the Coda children of Cohort 1," "children of Cohort 1," and "Codas" interchangeably.

typical for Codas, just as for Heritage speakers, to only use the sign language with one's (deaf) parents, but to speak the dominant spoken language (e.g., English in the United States) with hearing members of the family, including siblings, even if the siblings also sign with the parents (Pizer, Walters & Meier, 2013). In fact, several lines of current research regard Codas as heritage speakers of sign language given the particulars of their language environments (e.g., Reynolds & Palmer, 2014; Williamson, 2015; Chen Pichler, Reynolds, Palmer, de Quadros, Kozak, & Lillo-Martin, 2015). Codas represent individuals who are natively exposed to sign language (with vertical transmission), but do not typically experience peer interactions using the sign language (without horizontal transmission of said sign language). The question addressed in this dissertation is whether the sociocultural context of the NSL Codas (as potential heritage speakers of Nicaraguan Sign Language) affects the regularization and conventionalization processes observed in NSL. Will they "fall short" of their input by acquiring only that what their parents model for them, like the L1-Spanish L2-English heritage speaker discussed in section 1.1.2, or will they go beyond that input to create richer morphological structures using space, in the way that other children are shown to be able to do? That is, can they regularize the use of space like Cohort 2 did, except on an individual basis, or does regularization and conventionalization of spatial modulations and spatial layout in NSL grammar depend on the presence of linguistic peers?

The use of signing space in Sign Languages

Because the crucial question in this set of studies is the grammaticization or regularization of the morphosyntactic use of space in an emerging sign language, it is imperative to clarify the ways sign languages can use space for the reader unfamiliar with sign language grammars. Of particular interest for the current studies, the use of space is a morphological

element available in sign languages and *not* in spoken languages. This aspect of grammatical structure is therefore an ideal one to study in the bilingual (Spanish and NSL), bimodal (spoken and sign) children of deaf parents. By choosing a structure that can appear only in NSL, there is virtually no risk of transfer from spoken Spanish to signed NSL. That is, if we find that the children of deaf NSL signers use space in the way described below it is likely that it was generated organically and solely for the purpose of using it within the sign language system and not because it was provided the child via his exposure to Spanish. This section, therefore, reviews the basic observations and theories regarding the use of space in sign language research.

Articulation of the signs in sign languages, by virtue of their modality, requires moving the hands through the air -- in this way, all sign languages are "spatial." That said, not all aspects of signs are the same even within any particular sign language. For instance, one can express a sign without having the movement through space affect the meaning of the sign. One example is the sign LOVE in ASL (Figure 3), where the hands must be raised and placed on the chest, but the movement of the hands to the chest doesn't contribute to the meaning of the sign LOVE. It is the final position of the hands that is the expression of the sign.

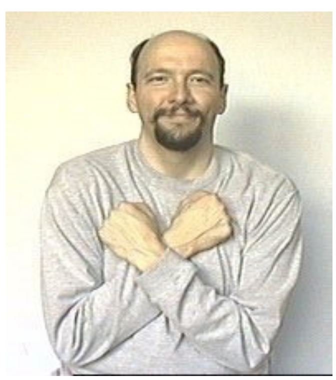


Figure 3. LOVE is considered a "plain" verb in ASL – plain verbs actually make up the majority of ASL verbs (Sandler & Lillo-Martin, 2006), but are not the types of verbs of interest for this paper as they do not use space meaningfully. (© www.lifeprint.com, used by permission)

In contrast, the movement involved in other signs may be meaningful. For example, the sign GIVE has two types of forms: a "citation form" whose movement away from the body metaphorically expresses the concept of giving. This form, while it does move in space, provides no information regarding the thematic structure of the event: the giver, the receiver, or the object being given (Figure 4). This citation form can be used in everyday communication and would rely on word order in order to express the information necessary to understand who gave what to whom. However, Figure 5 provides an example of another way signers can express GIVE that does provide thematic information: GIVE's direction can be changed to show who the giver is (the location in which the sign begins, e.g., the signer, the listener, or another location in space previously established as expressing the meaning of another entity); who the receiver is (the location in which the sign ends, e.g., the speaker, the listener or another location in space previously established as expressing the meaning of another entity).[14] In this way, give is said to "agree" with referential locations morphologically (e.g., Aronoff et al., 2004; Aronoff, Meir, & Sandler, 2005; Meir, 2002, see section below on *r-loci,* section 1.5.2, in the same way that spoken languages may indicate this information using affixation or by varying pronouns[15].

Importantly, the citation forms of signs are usually signed in what most call "neutral space," which is not equivalent to what is generally referred to as "signing space." *Neutral space* is usually the space that the arms fall into in their relaxed signing positions, from about the waist of the signer to the throat of the signer, whereas *signing space* can encompass a larger area. Signs which have a citation form in "neutral space" can "… change meaningfully so that they are

[14] Further (not depicted), the hand configuration of GIVE can be changed to express the size and shape of the object being given, be it a book, a pen, a cup or a number of other objects.

[15] For example, the English "I" vs. "me" both refer to the first person, but one is more typically understood as the subject or source ("I") and the other as an object/goal ("me") (see e.g., Carlson & Tanenhaus, 1988; Dowty, 1991).

no longer made with the hands in neutral space, but the hands stay inside the [overall] signing space…" (Engberg-Pedersen, 2003).

Figure 4. The citation form of GIVE in American Sign Language. This citation form can be modified to express subject/object (or giver/receiver) of the object, and the hand can change configuration to show the size and shape of the object. (© www.lifeprint.com, used by permission)

Figure 5. GIVE in Danish Sign Language showing that the signer represents the giver and a previously assigned location to the right of the signer represents the receiver. Importantly, the listener is *not* the receiver of whatever is being given (Engberg-Pedersen, 1993).

Spatial verbs vs. Agreement verbs. In ASL and in other sign languages, verbs are often distinguished from each other according to whether they capitalize on particular meaningful changes in space or not, as well as how they capitalize on space. Verbs that do use space meaningfully are thus subcategorized as either being *spatial verbs* or *agreement /inflecting* verbs (Padden, 1988; Sandler & Lillo-Martin, 2006).

Padden (1988) was one of the first researchers to document and suggest categorization of verbs as using space or not in meaningful ways. Since then, other researchers have contributed to

our understanding of spatial modification, though sometimes variations in terminology can confuse readers as we have various names for spatially modified verbs. For example, terminology commonly found in the literature refers to the same group of verbs as either *inflecting verbs* (Padden, 1988), *agreement verbs* (Padden, Meir, Aronoff, & Sandler, 2010; Sandler & Lillo-Martin, 2006) or *indicating verbs* (De Beuzeville, Johnston, & Schembri, 2009; Johnston & Schembri, 2007; Liddell, 2000), or verb *directionality* (e.g., Lillo-Martin & Meier, 2011).

According to Padden (1988), *inflecting verbs* (a.k.a. *agreeing* or *indicating* verbs) provide information about the subject/object of an event, and/or incorporate agreement for person, number, tense and aspect, for example (a) giving to a number of people one at a time at one time point, vs. (b) giving to a number of people at one time, but repeating the act numerous times, vs. (c) passing things out to everyone once vs. (d) passing things out to everyone numerous times. These are different from *spatial verbs*, which also use space, but in a more concrete way – they indicate information about the relation between different locations (e.g., "a book is on a shelf") or indicating actual or relative positions (e.g., "the tree is over there" or "(suppose) the tree is over there," using a pointing gesture/sign). Meir (2002) argues that the main difference between spatial verbs and agreement verbs are the entities involved rather than the information involved, stating that agreement verbs include at least one, if not two or more, animate participants in the event where a concrete or abstract object changes ownership, whereas spatial verbs do not (also see Bauer, 2014 for a summary).

R-loci. So far we see that sign languages, like spoken languages, have the potential to have rich and complicated morphological structures to provide information in very concise ways. The main difference between spoken languages and sign languages is the ability to capitalize on

the affordance of spatial modification for simultaneous morphology, which is simply not available in spoken language productions (e.g., Perniss, Zwitserlood, & Ozyürek, 2015). This spatial morphology is most readily realized with the use of what has come to be known as *r-loci* (Aronoff et al., 2004, 2005; Lillo-Martin & Klima, 1990; Meir, 2002).

R-loci, therefore, are the locations in space to which a referent has been assigned, particularly when the entity to be referred to is not available in the situational context (Engberg-Pedersen, 1993). This allows for a rich spatially-based morphological system permitting anaphoric and pronominal reference using modified verbs and deixis (pointing) (Bauer, 2014; Engberg-Pedersen, 1993; Liddell, 1996; Lillo-Martin & Klima, 1990; Lillo-Martin & Meier, 2011; Perniss et al., 2015; Van Hoek, 1996).

Encoding Spatial Events

When asking whether an individual can describe spatial events using language that describes spatial relationships such as establishing an *r-locus* to the right to mean "the person to his right" or in spoken language saying "the person to his right," an important question is whether the relevant spatial relationships were attended to and recalled in the first place. If there are difficulties in encoding (attention to and memory of) spatial relations or spatial events, then clearly the ability to relay those events may be diminished. Likewise, difficulties with encoding spatial information may result in difficulties understanding others' descriptions of spatial events. This is of particular relevance for NSL Cohort 1, given two previous results. First, while NSL Cohort 1 signers do not seem to struggle with recalling and describing various perspectives in short narratives, they do not seem to do so using spatial devices as much as lexical devices (Kocab, Pyers, & Senghas, 2015) even though it seems the ability to use space in sign is available to Cohort 1. Second, NSL Cohort 1 signers have been found to struggle with the

production of left-right relations and consistent descriptions of spatial relations between objects (Pyers, Shusterman, Senghas, Spelke, & Emmorey, 2010). For the purposes of these studies then, it is worthwhile to consider the possibility that the inconsistencies found in NSL Cohort 1 signers' descriptions of events using *rotated* or *unrotated* space, or interpreting others' productions inconsistently by having *unrestricted* interpretations (accepting both *rotated* and *unrotated* interpretations) could stem from difficulties in encoding spatial information.

Overview of Studies

In this series of studies I aim to (a) replicate the previous results of Senghas (2003) by showing that Cohort 2 signers are more consistent in both productions *and* interpretations than Cohort 1 signers (b) add the hearing children of Cohort 1 to the picture, thus disentangling the contributions of vertical and horizontal input by comparing them to Cohort 2 signers, and (c) bring in other factors to further understand the results, namely encoding abilities and the child's possible desire for communication over regularization.

This study also provides two innovations and further discussion points. First, previous studies of the use of space in NSL have not ruled out whether participants actually understand (encode) the events laid out for them spatially. The encoding task aims to do so. Second, by testing both Cohort 1 (the parents of the Codas) and Cohort 2 signers, not only will this study be able to show whether previous results can be replicated, but also possibly test for whether Cohort 1 signers simply needed more time and exposure to regularize their use of space. In other words, because Cohort 1 had the monumental task of regularizing many other foundational aspects of the language (e.g., the lexicon), they may not have been able to regularize space by the time they were tested Senghas (2003). It is possible that by now (upwards of 15 – 20 years later), that Cohort 1 signers may have regularized their use of space, either given the time, or interaction

with now-adult Cohort 2 signers. This study will therefore either replicate the previous findings (thus also supporting a sensitive period for the regularization of such structures), or show that given time and exposure, these structures can be regularized in Cohort 1 signers.

Regarding the core population of interest, the Codas, if we find that the Codas regularize their input in spite of not using NSL with other hearing native signers (e.g., with siblings who are also natively exposed to the sign language), then we come closer to accepting that individual children have the capacity to improve on their vertical input without the need for peer interactions. In other words, if the Codas regularize, then we can say it is a result of an input – learner interaction, and not of the peer community.

If, however, the hearing (Coda) children of Cohort 1 do *not* regularize (to the same degree as Cohort 2 signers), then we may ask why – and one of those possibilities of why is that they simply do not have the opportunity to interact with enough signers who rely on the language, and perhaps other linguistic or communicative pressures ought to be considered. Thus their status as heritage learners may limit their ability to improve on their vertical input.

In sum, it is undeniable that language emerges via some type of probabilistic epigenesis, with interleaved interactions between the child learner, the input, and the environment. This series of studies aims to disentangle some of these factors in order to better understand the contributions of each.

Chapter 2. Participants

The participants in all studies were drawn from a sample of 24 Nicaraguan Signers representing two stages in the evolution of the language; these signers were divided into three groups based on the year they entered the Nicaraguan Deaf community and/or whether they were the child of a signer. The groups are: Cohort 1 signers (8 total, 1 male); Children of Cohort 1 ("Codas," 8 total, 2 male); and Cohort 2 signers (8 total, 3 male). All participants completed a basic demographics questionnaire including questions about sign language use, age, date of birth, and age at which they began to acquire NSL (see Table 2 for a summary of participant characteristics). A subset of Codas and parents (n=5 in each group) completed an additional demographics questionnaire that requested more details regarding language use at home and perspectives on language intelligibility in the household, with these details provided throughout the next few sections, where relevant.

Capacity to Consent

All participants were consented using the language they preferred (NSL or Spanish). For all the deaf participants (Cohorts 1 and 2), NSL was used with additional visuo-gestural communicative methods employed by the primary researcher and monitored by the Deaf research assistant. The author is a hearing native signer of American Sign Language (ASL), holds several interpreting certifications, has had training in communicating with individuals from varied language backgrounds, has several years' experience working with homesigners, and, at the time of testing, had extensive experience working with Nicaraguan Sign Language. The research assistant was a Deaf fluent signer of ASL and had prior experience working with Homesigners and Nicaraguan Signers, as well as personal experiences interacting with deaf individuals with varied language backgrounds. All consent-related interactions with deaf signers

were videotaped. Most hearing participants (the hearing children of Cohort 1) were consented by the author using spoken Spanish[16], with NSL support as needed. Child participants under 18 years of age gave their assent; the assent procedure *and* their parents' granting of permission were videotaped.

An additional research assistant was hired in Nicaragua. This research assistant is a native NSL signer and a child of a Cohort 1 signer, and is also fluent in English.[17] The research assistant's primary duties were to monitor understanding between all parties in NSL and Spanish and to facilitate contact with Cohort 1 families.

Age of first exposure to Nicaraguan Sign Language

As is the case for most Deaf children in the United States who learn to sign (Padden & Humphries, 1990), the first exposure to any signed language is the time of arrival at a School for the Deaf, whether that school is of an oral/aural philosophy or not, by way of interactions with other Deaf students who may sign during recess or other free time. Thus, the age of NSL exposure for Cohort 1 and Cohort 2 are the age at which they were also introduced to education/ schooling. The Codas' age of exposure is considered to be birth, as they were exposed to their deaf parents' signing from birth. All Codas except for one report having two deaf parents who lived in the home during their childhood ($\leq$ 10 years of age).

[16] The primary researcher (DLG) is a native heritage speaker of Spanish and at the time of testing, had visited Nicaragua previously.

[17] This research assistant also participated in all tasks with their Cohort 1 parent. Importantly, this person completed all tasks before assisting with data collection with other participants, and was not privy to the theoretical goals of the tasks or the hypotheses.

	Age of NSL exposure (years)[18] M (Range)	Age at test (years) M (Range)	Years of NSL use[19] M (Range)
Cohort 1 (n=8; 1 Male)	8.5 (5.25 – 10.5)	45 (38-52)	36.7 (27-42)
Children of Cohort 1, "Codas" (n=8; 2 Male)	0 (0 – 0)	16.5 (12-27)	16.5 (12-27)
Cohort 2 (n=8; 3 Male)	4.4 (3.1 – 7.25)	30.5 (28-35)	26.1 (23-28.4)

Table 2. Participant groups and demographics.

Families

The Codas and Cohort 1 participants are related and represent child-mother pairs with two exceptions: One parent participated with two children, and both parents of one Coda participated (Table 2), representing seven families but nine parent-child pairs. For the most part, the deaf participants (and the families, whenever analyzed as a family) are arranged by year of arrival at the school for the deaf in Managua, which marks the parent's age of exposure to other signers. The children are arranged in order of their parents' arrival, using the reasoning that the child's language is related to the parents' language, and the parents' language is most reflective of their year of entry to the community (i.e., their Cohort).

[18] The age of exposure for deaf NSL signers is the age at which they started attending school with other deaf children. The age of exposure for the Codas is from the moment of their birth to their deaf, signing parents.

[19] The years of exposure to NSL are significantly different for Codas than for Cohort 2 (*p=.005)*, though one could argue that the intensity during the formative years (0–5yrs old) is higher for the Codas and the Cohort 2 signers haven't changed since they were tested 20 years ago (when they only had an average of 11–12 years of exposure).

Family number	Parent(s) demographics			Child(ren)
	Sex	*Year of entry*	*Age at test*	*Age at test*
1	F	1974	52	13
2	M	1974	47	27
	F	1978	46	
3	F	1974	46	21
4	F	1974	46	19
5	F	1977	42	13
6	F	1981	44	16
				12
7	F	1984	38	12

Table 3. Participant families, ordered by the year the older parent participant arrived at the Center for Special Education in Managua.

Language Characteristics of the Children of Cohort 1

A major concern when working with bilingual children is their overall exposure to the second language, especially when the language of the home is not the dominant language of the region. As is the case for most, if not all, Deaf community sign languages, most hearing people in the neighborhood or larger city or country do *not* know or use Nicaraguan Sign Language. Therefore, establishing that the Coda Children of Cohort 1 have acquired NSL and use it regularly is essential in order to rule out explanations of their language patterns based on incomplete acquisition. All eight of the Coda children completed a demographics questionnaire asking about the language(s) used in the home and their interactions with other signers. Five (5) of the eight also completed a follow-up language background questionnaire (Appendix A) detailing more of their language experience by specifying age ranges of use and interaction,

topics of conversation, interpreting responsibilities and reaffirming (or not) the presence of signing peers. These data are summarized below.

Age of exposure. As stated above, all Codas (n=8) reported living with two deaf parents from birth (both parents (mother and father)), with the exception of one who only had one deaf parent in the household throughout her[20] childhood.

Language(s) in the home. Five of the eight Codas reported other hearing people living in the home on the additional questionnaire presented; the other three did not complete the additional questionnaire. For the five who did complete the additional questionnaire, the hearing people in the household included grandparents (3/5), uncles (2/5), aunts (1/5), cousins (1/5) and siblings (2/5). It is noted that from verbal interactions with the remaining three who did *not* complete the second, more in-depth questionnaire, that all three also had siblings in the home, bringing the total number of codas with siblings to 5/8. Two of these 5 participants were from the same family, leaving 3/8 who were only children living with their deaf parents and/or other hearing adults (anywhere from 1 – 3 additional adults in the household). It is also of note that two of the Codas reported other Deaf, signing family members[21] but did not specify whether they lived in the home.

Language use with peers. On the initial demographics questionnaire, all eight of the Codas responded to the question "Are there any other deaf people who communicate with their hands?" by listing *adults,* such as "friends of my parents" or "my parents' friends." Not one of the eight Codas identified any peers or same-age deaf people using their hands to communicate. As a follow-up, the second questionnaire (completed by 5/8 of the Codas) asked more

---

[20] Because the majority of the Coda participants were female, the female pronoun will be used throughout to protect the identities of the child/Coda participants.
[21] One reported a deaf uncle (family 2) and one reported a deaf aunt (family 1).

specifically “Do you have deaf friends your age?” and “Did/Do you sign with family members who can hear?” Not one of the Codas (0/5) stated they have same-age deaf friends, and only one Coda (Family 1) reported signing with *hearing* family members in limited situations (she explained that she signs with hearing family members in lieu of shouting when they are at a distance from each other).

Contact with Deaf adults. All Coda participants (n=8) reported having contact with their parents’ friends. On the follow-up questionnaire, 5/5 Codas reported that their parents’ deaf friends visited their home, though none of the five reported daily visits. There were some discrepancies between the first and second questionnaires, however. For instance, on the initial general questionnaire, when asked about participation in the Deaf community, 5/8 reported “participation” when their parents’ friends visit. However, on the second questionnaire when asked about signing with parents’ friends, only 2/5 report “sometimes” signing with these visitors, and 3/5 report rarely signing with these visitors. Discrepancies are also noted between participants’ responses about visitors, and regarding the topics/ context of conversations (section 2.4.6, below); namely, all 5 Codas who completed the second questionnaire reported signing with other deaf people about a number of topics, which seems inconsistent with occasional (“sometimes”) interactions.

Diversity of topics of conversation. Senghas (2005) and Meir et al. (2010) note that one of the possible contributors to the rate of language emergence and evolution is the variety of topics discussed and contexts in which the language is used. This is obviously a concern for the current participant samples, as the diversity of language use contexts is likely to be greater for the deaf cohort members by virtue of their displaced location from the home at the time(s) of sign language use. The mere fact that the Cohort 1 and 2 participants interacted with each other

at school (displaced from home contexts, when reporting, for instance, activities conducted over the weekend with family, or when discussing things like mealtimes/ cooking with family) creates a language environment in which they *cannot* rely on the physical context (i.e., pointing to a person or to the stove) to fill in the gaps in their language production(s) or to help with understanding others' productions. However, this is not to say that conversations at home are *de facto* limited to conversations which take advantage of the environmental context. This may be the case between say, deaf children and hearing parents who do not know a sign language (Carrigan & Coppola, 2017), but a hearing child who has been exposed to his/her parents' sign from birth (and who is possibly fluent in the sign language, or at least at communicating with his or her parents) may still have the opportunity to interact with a variety of persons regarding a variety of topics. This is also possibly the case when the parents' language is *not* that of the larger community and so the child may be called upon to interpret for his/her parents (Williamson, 2015).

As part of the detailed follow-up language questionnaire, the Codas were asked to indicate, from a list of 22 topics, the kinds of things they conversed about with their family members before and after the age of 10, as well as topics they conversed about with *other* deaf people before and after the age of 10. This list included a variety of items ranging from the contextual (e.g., mealtimes, laundry, siblings' problems) to school-related (e.g., teachers, homework), abstract topics in the family setting (e.g., family finances), and more abstract topics (e.g., climate change, cultural differences). All topics were selected at least once by at least one participant, though no participant selected all items for any particular category (before/after age 10, with parents/with others), suggesting that participants were attending to the questionnaire and not answering 'yes' automatically (Appendix A).

The number of topics of conversation participants reported having with their parents and with others, are shown in Figure 6 below. The codas reported signing about more topics with their parents than with others, though the average number of topics for both types of interlocutors increased after the age of 10; from 14 topics to 16 topics with parents, and from 5 topics to 6 topics with others. Topics that are conversed about in later childhood that were not conversed about at younger ages include things like romantic relationships (having a boyfriend/girlfriend) or body/puberty "problems." Topics discussed with parents at an early age that were not discussed with others included things like teachers at school and family finances.

Overall, the topics reported for conversational sign range from the more concrete/contextual (meals, laundry) to the abstract (weather/ politics), and follow what one would expect for a typical child in that some topics are reserved for conversation with family

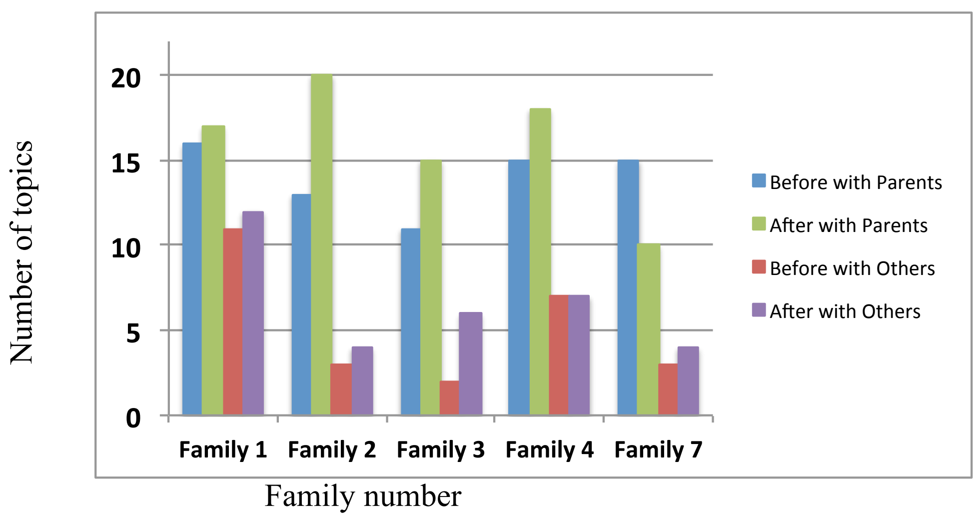


Figure 6. Codas' reported number of topics discussed with their parents before and after the age of 10. Four of the five codas reported conversing with their parents about more topics after the age of 10 than before the age of 10.

only and others are open for conversation with non-family. Expectedly, the number of topics generally increased over time with the addition of typical (predictable) topics such as romantic relationships and puberty/body changes that become more relevant in later childhood.

Diversity of interpreting contexts. While the list of topics for conversation is informative, we were also interested in the variety of contexts in which the Codas found themselves using NSL. As a proxy for a direct question of the types of contexts (especially those outside of the home) in which the child uses NSL, we asked about contexts in which the child has interpreted from NSL to Spanish and vice versa for their parents or other individuals. Interpreting was asked about in two ways; first the Codas were asked to respond on a Likert scale of 1 – 5 "How often were you asked to interpret?" with 1 being "Never" and 5 being "Daily." Then, Coda participants were asked to check off the situations in which they have interpreted from a list of 20 items which ranged from the concrete/contextual/home environment (e.g., "Conversations with hearing family members") to those that could be deemed complicated and removed from context (e.g., "Medical/hospital for your deaf parent" or "with police/ in legal situations). Figure 2 presents the number of reported items per participant (columns) with that Coda participant's family number and how s/he rated the frequency of interpreting for family members. The average frequency is 3.8 with a range of 2-5, and a median of 4 (almost daily, Figure 7).

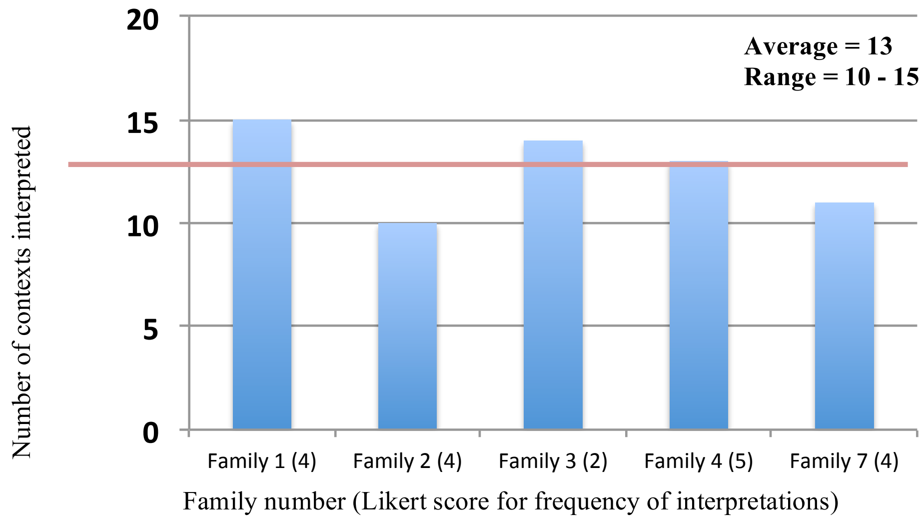


Figure 7. Number of situations/contexts in which each of five Codas reported having interpreted, arranged by family group. Numbers in parentheses are the score that child reported for the frequency of interpreting on a range of 1 (never) to 5 (daily), and the red line represents the average number of contexts across all five Codas.

Some additional patterns emerged. First, there were two contexts in which no child reported having interpreted. They were "school/meeting with teachers" and "with police/in legal situations." This could be for cultural or legal reasons. While education is mandatory in Nicaragua, parent-teacher conferences appear less likely (or perhaps were simply not scheduled for the children with Deaf parents). Second, the relative lack of reported interpreting in police/legal situations could be just situational in that the parents haven't had need to interact with the police in a regular way. Following up on both of these would be helpful to understand the larger contexts in which these hearing children of deaf parents live. Second, there were five interpreting contexts that were universally reported (5/5 respondents): (1) medical/doctor's office for the parent, (2) medical/hospital for the parent, (3) at the market (in Nicaragua this is a flea-market environment typically for foodstuffs and housewares or clothing, in which negotiating prices is expected), (4) when buying other things (not specified), and (5) for news from the

television or radio. Interestingly, the universally reported contexts were not the more context-heavy scenarios such as "conversations with hearing family members," though this did receive a high score (4/5 participants). It is possible that some hearing family members may know sign well enough to not need interpreting, or the Coda(s) don't deem that an "interpreting" situation. Interestingly, some interpreting scenarios were endorsed unexpectedly; these included interpreting for "university courses" (1 report) and "at the movies" (1 report). These and other low-frequency scenarios were not reported by the same individual, leading us to believe that it is indeed the case that each of the Codas has frequently interpreted in medical scenarios, for shopping, or newsworthy events, but that each has had unique experiences mediating language for their deaf parents in a variety of contexts.

Knowledge of Nicaraguan Sign Language and Spanish. While the Coda children report that they interpret in a variety of contexts, this does not necessarily mean that they use NSL to do so. Homesigners, individuals who have had no access to an established sign language and who do not have auditory access to the spoken language around them (Coppola & Newport, 2005), nevertheless have family members who "interpret" for them in a variety of situations (Coppola, 2002) using the idiosyncratic gestural communication system unique to their family. Therefore, it is important to have at least a baseline measure of knowledge of NSL for the current participants. Because no standardized measure of NSL exists, a simple vocabulary test was created to check participants' knowledge of NSL.

This measure used a format similar to the Peabody Picture Vocabulary Test (PPVT) wherein participants saw videos of signs or heard recordings of spoken Spanish and were asked to select the corresponding picture. We began with a set of items from the TVIP (Test de Vocabulario en Imágenes Peabody, a standardized test of spoken Spanish) that had been

narrowed down to a subset via interviews with hearing Nicaraguans that were conducted by Ann Senghas and her lab (Language Acquisition and Development Laboratory, 2013). Then, this subset of spoken Spanish items was presented to a Cohort 2 signer who was working at the school for the deaf and who could judge whether 5th-grade students would know the sign corresponding to that Spanish word. This resulted in a set of 53 items. We then asked a native NSL signer (a Coda) to sign each of the Spanish words in NSL, which were video recorded. This set of 53 videos was then shown to the Cohort 2 signer, along with the picture array for each of the original Spanish words from the TVIP. The Cohort 2 signer matched the sign to the accurate picture for 52/53 items, which determined the final set of 52 NSL and Spanish vocabulary items presented to Codas and Cohort 1 signers.

	NSL Mean **(range)**	**Spanish Mean** **(range)**
Cohort 1 (Parents) (n=4)	0.86 (0.77-0.89)	N/A
Children of Cohort 1 (n=5)	0.87 (0.75-1.00)	0.88 (0.86-1.00)

Table 4. Mean group scores on the NSL and Spanish version of a picture matching receptive vocabulary task. Coda children performed equally well as their parents for NSL, and the coda children showed no differences between their NSL and spoken Spanish scores.

Four Cohort 1 parents and five Children of Cohort 1 completed the NSL version of the TVIP. Spoken Spanish recordings, created by a native Spanish speaker in the United States of all 52 words were also presented to four of the five Codas who completed the NSL TVIP. Table 4 presents the individual and mean scores for each group.

While only a subset of the Codas and their parents completed this task, the results are quite robust. First, Cohort 1 participants performed well on the NSL vocabulary items; indeed, a

stable lexicon conventionalized fairly early in the emergence of NSL (Polich, 2005; Richie, Coppola & Yang, 2014). Second, the scores of the Coda children of Cohort 1 and their Cohort 1 parents do not differ greatly, though no comparative statistical tests can be done given the small number of results. These results suggest that the Coda children essentially learned as much as the parents could offer (in terms of lexicon) and no more (for example, had they been exposed to Cohort 2 signers, might they have scored better than their own parents?). Finally, the Codas' own scores on the NSL and Spanish versions of the same concepts did not vary much individually or as a group. Given our testing priorities, the NSL TVIP was tested before the Spanish TVIP. This ordering bolsters our confidence that performance on the NSL version reflected Codas' true understanding of the NSL signs rather than recall of the image array from having recently completed the Spanish version, and that individual performance reflected their true abilities in each language.

Mutual intelligibility. As a final measure of language use in the home, we presented the children with questions about whether they understood their parents' signing and whether their parents understood their signing. We also presented the parents with a series of questions asking about *Social Perspective Taking* in their interactions with their children. Social Perspective Taking is a sub-skill of Theory of Mind (Smith & Rose, 2011), a cognitive domain with known difficulties for Cohort 1 signers (Pyers & Senghas, 2009; Morgan & Kegl, 2006, Gagne & Coppola, 2017). We were interested in understanding how the Coda children and their parents perceived their own interactions. As possible heritage signers (Isakson, 2016; Palmer, 2016; Williamson, 2015), Codas may share experience with other heritage speakers, such as the use of the language in limited contexts, and/or the use of the dominant (non-heritage) language in academic environments. It is known that Cohort 1 parents may not be ideal or "fluent" language

models, creating a difference between the Deaf community in Nicaragua and other heritage language environments, in which most parents are assumed to be fluent, if not native, users of the home language (e.g., Montrul & Polinsky, 2011). Therefore, this first generation of Codas in Nicaragua may be better at understanding their parents than the parents are at understanding them.

First, the children were asked four Likert–scale questions, ranging from 1 (never) to 5 (always) (Table 2) about how well they understand their parents and how well their parents understand them. The pattern of Coda responses indicated that they understand their parents better than they perceive their parents understanding them. No Coda participant reported *never* or *rarely* understanding their parents, or reported feeling like their parent *never* or *rarely* understood them. However, it is unclear whether this is because the child's language ability is weaker or stronger than their own parents'. Either could be the case from the data reported so far.

	Sometimes (3)	**Often (4)**	**Always (5)**
I understand my father's sign	0	0	5
I understand my mother's sign	1	0	4
My father understands my sign	0	2	3
My mother understands my sign	1	1	3

Table 5. Codas reported on how well they understand their parents' signing versus their parents' abilities to understand their own (the child's) signing.

For instance, if the child's language is weaker, they then could feel their parents' signing is clearer, and their own is less clear, contributing to the difficulties their parents have in understanding the child.

I then attempted to gain an understanding of the parents' perspective on their interactions with their children by asking them to complete a communicative Social Perspective Taking (SPT) questionnaire (Appendix B). Parents answered five questions from their own

perspective (e.g., “I sometimes try to understand my child better by imagining how things look from her/his perspective.”) and then the same five questions from their child’s perspective (e.g., “My child sometimes tries to understand me better by imagining how things look from my perspective.”). All questions used a Likert-like scale of 0 (Does not describe me at all) to 4 (Describes me very well). To standardize the presentation of the questions, all statements were videotaped by a native NSL signer and clipped and presented to the parents individually in a PowerPoint presentation. Parents then indicated on a printed laminated sheet with a scale of 0 (and the words “NO” and an image of a signer signing “NO”) to 4 (and the word “SI” (“yes” in Spanish) and an image of a signer signing “SI”). The scale was explained to the parent before proceeding. Figure 8 presents the parent reports of their own SPT abilities as compared to their reports of their children’s SPT abilities.

The parents’ own reports show that they believe their children to be *better* at taking their perspective than they (the parents) are at taking their child’s perspective. These results converge with the children’s reports that they are better at understanding their parents than their parents are at understanding them (Figure 8). In this way, the onus may be on the child to provide clarity in conversations, in interpreting situations, and in daily life. This is one way in which the Coda children in Nicaragua, and possibly Coda children elsewhere (especially those whose parents’ language productions are inconsistent for some reason, for example, having learned a sign language late in development) differ from “traditional” heritage learners. In the traditional model, the parents are fluent language models of the home language, but the environmental and sociolinguistic pressures make it so that the home language is not used in many contexts experienced by the child. Here, the contextual experiences of the Nicaraguan Codas of Cohort 1,

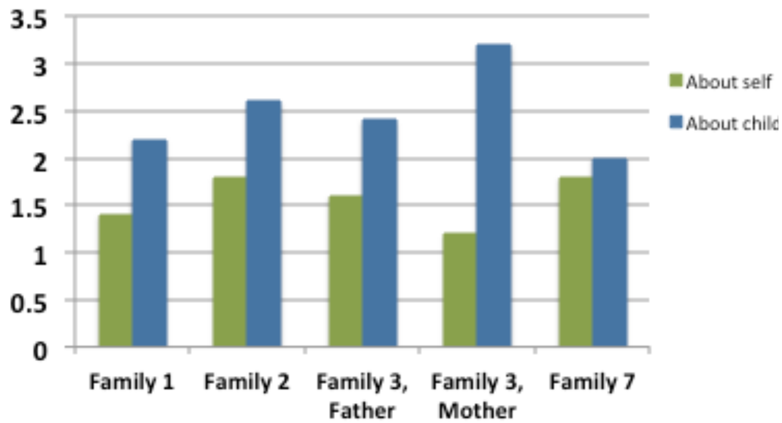


Figure 8. Parents' reports of their own (green bars) and their children's (blue bars) abilities and tendencies to take each other's perspectives in communicative settings. Parents consistently rated their children *better* than themselves at social perspective-taking.

including Codas of other languages (e.g., Isakson, 2017; Pizer, Walters & Meier, 2013), but may also be different due to their parents' weaker language ability given their use of an emerging language.

In sum, we examined three sets of participants who all use Nicaraguan Sign Language in varying ways. Cohort 1, who represent the first group of NSL users, served as the language input to Cohort 2 (starting at around age 5, when they arrived at the school for the deaf) and to their own hearing children, who are native signers (exposed from birth). While the Coda children are bilinguals, and arguably heritage users of NSL – that is, NSL is not a dominant language in their lives – all Codas reported interacting with deaf adults beyond their parents, discussing various topics and interpreting in a range of contexts. Furthermore, tests of Codas' vocabulary knowledge showed equivalent knowledge to their parents, and both the children and their parents acknowledged that the children are more accommodating of their parents' struggles with perspective taking, thus putting the onus on the Coda child to make sure the interaction is understandable by his/her Cohort 1 parent.

Chapter 3. Study 1: Productions

The structure of the Nicaraguan Deaf community and the dynamics of language transmission in a new language (NSL) offer a unique opportunity to study how languages emerge and change. Here we focus on the NSL Codas' regularization of rotated or unrotated spatial layouts, which offers insight into the transformation of spatial modulations into a morphological marker. The Codas have the potential to regularize their use of space given the inconsistent input they receive from their parents and their parents' friends (Cohort 1 signers), and few, if any, signing peers. Cohort 2 signers also received Cohort 1 signing as their vertical input, but unlike the Codas, Cohort 2 signers had similar-aged peers to sign with (Senghas & Coppola, 2001; Senghas 2003). The Coda's language experience suggests two possible language regularization scenarios: First, given that children *are* able to regularize input *without* a peer language context (e.g., Hudson Kam & Newport, 2009; Newport, 1999; Singleton & Newport, 2004), one could hypothesize that the Codas, given the inconsistent input they receive from Cohort 1, would regularize and show a preference for producing *rotated* spatial layouts. In this way, we would view the results from Senghas' previous (2003) findings as the cumulative result of many individual children.

The second possibility is that the Codas would *not* regularize to the extent that Cohort 2 participants did, given the lack of peer interaction, and in spite of years of exposure to their parents' and parents friends' signing about diverse topics (see Chapter 2 for details regarding the varied contexts of Codas' language use). This second possibility is based on studies with *Heritage speakers* – individuals who are exposed to established, fluent language from their parents or other adults in their homes, but who, by virtue of the larger linguistic context, do not have same-age peers who speak the home language (e.g., Benmamoun, Montrul, & Polinsky,

2013; He, 2010; Soltan, 2013; Van Deusen-Scholl, 2003). A good example of a heritage language speaker is a child of Russian-speaking immigrants to the United States. Unless that family moves to a neighborhood with many Russian-speaking families and finds a school that provides instruction in Russian, the children in that family are likely to learn English in school, speak English with their friends, and use English when interacting in public places. Even siblings in that Russian-speaking household are likely to use English with each other and use Russian only with their parents (e.g., Benmamoun, Montrul, & Polinsky, 2013; Montrul, 2012). Heritage speakers' acquisition of their home language varies in its completeness, with some elements (e.g., phonology) reaching native-like capacity, with others (e.g., morphosyntax) falling short of native fluency (e.g., Lynch, 2008; Montrul, 2010; Rothman, 2009; Soltan, 2013). Therefore, the language acquisition and production patterns of heritage speakers are not exactly the same as that of second language learners (e.g., Montrul, 2010, 2011; Soltan, 2013).

Recent proposals have argued that Codas (whose home language is American Sign Language, and possibly other sign languages around the world) ought to be considered heritage speakers of their sign language (e.g., Chen-Pichler et al. 2015; Isakson, 2016; Palmer, 2016; Williamson, 2015). Therefore, the question here is whether the sociocultural context of the NSL Codas (as potential heritage speakers of Nicaraguan Sign Language) affects the regularization of spatial modulations reflecting rotated vs. unrotated spatial layouts in NSL, which have developed into morphological elements. Thus, based on patterns of language acquisition by heritage speakers and the possibility that the hearing children of deaf signers could be considered heritage *signer,* the second hypothesis is that the Codas will *not* regularize inconsistent uses of space in their input. In other words, even though the Codas received the same inconsistent language models as did Cohort 2, this hypothesis holds that the presence of linguistic peers is necessary

for the regularization of spatial modulations (a morphological element of the language). Because heritage speakers often struggle with the acquisition of morphosyntactic structures (e.g., Montrul, 2012), then the NSL Codas may do the same.

In both cases, the lack of peers may lead to insufficient language acquisition, though in one case the children cannot acquire the language fully as it is modeled by adults (heritage speakers) and in the other the children may not be able to regularize inconsistent input as well as those who have peers. Similarly, in both cases peers may contribute to a richer language experience, possibly by providing a variety of interlocutors, or interlocutors of a different (more equal) status to the child, which completes the language regularization/ acquisition.

Method

Participants. The participants in this study were the eight Cohort 1 signers, eight Children of Cohort 1 (Codas), and eight Cohort 2 signers described in Chapter 2.

Procedure. First, participants watched a video of actors engaged in typical actions associated with one of two scenarios (scenes at a dinner table or scenes of individuals kicking a soccer ball to each other, each approx. 30-120 seconds long) to familiarize them with the bigger picture "story." They were told they didn't need to remember the entire video during this familiarization phase, but to watch it to get an overall sense of the story it depicts. Subsequently, they were shown fourteen shorter clips taken from the recently presented video (approx. 5 – 15 seconds long). The fourteen video clips included: Seven single-event spatial videos, two filler videos with no left/right direction included (both were spatial events that happened across from the actor – one kicking and one waving), and five multi-event spatial videos depicting at least two actions. Participants were then asked to describe the event in the clip to a deaf researcher

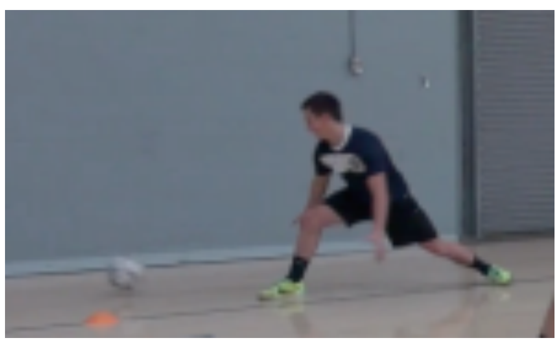
sitting across from them who could not see the computer screen. All productions were videotaped for offline coding.

Improving on previous stimuli. The current stimuli were modeled after the task reported in Senghas (2003), but include some notable changes. First, the previous stimuli did not situate the spatial events in a larger story context (e.g., a dinner scene), possibly leading to disjointed productions of the depicted events. In other words, previous participants couldn't predict what event was happening next, or whether they would even see the same actors in the next clip. Many sign languages take advantage of repeated mentions of the same character by creating a referential location (r-locus) in the signing space to represent a particular character or location and then moving verbs between established loci to depict that verb's path and the thematic roles of the endpoints of that path. Providing a larger story context for the current clips may encourage signers to use their available signing space in ways that may have not been captured previously. Second, the characters in the current stimuli are all of the same gender, with Latino/a-like appearances (long dark hair for women, short dark hair for men, all with dark eyes). Senghas and Coppola (personal communication, 2013) reported that the actors in the previous stimuli (e.g., Figure 9a) caused some confusion and comments from participants because of their appearance (all were Caucasian, and one of the female actors had a short hairstyle not common for females in Nicaragua). The current dinner scene included three females with long hair to avoid this confusion. Third and finally, the inclusion of soccer playing scenes, again with actors all of the same gender (male), presents spatial relationships in a different type of layout/perspective than previously used. The spatial relationship between the actors in the soccer scenes is of a larger spatial scale (in reality), which may elicit different spatial responses (or not), which is an empirical question.

stimulus event:
a woman giving a cup to a man

9a. Stimulus from Senghas (2003) of a woman passing a cup to her right.

9b. Current dinner scene stimulus, a woman passing a cup to her right.



9c. Current soccer scene stimulus, the ball passing to the right of a man (goalie).

Figures 9a-c. Example of the previous stimuli (Senghas, 2003) (a) which were improved in the current stimuli (b and c) in several ways: first, the gender is now uniform within each video (all female or all male), second, actors were chosen for Latino/a-like characteristics, (b), and in the current stimuli, third, participants will have an opportunity to watch a scene/story/series of events in their entirety before watching shorter clips (and then describing those events in the shorter clips). Finally, the addition of the soccer scenes (c) introduces a different, larger, spatial layout.

Coding

All productions were coded offline by a research assistant. The seven single-event clips were selected for coding, five from the dinner scene and two from the soccer scenes. The current studies focus only on the single-event stimuli and responses. When creating the stimuli, a total of nine single-event clips were created; however, two of the nine included events that were "neutral" in that they did not depict an action to the right or the left. These "neutral" events occurred in an actor's own space (e.g., serving oneself rice) or involved another actor positioned directly across from them (e.g., calling someone's attention across the table). An odd number of single event videos *with actions to the left or right* were chosen in an attempt to minimize the number of possible 50/50 splits between rotated and unrotated productions. Finally, a disproportionate number of the single-event videos were selected from the dinner scene because the dinner scenario afforded more possibilities to vary the spatial events (e.g., *give a cup to the right, serve food to the right, tap a person on the left*). The soccer scenes, while beneficial for their spatial layout, did not afford much variation in the event, which is primarily *kick in a particular direction*. The remaining videos represented two non-spatial filler events (*wave across* and *kick straight*), and five multi-event, multi-actor short clips that have been reserved for future analyses.

Productions of the verbs describing these target events were coded as either *Rotated*, *Unrotated*, or *Neutral* (neither right or left). A production was coded as *Rotated* when the participant, upon seeing a spatial event to an actor's right, then produced the sign for that event to his/her own right (Figure 10). This is called *Rotated* because when facing the video, one is <u>not</u> mirroring the video, but rotating the spatial relationships when describing the action. Figure 10 depicts the physical location(s) of the participant, experimenters, and stimuli in a *Rotated* production.

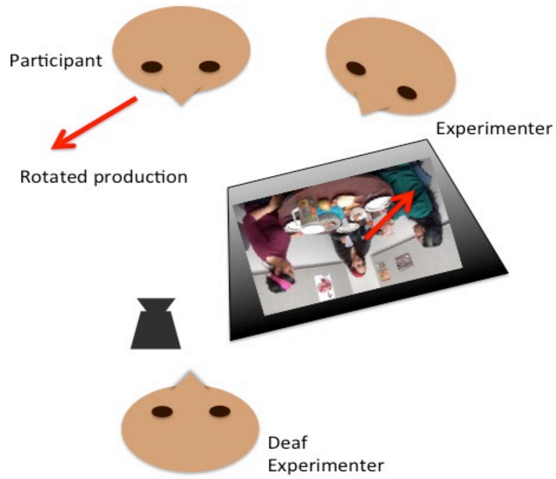
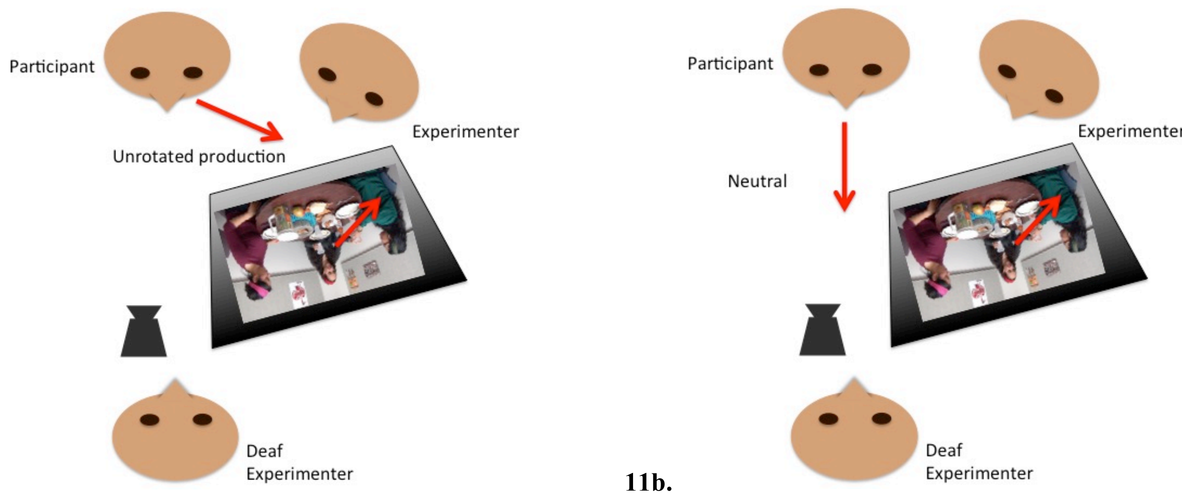


Figure 10. Physical layout of the testing environment for the Productions task. Here the participant sees the woman in the video pass a cup to her right, and then produces a *rotated* description: s/he signs the verb GIVE to his/her own right.

Productions were coded as *Unrotated* if the participant's spatial modulation mirrored the physical layout of the stimuli (Figure 11a). That is, upon seeing the actor pass an object to her right (as depicted in Figure 11a), the participant produced the verb to his/her own left, thus mirroring the video. Finally, sign productions that did not use right/ left space but the neutral space directly in front of the participant were coded as *Neutral* (Figure 11b).

Inter-rater reliability. All single-event productions (n= 168 items: 7 items x 8 participants x 3 groups) were viewed by three coders. First, all videos were coded by me (a hearing native signer of ASL with conversational fluency of NSL), then separately by a hearing L2 ASL signer. Differences in assignments of verb productions to the categories described above were reviewed by both coders and resolved by discussion. Then, as a third pass, all videos and coding decisions were checked by a third coder who is a deaf early signer of ASL with working fluency of NSL. No discrepancies were identified in the third pass.



11a. **11b.**

Figure 11. Examples of *Unrotated* (a) and *Neutral* (b) productions in relation to the stimuli and locations of the two experimenters and camera.

Results

Group-wise preferences for Rotated, Unrotated, and Neutral spatial modulations.

The primary question of this study was to ask whether as a group, the children of Cohort 1 regularize the use of space in the same way that previous reports show occurred for Cohort 2 (Senghas 2003). Figures 12a-12c show the proportion of *Rotated, Unrotated* and *Neutral* spatial modulations produced by individual participants in each group. The current results clearly replicate the findings of Senghas (2003) for Cohort 1: (1) internal consistency within individual signers is low, save for one participant (Cohort 1 participant 3, who arrived at the school in 1974); (2) this lack of individual internal consistency precludes a preference for any spatial layout across Cohort 1 members. The current findings also show that Cohort 2 uses *rotated* spatial modulations significantly more than Cohort 1 (Mann-Whitney U=51.5, n_1= n_2=8, P= 0.045, two-tailed), even though the current data does not show as strong of a preference as previously reported (Senghas 2003). The possible reasons for differences in strength from Senghas (2003) to the present study include (a) differences in the stimuli, particularly the

changes made to increase their ecological validity, and (b) differences in the composition of the participant samples. These factors will be addressed in depth in the general discussion for this study (Chapter 7). Having replicated the previous results, I now report the results from the Coda Children of Cohort 1 to see whether they regularized the inconsistent input they received from their Cohort 1 parents, and if so, whether they too show a preference for *rotated* spatial modulations, as Cohort 2 do.

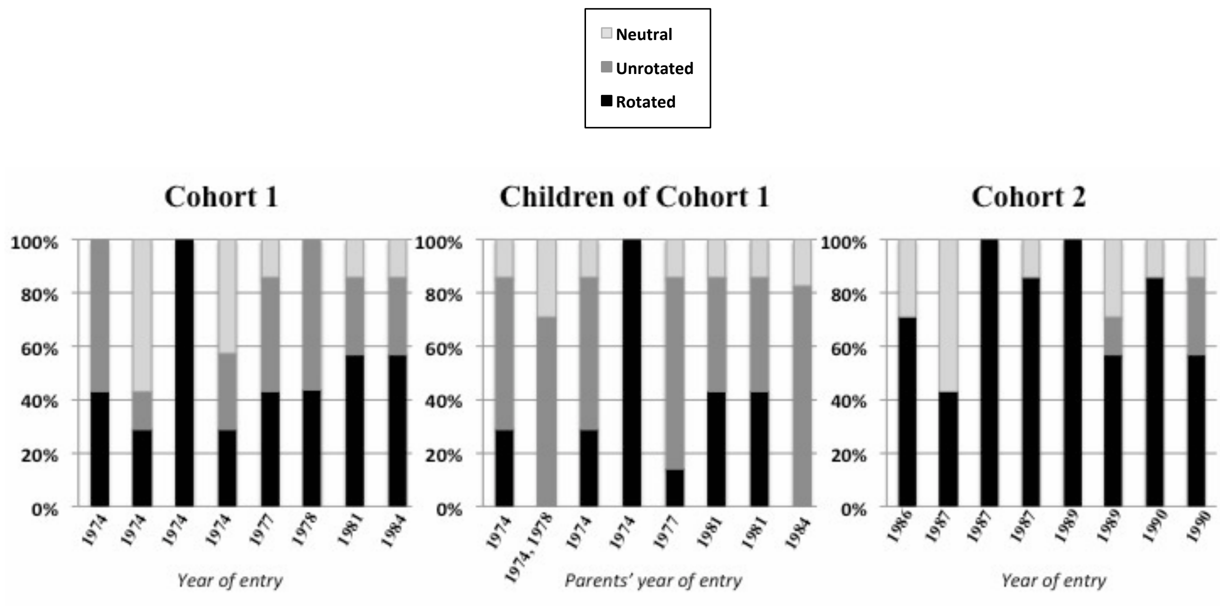
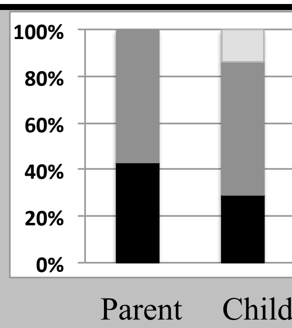
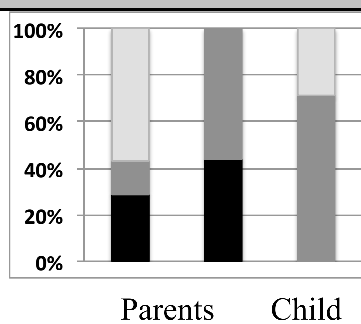
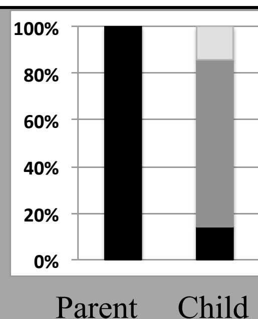
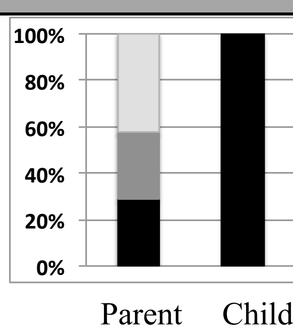


Figure 12. Proportions of *Rotated*, *Unrotated*, and *Neutral* productions for Cohort 1, the Children of Cohort 1 and Cohort 2. Results from Cohort 1 replicate previous findings.

Figure 12 shows that the Children of Cohort 1 do *not* look like Cohort 2 in the preference for *rotated* spatial modulations. As a group, the Coda Children of Cohort 1 do not use *rotated* significantly more than Cohort 1 (Mann-Whitney U=15.5, n_1=n_2=8, p= 0.093, two-tailed), though descriptively, the chart seems to show less frequent *rotated* modulations overall than either Cohort 1 or Cohort 2. Only one Coda, Coda participant 4, shows a clear preference for *rotated* spatial modulations. It is possible then, that the Coda participants may prefer *unrotated*

spatial modulations more than their parents, though this result would be surprising given that Cohort 2 settled on *rotated* productions and that *rotated* productions are the predominant layout used by the world's sign languages (Pyers et al. 2015). Therefore, I turn now to a comparison of the parents' production of spatial modulations and of their children, discussed next.

Family-wise preferences for Rotated, Unrotated and Neutral spatial modulations. Given the absence of linguistic peers for the Children of Cohort 1 (See Chapter 2), and the early, consistent exposure of these children to their parents' signing, we can assume a more direct relationship between input received from the parents to the child's later productions than was experienced by signers of Cohort 2. Of course, as discussed in Chapter 2, all Codas report interacting with multiple deaf people of their parents' generation. However, as shown earlier and in Senghas (2003), it is reasonable to assume that most of the Cohort 1 signers that the Codas encountered would have produced *inconsistent* spatial modulations, just as the majority of the parents here do. Table 6 presents individual preferences for *Rotated, Unrotated* and *Neutral* spatial modulations, arranged by family.

Family number (ordered by year of entry)	Parent, Child Chart No direction Unrotated Rotated	Description
1		• Child and Parent both use *Unrotated* to the same degree (57%) • Parent does not include any *Neutral*; Child uses *Neutral* for one item
2		• Child does not use *rotated* spatial modulations, parents do • One parent and child uses *Neutral* • Child prefers *unrotated* modulations more than each parent
3		• Parent strongly prefers *rotated* spatial modulations • Child prefers *unrotated* spatial modulations
4		• Parent evenly distributed across *rotated, unrotated* and *Neutral.* • Child strongly prefers *rotated* spatial modulations

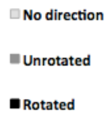
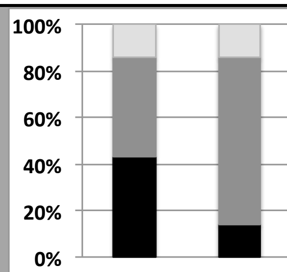
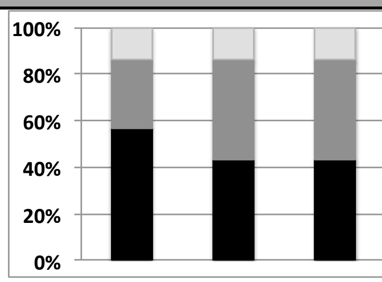
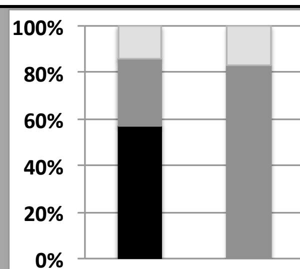
Family number (ordered by year of entry)	Parent, Child Chart 	Description
5	 Parent Child	• Parent equally divided between *rotated* and *unrotated* (43% each). • Child prefers *unrotated* spatial modulations. • Both child and parent use *Neutral* once.
6	 Parent Children	• Parent has a mild preference for *rotated* spatial modulations • Both children evenly divided between *rotated* and *unrotated* spatial modulations • Parent and both children use *Neutral* once.
7	 Parent Child	• Child does not use *rotated* space, parent does. • Both Parent and child use *Neutral* once. • Child prefers *Unrotated* more than the parent.

Table 6. Family-wise comparisons of spatial productions between parent(s) and child(ren).

Reviewing the descriptions of each family chart, a recurring pattern is that the children use *unrotated* spatial modulations more than their own parents. An exploratory paired-samples *t*-test was conducted across 9 pairs (one child had two parents represented, but one parent had two children, creating 9 parent-child pairs), and confirms that the children use *unrotated* spatial modulations significantly more than their own parents (correlated-samples *t*-test, $M_{parents}$=0.317, $SD_{parents}$=0.267, M_{codas}=0.567, SD_{codas}=0.51, *t*=-2.39, *p*= 0.044). Given the small sample size, this

was also confirmed with a Mann-Whitney[22] test, which also showed a significant difference between the Codas and their parents' preferences for *unrotated* spatial productions (Mann-Whitney U=67, n_1=n_2=9, p= 0.021, two-tailed). Interestingly, this may support an argument that while the children's specific preference (for *unrotated*) does not resemble Cohort 2's preference (for *rotated*), they may still be regularizing, or choosing a preferred spatial modulation consistently. This is discussed in the next section.

Regularization regardless of choice of layout. Language regularization is usually thought of as occurring both within the individual and across the group to which the individual belongs. This makes sense for most cases of language transmission, in which children benefit from having peers. However, in cases of primarily vertical language transmission, children may impose their own stylistic or idiosyncratic preferences on their input, especially if their input lacks consistency. In most cases, we expect that regularization of any linguistic device would manifest as a preference within individuals as well as across the group. This is the case for the regularization we see with Cohort 2 who, as a group and individually, prefer *rotated* spatial modulations. However, for the Coda Children of Cohort 1, we cannot presume that regularization would happen the same way across all individuals within the group. Indeed, the Codas were selected as a comparison group to Cohort 2 precisely because they did *not have* horizontal language experiences with each other or other signing peers. This dynamic creates a scenario in which each individual child may show a preference, but the preferences across the group may differ in both type and strength. We focus here on the spatial modulations only (the black and grey portions of the charts above), to see whether each participant shows a preference, regardless of what that preference is (*Rotated* or *Unrotated*). To give three examples: (1) Cohort 1,

[22] The more appropriate Wilcoxon signed-rank nonparametric test was not calculable given the small sample size.

participant 5's responses were .43 *rotated* (3 items), .43 *unrotated* (3 items) and .14 *Neutral* (1 item). Since we are focusing on the spatial modulations only, we used the six items that were produced <u>with</u> spatial modulations for the denominator (6). Thus this participant's preference score is .5 (3 Rotated responses out of a total of 6 responses with any left/right spatial modulation). (2) Cohort 2 participant 8 has proportions of .57 *rotated* (4 items), .28 *unrotated* (2 items), and .14 *Neutral* (1 item). Therefore this participant's preference score out of the six that show spatial modulations is .66 (4/6 of those with spatial modulations, this one with a preference for *rotated*). 3) Finally, Coda participant 5, who has proportions of .14 *rotated* (1 item), .71 *unrotated* (5 items), and .14 *Neutral* (1 item). This participant then has a preference score of .83 (5/6 of those with spatial modulations, which happens to be a preference for *unrotated*). Figure 13 shows each participant's strength of regularization for their preferred spatial modulation type only.

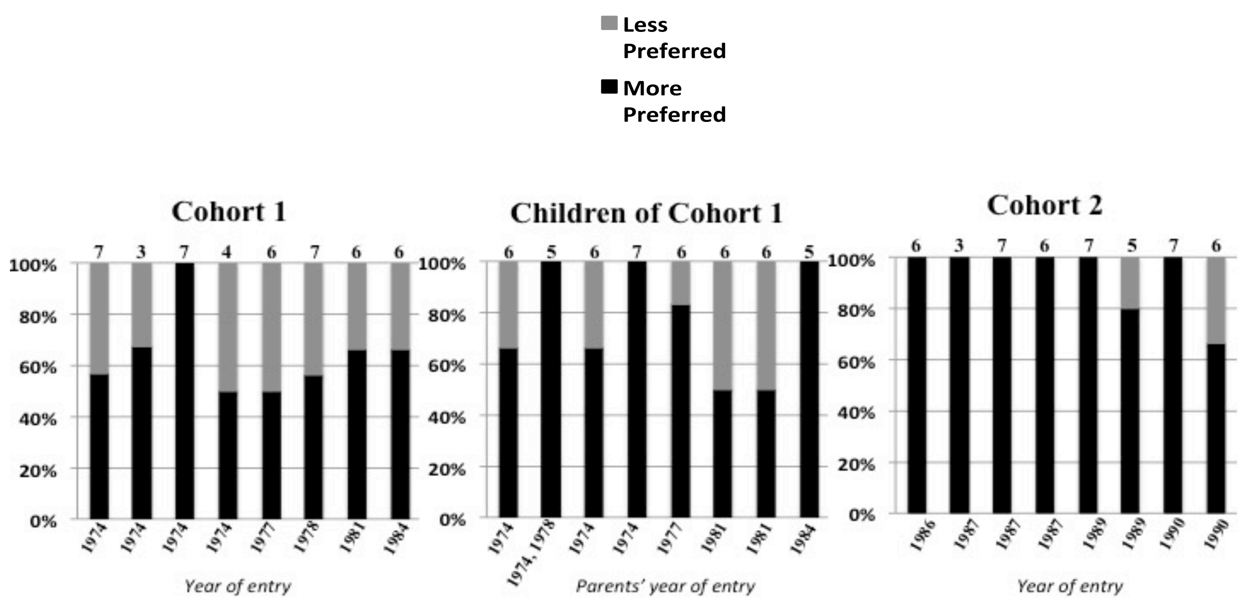


Figure 13. The number of black bars (more preferred choice per participant) across groups indicates the degree of internal consistency of spatial layout. Cohort 2 members are all highly internally consistent in choosing *rotated* layouts over *unrotated* layouts, Cohort 1 members are quite internally inconsistent, and the Codas fall in between these levels of internal consistency.

Groups differed significantly in spatial modulation regularization (preference) (Kruskal-Wallis H(2)= 7.17, p = 0.027), with a mean rank of 8 for Cohort 1, 12.1 for the Children of Cohort 1, and 17.4 for Cohort 2. Three post-hoc analyses were conducted. No statistical difference was found between Cohort 1 and the Children of Cohort 1 (Mann-Whitney U=42.5, $n_{Cohort1}=n_{codas}=8$, p= 0.293), or the Children of Cohort 1 and Cohort 2 (Mann-Whitney U= 46, $n_{Cohort2}=n_{codas}=8$, p= 0.156), but a significant difference was found between Cohort 1 and Cohort 2 for strength of preferred spatial layout (Mann-Whitney U= 57.5, $n_{Cohort1}=n_{Cohort2}=8$, p = 0.009), even when the alpha was corrected for the three additional hypothesis tests (alpha adjusted to .05/ 3 = 0.016). It seems, then, that the driving factor for the earlier significant result in the Kruskal-Wallis test is the difference between Cohort 1 and Cohort 2. The fact that the Codas are not statistically different from either Cohort 1 or Cohort 2 suggests that the Codas fall somewhere in between.

Use of Interlocutor. One possibility when an interlocutor is present is that the participant may assign a thematic role to person(s) in the environment and then produce signs to indicate the recipient as a thematic role irrespective of spatial location. Thus, a participant who has an experimenter sitting to her left (see Figures 10 and 11 above) may produce both *rotated* and *unrotated* items equally as often simply because she is describing the events as "GIVE TO PERSON(experimenter as recipient)" rather than "GIVE TO PERSON(location)." As part of the initial coding, all participants' productions were coded as moving to his/her *left* or *right*. Only one participant, Coda participant 1, seemed to consistently sign in a particular direction, to the left (6/7 items, with 1/7 as *Neutral*). Review of the video suggests that she consistently produced items toward the experimenter, who was sitting on her left. However, this participant's data was not removed because her tendency to produce her signs toward the experimenter only highlights

the fact that she has no spatial modulation preference, which is evident in her scores for *Rotated* and *Unrotated* spatial modulations, which are split evenly.

Discussion

In this study, participants from three groups (NSL Cohort 1, NSL Cohort 2, and the hearing, signing children of NSL Cohort 1) described events in which animate actors moved inanimate objects through space towards another animate character (e.g., give cup to person on the right, kick ball to the person on the left), which are often expressed with ditransitive constructions. Productions were then coded as *rotated* (using one's own space as analogue to the space around the actor), *unrotated* (mirroring the actors on the screen), or *neutral* (not using either rightward or leftward space).

Results for Cohort 1 and Cohort 2 essentially replicate previous findings (Senghas 2003). Cohort 1's productions are inconsistent, with no clear preference for *rotated* or *unrotated* space within or across individuals. These inconsistent productions are maintained when viewed by most consistent choice (as a measure of spatial modulation preference) regardless of type – most Cohort 1 participants do not show a strong preference individually for either spatial modulation. Cohort 2 shows a significantly more consistent preference for modulations reflecting a *rotated* spatial layout.

The Children of Cohort 1 seem to fall between Cohort 1 and Cohort 2. These Codas show a significantly stronger preference for *unrotated* space over their own parents, but are neither significantly different from Cohort 1 or Cohort 2 when it comes to consistent choice of spatial modulations. The current results suggest that in the absence of a peer network, the Codas have only their parents and their parents' generation of signers to inform their choice of spatial modulations. The fact that they are possibly more internally consistent than their parents

indicates that there is likely an innate *tendency* or *desire* to regularize; however in the absence of linguistic peers, that regularization does not come to fruition as much as it would have had they linguistic peers, a benefit that Cohort 2 had. This is in line with Hoff (2006), who suggests that both factors come into play, the "data" from the language model, as well as the sociolinguistic context shaping the acquisition and application of said data.

A curious result is the fact that the Codas preferred *unrotated* spatial modulations more than their own parents. To understand this result, it is important to take into account several sociolinguistic factors pertaining to the Codas' linguistic lives when it comes to their use of NSL. First, we can confidently assume that their productions are strongly influenced by their interactions with their own parents. However, their parents' inconsistent productions and the fact that their own parents may not be very competent at using spatial descriptions (e.g., Pyers et al. 2010), or at understanding others' mental perspectives (e.g., studies with Cohort 1 and Theory of Mind; Gagne & Coppola, 2017; Morgan & Kegl, 2006; Pyers & Senghas, 2009) may create a situation in which the Coda children may choose to produce *unrotated* spatial productions to reduce the demands on their own parents to have to mentally rotate the layout in order to understand the spatial relationships described. Interestingly, in this task, the Codas produced their responses to someone who was not their parent. This "listener" was a Deaf American who was conversationally fluent in NSL and who had established rapport with all participants prior to the testing session through the consent process and introductory conversations. It is possible that while this "listener" focused on using NSL during these interactions, American Sign Language grammar could have nonetheless emerged in his signing (or that of the other experimenter present). However, ASL is a language that uses a *rotated* spatial layout (e.g., Pyers et al. 2015). It is even more notable then, that the Codas maintained their tendency to use an *unrotated* layout

even in the face of new interlocutors who are closer in age to them and who use a sign language that employs *rotated* spatial modulations (e.g., Emmorey & Tversky, 2002; Pyers et al. 2015).

Of additional significance is the replication of results from Senghas (2003). Only two of the present participants (one in Cohort 1 and one in Cohort 2) had also participated in the studies reported in Senghas (2003) (personal communication). This replication of results, from a practically independent sample, underscores the prevalence of the findings from both studies. This replication also leads us to feel confident in the results for the Children of Cohort 1, a novel sample in these studies. Finally, the fact that the samples include different people may contribute to some of the slight differences we find in strength of regularization, particularly in Cohort 2.

A question left by the current results is whether the patterns found in the productions represent an underlying grammatical rule for spatial layout. Specifically: is the use of *rotated* space (for example) intended to meaningfully inform the listener that the space to the signer's right represents the space to the actor's right? While there is some clue here that some participants (most notably those in Cohort 2) are consistent in their *productions*, we cannot yet be sure that those consistencies are derived from an established form-meaning association. In other words, we cannot be sure that the consistency in the productions is a byproduct of individual preference (without the intended information), or whether the consistency shown is intended to meaningfully inform the listener about the recipient/ final location of the objects being transferred. Note that so far we have only asked each participant to describe each video *once*, rather than multiple times. Producing inconsistent spatial modulations for the exact same vignette over the course of two to three productions would have been one way to capture meaningful patterns of form-meaning mappings in productions. Another way to gauge the consistency of form-meaning mappings is to assess whether participants apply their type of

production preference (*rotated / unrotated*) to their *interpretations* of others' productions.

In this series of studies, we so far see that the Codas may be regularly using *unrotated* space as a means of accommodating their parents' difficulties with spatial cognition and/ or theory of mind difficulties (to be assessed further here in Chapter 5, Spatial Encoding). However, we still cannot be sure that their use of *unrotated* spatial modulations represents an underlying grammatical rule for those Codas. As discussed in Senghas (2003), in order for us to find a crystallized spatial modulation in any one person's grammar, we must seek clues present in both their productions *and* their interpretations of others' productions, the topic of the next study.

Chapter 4. Study 2: Interpretations

Study 1 replicated the pattern of production of spatial modulations that were reported in Senghas (2003). An (almost)-independent set of participants from Cohort 2 clearly regularized from the vertical production input they received from Cohort 1. As suggested by Senghas (2003), however, regular production alone is insufficient to establish that a pattern is truly part of the user's grammar. Senghas (2003) went on to show that the use of modulations on verbs reflecting a *rotated* spatial layout to indicate the direction, location, and /or recipient of events is part of the current grammar of Nicaraguan Sign Language (starting with Cohort 2), even though this particular grammatical device is not evident in the production or interpretations of Cohort 1 signers.

Study 1 also showed that the Children of Cohort 1, who had been (presumably) presented with repeated exposure to inconsistent uses of space, attempted to create a regular production rule individually. While their preferences for a given spatial layout are weaker than those of Cohort 2 signers, the Children of Cohort 1 may be consistently accommodating their parents' inability to take others' spatial perspective and may thus more consistently use *unrotated* productions, as possibly evidenced by Pyers et al (2010), who showed that Cohort 1 struggles with spatial cognition, and by Pyers and Senghas (2009) who showed that Cohort 1 struggles with Theory of Mind tasks (taking others' beliefs or perspectives into account), as compared to Cohort 2. Producing an *unrotated* layout may relieve the demand on the viewer to have to account for spatial relations, since *unrotated* or *mirrored* layouts position the spatial relations relative to the listener rather than to the speaker. However, as discussed at length by Senghas (2003), the consistent productive use of either device does not amount to a crystallized grammatical device. That is, the consistent production in the Coda Children of Cohort 1 may be

the result of communicative or environmental factors (their own parents' struggles with spatial understanding) rather than the creation or application of a grammatical device.

As in Senghas (2003), the best way to test whether consistent production is an indicator of the presence of a grammatical form is to see whether the signer also applies that rule to his/her interpretations of others' productions. This is the goal of Study 2.

Cohort 1, Cohort 2, and Coda participants watched video clips of various NSL signers representing all three groups describing the events from Study 1. They were asked to match each production with 0, 1, or 2 images out of an array of four. The arrays were constructed to reveal whether participants' interpretations of those utterances conformed to one of three spatial layout types: *rotated*-only, *unrotated*-only, or *unrestricted* (i.e., rotated or unrotated). For each participant, we first determined whether their interpretations reflected a consistent spatial layout. If their preferred layout for interpretations was the same as the layout they preferred in their productions, we can conclude that this pattern is evidence of a grammatical rule. In particular, we ask whether (a) Cohort 1 is as flexible in their interpretations of spatial modulations as they were in Senghas (2003), (b) If Cohort 2 is as regular in their interpretations of spatial modulations as they were in Senghas (2003), and finally, (c) whether the Codas' somewhat consistent preference for *unrotated* productions is also apparent in their interpretations of others' productions.

Method

Participants. The participants in this study were the eight Cohort 1 signers, eight Children of Cohort 1 (Codas), and eight Cohort 2 signers, all described in Chapter 2.

Procedure. Participants were presented with 22 video clips of other NSL signers (and sometimes themselves) producing signed sentences describing events that occurred either to the right, to the left, or to neutral space, and were asked to choose matching pictures.

Materials. The signed sentences were drawn from clips of productions by the participants in Study 1 who had given consent to show their videos to other participants. Each of the signed sentences was accompanied by an answer array of four images. These arrays were balanced to have 0, 1 or 2 potential responses, and the structure of the responses with respect to the target sentence were designed to reveal the constraints on participants' interpretations of the spatial modulations they saw. The arrays with 2 potential responses depicted the agent and theme of the target event twice, one image being a mirror image of the other (as in Figure 2c). If a participant had a strong preference for a spatial layout (rotated or unrotated), they would only deem one of those images to be a possible match for the sentence they saw. However, choosing both images featuring the same agent and theme with the event occurring to both the right and the left (as in the two mirror images) would reveal a participant's flexible interpretation of the spatial modulations in the sentences.

A total of 22 video clips (each containing one sentence/description) was presented to participants: 4 training items, 8 test items, and ten filler items. The 22 clips (including the training sentences) consisted of 9 sentences produced by Codas, 6 by Cohort 1 signers and 7 by Cohort 2 signers. Likely the Cohort 1 and 2 signers in the videos were familiar to the Cohort 1 and 2 signers watching them, and Cohort 1 signers were familiar to most Codas, but it is unlikely (though not asked explicitly) how many Codas knew the Cohort 2 signers they saw in the videos.

The first four videos (of the 22 total) served as training items; these described events that were "neutral" (e.g., pouring water for oneself, Figure 14a-b). These trials trained participants that it was *expected* and *permitted* to answer in one of three ways: (1) that no images in the array matched the video clip, (2) that one image matched, or (3) that two images matched. The (1 or 2) images that matched the video consisted of the original image of the event and/or its right-to-left

reverse (see Figure 15c). Feedback was given during the training options, for example, to emphasize “Right, in this one, none of the images match the exact event (even if some images depicted related items, such as from the same soccer/dinner scenario),” or “In this one, we don’t know the direction, so both of these images could match the description.”

a. 

b. 

Figure 14. Example of a training item in which the participant describes a non-spatial event of pouring water for oneself (14a), and its matching answer array image (14b).

Eight of the eighteen remaining after the training served as test items which involved the spatial events analyzed in Study 1 and included events like kicking, serving (food) or giving. These eight test items were counterbalanced for direction of modulation (to the right or the left) and for the original producer’s spatial layout (*rotated* or *unrotated*). These eight test items all had answer arrays in which up to *two* possible images could be selected (*rotated*, *unrotated*, or *both*, Figure 15). The other two images in the answer arrays consisted of two distractors: one image of a different event in the same scenario (dinner or soccer) and one image of an event from the other scenario (soccer or dinner).

The remaining ten video clips were fillers and included clips in which no direction was produced or a direction was produced but no matching pictures were available, or only one picture could possibly match the sentence displayed in the video clip. As in Senghas (2003), the sentence videos were then divided into two equal halves (set A and set B) consisting of four test

items and five filler items each (9 total). The order of sentences was randomized within each set with the following constraint: While the same signer could have been featured in more than one video (maximum two), the same signer was not presented in two videos in a row. Half the participants saw set A first and the other half saw set B first. Interpretation responses were videotaped for offline coding.

(a) (b)

(c)

Figure 15. Participants watched 18 short videos of signers describing events in either the dinner scenes or soccer scenes. Participants then chose from an array of four (c) the image(s) that matched the signer's description. Videos were counterbalanced in that some had signers signing in a particular direction (e.g., (a)), and others had signers signing to neutral/central space (b). Answer sheets were balanced to have 0, 1 or 2 potential answers; (c) is an example of an array with two possible answers for the description in (a) or (b) of CUP GIVE. Note that *if* the viewer does *not* have a grammatical rule for the use of space, or if he saw a neutral production like (b), he should choose both answers B *(top right of (c))* and C *(bottom left of (c))*. However, if the participant interprets the spatial modulation according to a single spatial layout, he should choose only one answer, either B *or* C (i.e., "C" for *rotated* interpretations, and "B" for *unrotated* interpretations).

Coding

All videos were coded offline by an undergraduate research assistant and a subset was checked by the author. All disagreements were resolved by discussion and mutual agreement. Of the eight original test items, seven were used for analysis, as one stimulus video was corrupted by a technical problem and elicited mostly "no match" responses (14/24 responses). As stated earlier, the remaining seven test items all included videos of signers signing either to the right (3 items) or the left (4 items), and all seven videos had both *Rotated* and *Unrotated* options available in the answer array (Figure 15c). Responses were coded as *Rotated, Unrotated, Unrestricted,* or *None/Distractor.* A response was coded as *Rotated* if the participant selected only one image in the array, and that item depicted the action in the same direction relative to the actor as the verb was produced in relation to the signer (See Figures 15a and 15c, answer C). A response was coded as *Unrotated* if the participant selected only one image in the array and that item depicted the action in the opposite direction relative to the actor as the verb was produced in relation to the signer (See Figures 15a and 15c, answer B). *Unrestricted* responses were responses where the participant selected two images: *both* the *Rotated* and *Unrotated* images (Figures 15a and 15c, answers B *and* C). A response was coded as *None/Distractor* if the participant either said that no image matched ("none"), or selected one of the two distractors.

Results

Overall preferences for interpretation. Figure 16 presents the proportions of *Rotated*, *Unrotated*, *Unrestricted* and *None/Distractor* interpretations by Cohort 1, the Coda Children of Cohort 1, and Cohort 2. In a series of Kruskal-Wallis nonparametric tests of variance, no significant differences in interpretation type were found across groups (*Rotated*: $H(2)= 3.07$, $p = 0.215$; *Unrotated*: $H(2)= 2.8$, $p=0.247$; *Unrestricted*: $H(2)= 3.14$, $p=0.208$; *None/Other*: $H(2)=$

3.92, p=0.141).

While the Kruskal-Wallis tests revealed no significant differences, visual inspection suggests differences among the groups (Figure 16). First, Cohort 2 may show a preference for applying a *Rotated* interpretation, even if the strength of their preference is not significantly greater than that of the Codas or Cohort 1. The same could be said for the Coda Children's preference for *Unrestricted* interpretations. Also of note is that unlike Senghas (2003), Cohort 1

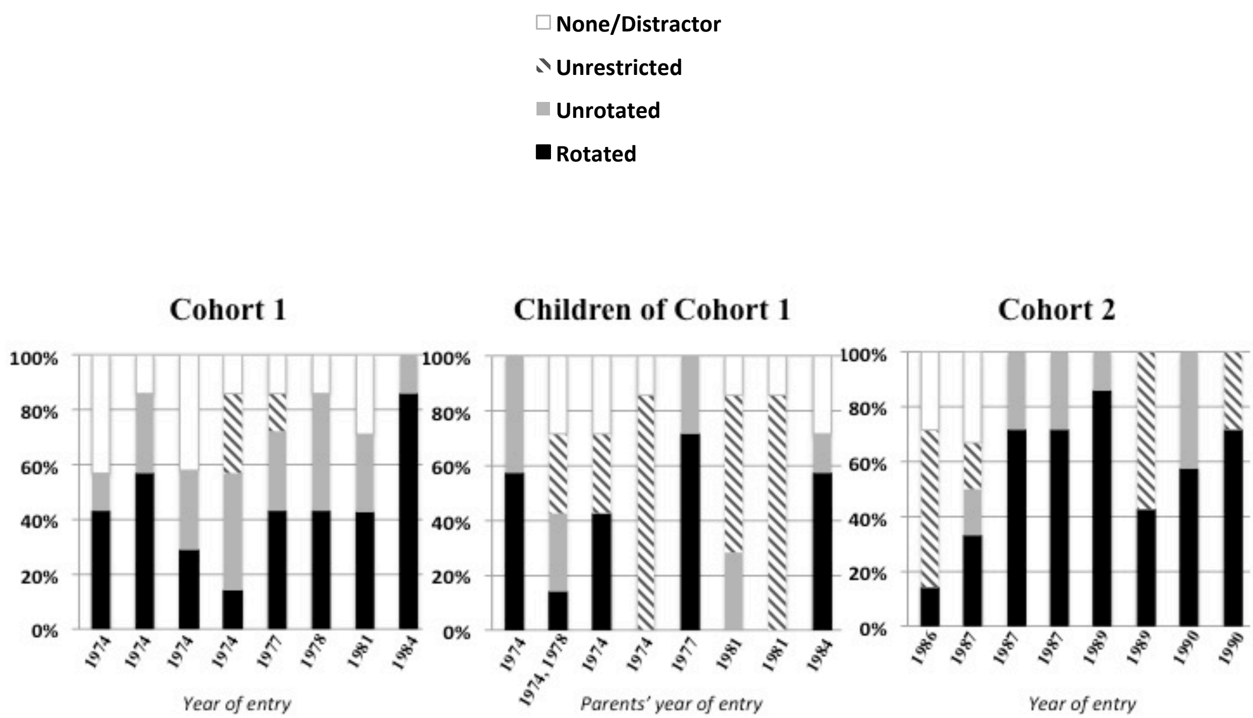


Figure 16. Interpretation responses by participant. While all three groups employed all options, the Codas ("Children of Cohort 1") responded with *unrestricted* responses the most (striped bars, representing the selection of *both* possible interpretations for any particular production). Cohort 2 showed the most preference for *rotated* productions.

participants were not as likely in the current study to respond with *Unrestricted* responses (that is, choosing both an image and its reverse). However, their choices when they chose only one response essentially reveal flexibility in their interpretations: a majority of Cohort 1 participants (6/8) chose *Rotated* and *Unrotated* interpretations in approximately a 50/50 ratio.

To evaluate the possibility that participants' interpretations of the signers in the videos related specifically to the producer's cohort, the interpretation responses were re-configured accordingly. Figure 17 shows the proportion of *Rotated*, *Unrotated*, *Unrestricted* and *None/Distractor* interpretations by signer group, depending on the producer of the sentence: Cohort 1, Cohort 2 or a Child of Cohort 1 (Coda). Four patterns emerge from Figure 17. First, it suggests that both Cohort 1 and Cohort 2 signers understand that Cohort 2 signers prefer *Rotated* productions, and thus both groups apply *Rotated* interpretations to Cohort 2 more often than other types of interpretations. The Codas may not know Cohort 2 signers' preferences as well (because they do not interact as much with Cohort 2 signers) and thus do not interpret Cohort 2

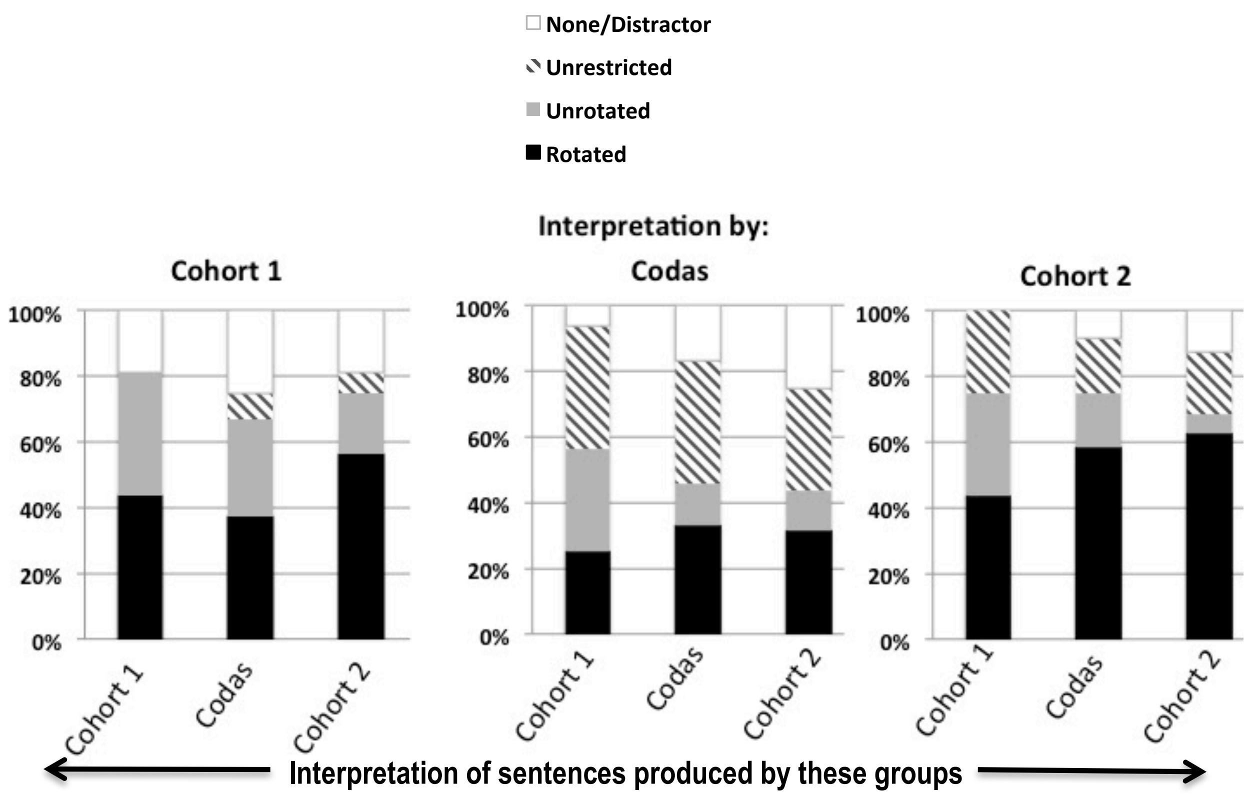


Figure 17. Mean proportion by group of participants' interpretations of other signers' productions, based on the group membership of the producer.

productions as strongly *Rotated*. Second, Cohort 2 signers interpret the Coda productions as *Rotated* (despite the results from Study 1 showing that the majority of Coda productions were in fact *Unrotated).* Third, the Coda children of Cohort 1 apply *Unrestricted* responses to all groups equally, and the remainder of their interpretations are pretty equally divided between *Rotated* and *Unrotated*. Finally, we see that Cohort 1 signers make the most errors. The stimuli and answer sheets were designed to elicit only *Rotated*, *Unrotated* or *Unrestricted* interpretations; however, Cohort 1 participants selected one of the other choices more often than the other groups: either they responded that no picture matched the production they saw, or they chose one of the distractors. Such responses call into question whether they understood the production in the first place.

Discussion

In Study 2 we presented the three groups of interest, NSL Cohort 1, NSL Cohort 2 and the hearing, signing children of Cohort 1 (Codas) with sentences containing spatial modulations that were produced by various signers from each group. They then selected from an array of images that varied in whether they matched the signs in the videos in spatial layout. Participants were trained that sometimes no picture matched, sometimes one picture matched, and sometimes two pictures matched.

Results showed no statistically significant differences among groups in proportions of interpretations as Rotated, Unrotated, Unrestricted (2 images) or errors in test items ("None/Distractor"). However, a closer look at the data revealed emerging patterns of interest. First, we saw that the Coda children of Cohort 1 tended to apply *Unrestricted* interpretations to others' signs, and that they applied this preference regardless of the group represented by the signer: Cohort 1 (like their own parents), other Codas, or Cohort 2. This pattern is

understandable. Recall that the Codas do not interact with many signers other than Cohort 1 signers (Chapter 2), who are inconsistent in their productions of spatial modulations (Senghas & Coppola, 2001; Senghas, 2003). They do not interact with other Codas using sign (else they may have started to apply *Unrotated* interpretations to other Codas), or with Cohort 2 signers (who prefer *Rotated* productions). Therefore, it is unsurprising that the Codas apply the same pattern of interpretation to others as they do to their own parents' generation. This pattern may be driven largely by their parents' inconsistent *productions*, rather than as imitation or learning from their parents' preferences for *interpretation,* that is, the Codas may not be interpreting in the way their parents are, because interpretations may be more dependent on the successful communication between interlocutors rather than direct learning from their vertical input. This point will be explored further when Productions, Interpretations, and Encoding are related in Chapter 6: Encoding.

Second, we see that Cohort 2 signers seem to interpret the Codas' sentences in the same way that they interpret their own. That is, as predominantly *Rotated,* even though we know from Study 1 that the Codas' productions tend to be *Unrotated*. This interpretation is unlike the way they interpret productions from Cohort 1, where they don't seem to think that Cohort 1 signers are rotating their spatial modulations. It is possible, therefore, that Cohort 2 signers, upon seeing a young signer (the Codas' mean age is 16.5), assume a *Rotated* spatial layout. However, Cohort 2's interpretations are not as consistently *Rotated* as reported in Senghas (2003). This difference could be due to several factors. First, as with the production study (Study 1), the current Cohort 2 participants are mostly different from those who participated in Senghas (2003), with an overlap of just one individual. Therefore, differences in interpretation tendencies may reflect individual differences. Finally, the timing of the two tasks may have affected the results. For the

Codas and Cohort 1 participants, between three and ten weeks passed between the production and interpretation[23] tasks. However, 5/8 of the Cohort 2 participants completed the interpretation task immediately after (on the same day as) their productions. Thus, some of Cohort 2 signers' interpretations that are not *Rotated* (*Unrestricted* or *Unrotated*) could be due to the participants actually recalling the original dinner or soccer scene videos and responding accordingly, rather than responding on the basis of what they believed the signer to be saying.

Finally, Cohort 1 signers are split in their tendency to interpret a spatial modulation as *Rotated* or *Unrotated*, though few of them actually chose two images (the *Unrestricted* interpretation type). This difference from Senghas (2003) could be procedural. In a personal communication (March 2017), Dr. Senghas explained that she checked after each answer selection whether the participant (regardless of Cohort membership) thought any other image could apply to the sentence they just saw. This procedure differed from the current interpretation study where, as in Senghas (2003), the participants were trained to understand that 2 answers were possible, but the experimenter did not explicitly re-check after every test or filler item. Because most testing situations require only one answer, it is possible that despite this training, the current sample of Cohort 1 participants reverted back to this default 1-answer-per-question tendency. Regardless of this possibility, Cohort 1 participants still did not show a strong preference for one interpretation type, suggesting that their interpretations are flexible or *Unrestricted* in general.

Another important observation about Cohort 1's interpretation choices is the fact that approximately 25% of their interpretations included the (incorrect) choice that no picture matched, or the choice of a distractor image. The degree of incorrect selection calls into question

[23] Participants produced their descriptions of the events and then a few weeks elapsed while the experimenter clipped all the productions and counterbalanced the stimuli to create the interpretation task.

Cohort 1's comprehension of the events that they saw: whether they recall the events at all, and/or whether they understood and recalled the spatial relationships in the sentences. This possibility would clearly affect their ability to consistently apply a *Rotated* or *Unrotated* interpretation to the sentences they saw. This is the focus of Study 3: Encoding.

Chapter 5. Study 3: Encoding of spatial information

While several previous studies have examined the use of spatial language in different groups of signers of NSL, no prior work has examined signers' abilities to *encode* and recall the relevant elements of spatial events. The main question the encoding task addresses is: *Did the participant encode/understand the events correctly in the first place?* That is, did these signers attend to and retain the relevant spatial information necessary to either sign an accurate description from memory or interpret another's descriptions of the spatial events displayed?

Previous studies with Cohort 1, in particular, have shown various cognitive deficits due to the circumstances of their language exposure, for example, in Theory of Mind understanding (Gagne & Coppola, 2017; Pyers & Senghas, 2009), and most relevantly, spatial cognition (Pyers, Shusterman, Senghas, Spelke, & Emmorey, 2010). Thus language-related cognitive deficits could play a part in any irregular signed productions and/or interpretations. Given Pyers et al. (2010), we expected that the two groups with exposure to and use of more consistent and established language systems (a more evolved version of NSL in Cohort 2 and Spanish, at least, for the Codas) would succeed (perform significantly above chance) on spatial tasks. Therefore, this encoding task served as a check that they understood the events they were to describe. No prediction was made for Cohort 1 as the encoding task was different from the linguistic description task previously used by Pyers et al. (2010), in which participants described the location of a hidden object. Note that the fact that an object is hidden ought not to have influenced their ability to describe its location. Gagne and Coppola (2017) show that Cohort 1's performance on a False Photograph task is at ceiling, showing that the removal or change of an

object in a scene can be accurately identified and recalled by Cohort 1 participants[24].

The encoding task was therefore designed to check whether key loci in the event or the directions of an actor's actions were recalled by participants. The task was divided into two parts: (1) an ***Identification task*** consisting of short yes-no answers presented as "does this image match the (5 – 10 sec) video you just watched?" (Figures 18a-d and 19a-d below) and (2) a ***Path marking task*** consisting of drawing the path of an object (ball, plates, or bowl) on a laminated layout (Figures 24b, 25b below). Each will now be described in its entirety, with their respective results and discussion.

Study 3a: Identification Task: Yes/No questions

Method.

Participants. The participants were the 8 Cohort 1 signers, their children, "Codas", (*N*=8), and the 8 Cohort 2 participants described in Chapter 2.

Procedure. Participants were presented with four short video clips (ranging from 5-10 seconds each) of actors participating in multi-event scenes taken from the same set of stimuli used for the production (Chapter 3) and interpretation (Chapter 4) studies. Two of the videos depicted scenes from the set of soccer events and two depicted scenes from the dinner events (Figures 1a and 2a). After watching each video, participants saw three trials of still images and were asked, for each image, "Is this picture the same as/does it match the video you just watched?" (Figures 18b-d, 19b-d). The first video and its corresponding three images served to

[24] Three of the current Cohort 1 participants participated in the False Photograph study by Gagne and Coppola (2017). While there isn't a greater overlap of participants from the previous study to the current, Cohort 1's excellent performance reported by Gagne and Coppola (2017) suggests that the language-related difficulties that Cohort 1 signers may experience likely do not extend to the domain of encoding changes in the scene when it comes to hiding objects. In fact, Gagne and Coppola (2017) also report ceiling performance on the False Photograph task among the homesigners, individuals who use an even less regularized, less shared communication system.

train participants that they ought to not only recall the general event itself (e.g., passing a plate in Figure 1a and not a cup as shown in Figure 1b) but also the direction of the event and the relative locations/positions of the actors and objects (e.g., Figures 18c vs. 18d or 19b vs. 19d).

Coding.

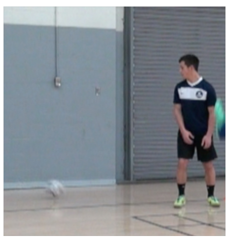
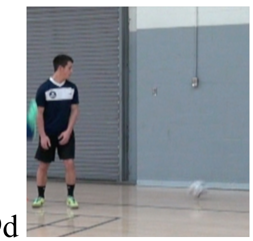
Responses were videotaped for offline coding; all participant responses were coded by a research assistant and a subset (17%, or 48/288 items) were subsequently checked for accuracy by the primary experimenter. Both the first and the best/final response were recorded for each participant for each of the twelve yes/no questions. The twelve items were made up of three training trials (using video 1) and nine test trials (using the remaining three videos).

18a Example 1 Stimulus video still

18b  18c  18d 

Yes/No images: *"Is this picture the same as/does it match the video you just watched?"*

19a Example 2 Stimulus video still

19b  19c  19d 

Yes/No images: *"Is this picture the same as/does it match the video you just watched?"*

Figures 18 and 19. Two examples of the encoding stimulus videos. Each set of four images shows a still image from one of the yes/no encoding stimulus videos (18a, 19a) and the three yes/no images presented for each. The yes/no images were presented in isolation, and represented an event check (18b, 19c), which was a thematically matched event but with the wrong actions (e.g., in the case of the dinner scene, the passing of a cup, rather than a plate), a direction check (18c, 19d) which was the correct event reversed, and the correct event and direction (18d, 19b).

Of the nine test trials, three displayed the correct event *and* direction (one per video), three displayed the correct event with the incorrect direction, and three were incorrect events (direction not valid). Responses were then categorized by participants' encoding of the *event* and of the *direction. Event* encoding was scored by accuracy on six particular trials: the three trials that displayed the correct event and direction (which should have elicited a "*yes"* response) and the three trials that displayed a different, but related event (which should have elicited a "*no*" response). *Direction* encoding was scored by accuracy on another, related, set of six trials: the three that displayed the correct event and direction (which should have elicited a "*yes"* response) and the three that displayed the correct event, but the wrong direction (by way of reversing the

image)[25]. As a first pass, the *best* response per picture was taken, after participants may have incorrectly responded earlier (e.g., identifying Figure 2d as matching the video (incorrect) but then correcting oneself and stating it does not match (correct)). Analyses were then also conducted on each participants' *first* response, to check whether participants' initial, spontaneous assessments were accurate.

Results.

Overall Results. Table 7 presents the number correct (out of three) for each of the critical types of images: (1) correct event and correct direction, (2) correct event and incorrect direction, and (3) incorrect event, per participant[26]. Finally, the last column in Table 1 presents the number of times each participant corrected their response, improving their score, coupled with the number of *incorrect* first responses (as an indicator of how much they *could have* improved). Thus, the fraction in the last column is an indicator not only of how *confident* they may be in their answers (lower number of corrections) as well as how well they are able to *identify errors* (higher proportion of identified vs. possible corrections). Analyses were then conducted to check for accuracy on two dimensions: whether they encoded the *event* correctly and whether they encoded the *direction* correctly.

---

[25] Note that the images that displayed the correct event but wrong direction could not be used to check *event* because the main question posed to the participants was "does this image match the video you just saw?" Someone who encoded both the event and the direction ought to have answered "no" to these images. Therefore, a "no" would have been coded as correct in one set (those checking direction), but incorrect in the other set (those checking event). Therefore, they are only helpful in checking the encoding of direction, but not event.

[26] The video for Cohort 2 Participant 5's last yes/no question was damaged; we unfortunately cannot report her score.

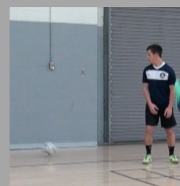
Cohort, Participant #	Correct event & correct direction 		Correct event & Incorrect direction 		Incorrect event 		Number of Corrections/ Number incorrect First responses
Cohort 1 (Parents) (by year of entry to school)	Number Correct out of 3						
	First	Best	First	Best	First	Best	
Participant 1	0	2	3	3	3	3	2/3
Participant 2	2	2	1	1	1	2	1/5
Participant 3	1	1	1	1	1	2	1/6
Participant 4	3	3	3	3	2	3	1/1
Participant 5	1	1	2	2	2	2	2/4
Participant 6	2	3	2	3	3	3	2/2
Participant 7	1	1	1	1	1	1	0/6
Participant 8	1	1	2	2	2	2	0/4
Children of Cohort 1 (Codas, *Parents' # in parentheses*)	Number Correct out of 3						
	First	Best	First	Best	First	Best	
Participant 1 (1)	3	3	0	1	2	2	1/4
Participant 2 (2,6)	2	2	3	3	3	3	0/1
Participant 3 (3)	2	2	1	1	3	3	0/3
Participant 4 (4)	3	3	2	3	3	3	1/1
Participant 5 (5)	2	2	2	2	2	2	0/3
Participant 6 (7)	2	2	0	0	3	3	0/4
Participant 7 (7)	3	3	2	2	3	3	0/1
Participant 8 (8)	3	3	2	2	2	2	0/2
Cohort 2 (by year of entry to school)	Number Correct out of 3						
	First	Best	First	Best	First	Best	
Participant 1	2	3	0	2	3	3	3/4
Participant 2	3	3	1	3	1	2	3/4
Participant 3	2	2	2	2	3	3	0/2
Participant 4	1	1	1	1	2	2	0/5
Participant 5	2	2	2	2	1	1	0/4
Participant 6	3	3	2	3	3	3	1/1
Participant 7	3	3	2	2	3	3	0/1
Participant 8	3	3	3	3	2	3	1/1

Table 7. Raw scores per participant for each of the yes/no question types: Correct event and Correct Direction, Correct event, Incorrect Direction, Incorrect event. Both participants' first uninhibited responses are presented ("first" columns) per question type as well as their "best" responses after any self-corrections. Finally, the number of corrections per participant is presented as an indicator of how well they may have noticed their errors and how confident they were in their first responses.

Encoding the correct event – best response. Participants' best responses[27] on six trials testing whether they recalled the correct event (See Figures 18a (stimulus), 18b (incorrect event), and 18d (correct event, correct direction) for example stimuli and possible responses) ranged from 2/6 correct (a proportion of 0.33) to 6/6 correct (a proportion of 1.00). Individual participant scores and group means are presented in Figure 20. Cohort 1 participants exhibited the widest range of scores, with the mean score not significantly different from chance (M= 0.67; chance = 0.5 for yes or no, indicated by the grey dotted line and significance at 5/6 trials or 0.83, indicated by the grey dashed line). Only three Cohort 1 participants scored significantly better than chance. Cohort 2 participants identified the correct and incorrect events significantly better than chance (M=0.86), with 6/8 participants reaching scores significantly higher than chance. However, Cohort 2 did not perform significantly better than Cohort 1 (Mann-Whitney U=46.5, p= 0.142). Just as Cohort 2, the Children of Cohort 1 also identified the correct and incorrect events significantly better than chance (M=0.85), with 7/8 participants reaching scores significantly higher than chance, yet they too did not perform significantly better than Cohort 1 (Mann-Whitney U=46, p= 0.156)[28].

[27] The best response did not have to be the final response. For example, an item was scored as correct for this analysis if at any point the participant gave the correct response.

[28] While the Children of Cohort 1 could be considered to be paired with their parents, calling for a Wilcoxon Signed Rank test (a non-parametric equivalent to a paired t-test), it should be noted that the *encoding* task does not test the linguistic relationship between the parents and their children in the way that the *production* or *interpretation* studies did. The *production* and *interpretation* studies directly measure the regularization of the language provided by the parent (and the parents' generation) to the child, whereas in the *encoding* study, it could be argued that the child's bilingual experience, or that linguistic experience *not* shared with the parent could be a factor in their encoding ability. Therefore, in this case, the Coda children were treated as a separate group from the Cohort 1 participants, calling for a Mann-Whitney nonparametric test (equivalent to an independent samples t-test).

Correct EVENT, Best response per participant

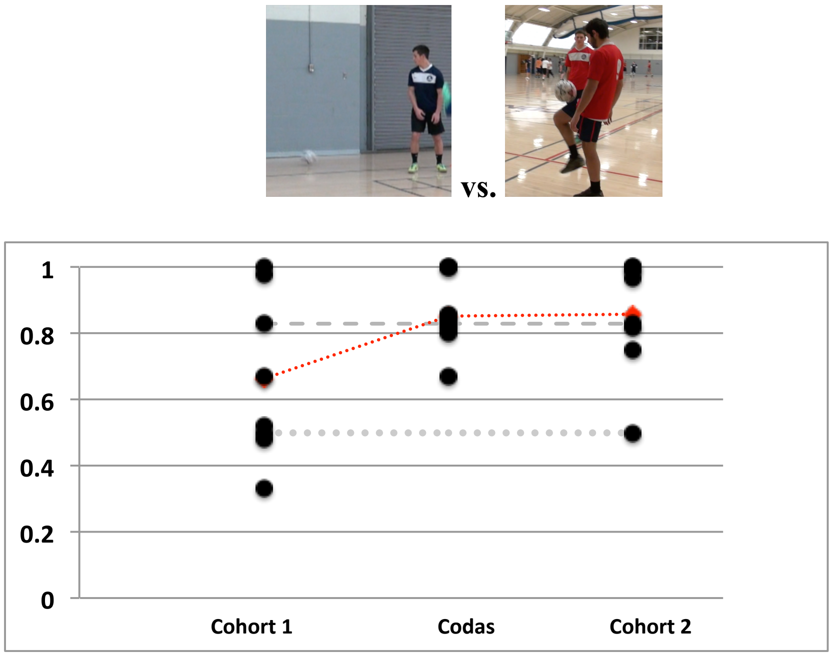


Figure 20. Participant scores for identifying the correct event, given their best (corrected) responses. Chance is indicated by the dotted line (at .50), and the critical value for performing better than chance is indicated by the grey dashed line at .83 (5/6) and was calculated for 6 trials with a 50/50 chance and a 95 percent confidence.

Encoding the correct event – first response. Participants' first, uninhibited responses on the six trials testing whether they recalled the correct event ranged from 2/6 correct (a proportion of 0.33) to 6/6 correct (a proportion of 1.00). Participant scores and group means for their first responses are presented in Figure 21. Cohort 1 participants had the biggest range of scores, with the mean score at chance (M= 0.54). Only two of the eight Cohort 1 participants' individual scores were significantly better than chance on their first responses. Cohort 2 participants' mean did not reach significance above chance (M=0.80, where significantly better than chance performance was calculated to be at 0.83), yet 5/8 of Cohort 2 participants individual scores did reach significance. As a group, Cohort 2 performed significantly better than Cohort 1 on their first responses (Mann-Whitney U=53, p= 0.032, n_{Codas}=$n_{Cohort2}$=8). The Children of Cohort 1 was

the only group whose mean correct on their first responses reached significance (M=0.85), and seven participants' individual scores reaching significance, and they too were significantly different from Cohort 1 (Mann-Whitney U=57, p= 0.010 n_{Codas}=$n_{Cohort1}$=8).

Correct EVENT, First response per participant

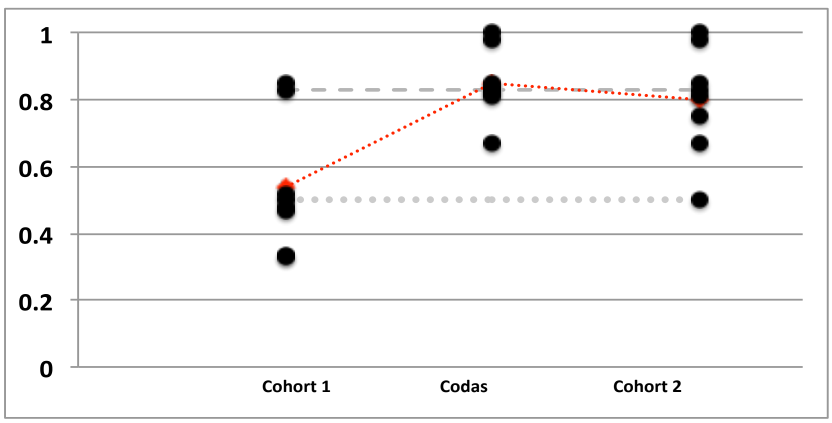


Figure 21. Scores as a proportion correct out of six trials testing the encoding of the correct *event*. Scores for Cohort 1 clustered around .5, which is chance (indicated by the grey dotted line). Only one person from Cohort 1 scored *significantly* above chance (0.83, indicated by the grey dashed line), whereas 7 Children of Cohort 1 (Codas) did, and 5 Cohort 2 participants did.

Encoding the correct direction – best response. Participants' ability to recall the correct direction was scored as the proportion correct for the six trials that depicted either the correct or incorrect direction (both depicting the correct event, see Figures 19a, 19b and 19d as examples). Overall, participants' correct scores for their *best* response ranged from 2/6 (0.33) to 6/6 (1.0). Individual scores per group and group means are presented in Figure 22. Cohort 1 and the Codas' group means did not reach significance as compared to chance (M= 0.63 and 0.71, respectively),

and only three Cohort 1 and four Coda individual scores reached significance as compared to chance, out of eight participants in each group. Cohort 2's mean did reach significance (M=0.83), with 6 participants scoring significantly above chance. Although there were these observable/numerical differences between groups as compared to chance as well as an observable increase in group means from Cohort 1 to the Codas to Cohort 2, there were no measurable significant differences between groups' scores (Mann-Whitney tests; Cohort 1 vs. Cohort 2: U= 45, p=0.190, Cohort 1 vs. Codas: U= 38, p=0.562, Cohort 2 vs. Codas: U= 44.5, p=0.208; for all comparisons, $n_{Codas}=n_{Cohort1}=n_{Cohort2}=8$, two tailed).

Correct DIRECTION, Best response per participant

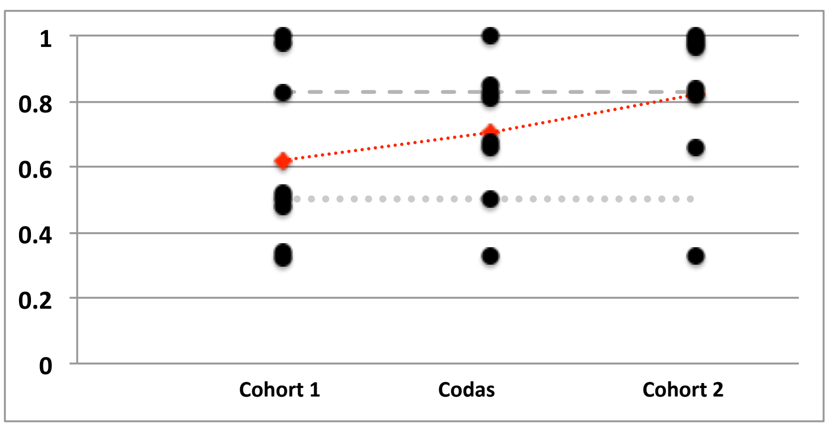


Figure 22. Participant scores for identifying the correct direction, given their best (corrected) responses. Chance is indicated by the dotted line (at .50), and the critical value for performing better than chance is indicated by the grey dashed line at .83 (5/6) and was calculated for 6 trials with a 50/50 chance and a 95 percent confidence. While all groups had scores of a similar range, the means of each group (indicated by the red line) improved from Cohort 1 to the Codas to Cohort 2.

Encoding the correct direction – first response. Participants' *first* responses on the six trials testing whether they recalled the correct direction also ranged from 2/6 correct (0.33) to 6/6 correct (1.00). Individual participant scores and group means are presented in Figure 23. Surprisingly, none of the group means differed significantly from chance (Cohort 1: M = 0.54, Coda: M = 0.63, Cohort 2: M = 0.71). Only 8 participants across all three groups *(N* = 24, so 1/3 of all participants) scored significantly higher than chance (1 in Cohort 1, 3 in the Codas, and 4 in Cohort 2). Finally, there were no group differences in scores (Mann-Whitney tests; Cohort 1 vs. Cohort 2: U= 44, p=0.226, Cohort 1 vs. Codas: U= 23.5, p=0.401, Cohort 2 vs. Codas: U= 39, p=0.497, for all comparisons, $n_{Codas}=n_{Cohort1}=n_{Cohort2}=8$, two tailed).

Correct DIRECTION, First response per participant

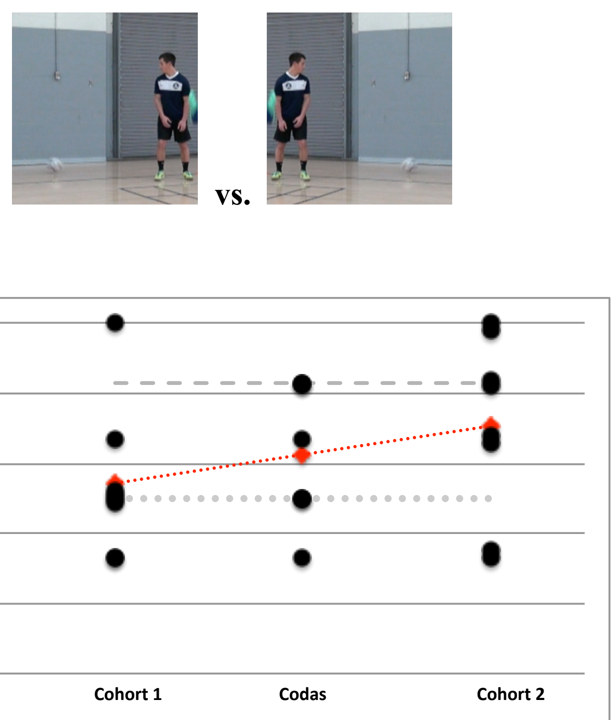


Figure 23. Scores as a proportion correct out of six trials testing the encoding of the correct *direction*. Scores for Cohort 1 clustered around .5, which is chance (indicated by the grey dotted line), but had a wider range than they did for encoding the correct *event*. One person from Cohort 1, three Children of Cohort 1 (Codas) did, and four Cohort 2 participants scored significantly better than chance (0.83, indicated by the grey dashed line). While there seems to be slightly better means for the Codas and Cohort 2, the three groups scores are not significantly different.

Encoding Direction vs. Encoding the Event. One question that may be of interest is whether participants have differential abilities in encoding the event versus the direction. Given results of previous studies showing that the ability to describe relative spatial locations varies with language exposure and improves from Cohort 1 to Cohort 2 (Pyers et al. 2010), participants may encode the correct *event* (an encoding that is not based on spatial understanding) more readily than the *direction* (an encoding that requires spatial understanding). This seems to be the case. A nonparametric paired t-test (a Wilcoxon Signed-Rank test) for scores on event vs. direction across all participants' *first* responses shows that scores for encoding *event* are significantly better than scores encoding *direction* (W=0.76, p=0.032, two tailed). Group sizes were too small to conduct Wilcoxon tests for any particular cohort, though given the means of each group for *event* and *direction* (0.54 for event and 0.54 for direction in Cohort 1; 0.80, and 0.71 respectively for Cohort 2, and 0.85 and 0.71 for the Codas), it seems likely that this difference is driven by differences in *event* and *direction* scores for Cohort 2 and the Codas, and that Cohort 1 is equally poor at encoding the *event* as they are the *direction*: recall that their scores hovered around chance (50%) for both types of questions.

Discussion. Here we investigated the simple encoding (recall by yes/no question) of spatial events by participants across all three groups. No group performed at ceiling, though some participants were able to achieve 100% scores on either *event* or *direction* though not both. Notably no participant scored 100 percent across all questions given their first responses. Only when participants' best (corrected) responses are taken into account that any individuals achieve 100 percent scores on both *event* and *direction.* Cohort 1 was significantly worse at identifying whether an *event* occurred in the stimulus video than both Cohort 2 and the children of Cohort 1

(Codas). Groups did not differ in correctly encoding the *direction of an event*. Overall, participants encoded *events* significantly better than *direction*.

The results are both surprising and unsurprising. In some ways, the results are surprising because all participants were users of a visuo-spatial language, which may boost their comprehension and encoding of spatial relationships (Emmorey, Klima & Hickok, 1998).

However, it is unsurprising that the correct/incorrect images for *event* would be easier to identify than for *direction* given the general complexity of each. It follows logically that given limited cognitive resources that one would recall the general details of the *event* and possibly forget smaller details such as *direction.* One could argue that the difficulties with *direction* are an artifact of the testing; that is memory of various videos could interfere with the recall of the current video. Recall that the images to check the incorrect events were taken from other videos with the same themes, either soccer or dinner, but the images displayed events that did not occur in the test video. Although this task is meant to explain the variation in their productions, it was the first task that participants were presented with, so there was no possibility that their incorrect recall of the event came from previous exposure to the full battery of videos used for the production and interpretation tasks.

Although the theme of the incorrect images was related to the theme of the test video, encoding a particular event was easier than recalling the correct *direction* when presented with two images depicting the *same event*. Only three participants (one from Cohort 1, two from Cohort 2 and 0 Codas) scored perfectly on the *direction* questions. This finding is surprising – given previous suggestions by Pyers et al. (2010) that language, not experience, supports spatial cognition, we predicted that the Codas, by way of their access to an established language (Spanish), that has lexical items (e.g., “left”, “right”) to encode this distinction, would have been

able to recall the spatial information presented in the videos. However, this is not what we found. We see that while there are generally observable differences between groups (e.g., group range and means available in Figures 5 and 6), we do not find any statistical differences between the groups on *direction* – that is, no group performs significantly better than chance at identifying the correct direction of images. This finding does not, however, necessarily counter Pyers et al. (2010). Pyers et al. suggested a language to cognition link, which may still be supported by the current data. Here we see three groups: One with a weak visuo-spatial language, one with moderate visuo-spatial language *and* a strong spoken (but not visuo-spatial) language, and one with a moderate to strong visuo-spatial language. While having a language may help, having a strong visuo-spatial language that is already established may help the most. Yet, there is yet another difference between this task and the task(s) presented in Pyers et al. (2010); namely, the current identification task required little production/expression of space from the participants. We turn now to a task that requires a more active depiction of spatial relationships – the path marking task.

Study 3b: Path Marking Task

It is one thing to recall an event in terms of its relevant spatial information and then recognize whether that relevant information is present in an image or not, and yet another thing to recall the relevant spatial information and use that to generate an informative description (linguistic, gestural or illustrated). In Study 3a, participants needed to compare an image with their recollection of an event. In study 3b, we asked participants to sketch out on a laminated sheet the path of an object as it moved from person to person in a video. We aimed to relate participants' abilities to encode and nonlinguistically represent the path of spatial events to the degree of regularization of their signed spatial productions. Notably, the requirements were

similar between the signed production task and this path marking task: participants needed to recall the relevant spatial information in their environment (in this case, the videos) and present it to someone else appropriately and reliably.

Method.

Participants. The participants were the 8 Cohort 1 parents, the 8 children of Cohort 1 (the "Codas") and the 8 Cohort 2 participants described in Chapter 2: Participants.

Procedure. Participants were presented with the same four videos used for the identification task (Study 3a) that depicted actions by which actors changed the location of particular objects of interest (soccer ball, plates, bowl). The path marking task was done after the identification task and before the language tasks described in Chapters 3 and 4. Participants were presented with the videos again in order to reduce any memory errors. Before watching the videos with the actors, participants were guided through training in which they saw a video of a soccer ball traveling down a hallway among colored bowling pins arranged in the same configuration as the men wearing red/blue shirts in the soccer trials and watched the experimenter indicate the path of the ball among the pins on a laminated sheet depicting the colored pins and their relative positions (Figure 24a-b). Then, the experimenter erased her own line and asked the participant to watch a new practice video (Figure 25a) and draw his/her own line depicting the path (see Figure 8b for an example of a correct path). Only two participants, both from Cohort 1, did not draw the correct path on their own during the practice. Feedback was given to those who required feedback and the task proceeded with the four test trials.

During the test portion of the path marking task, participants saw four videos consisting of two simple (dinner) paths and two complex (soccer) paths (Table 8). The dinner videos were

deemed “simple” because they had fewer participants (three participants rather than four), fewer changes in the object trajectory (two pivot points rather than three), and there was no change in

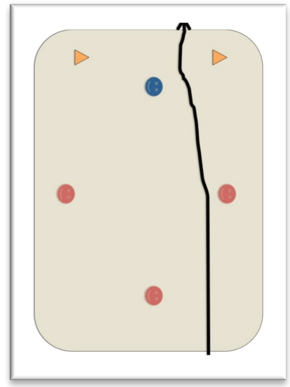
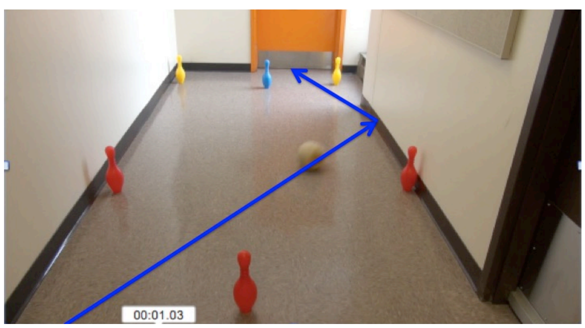
24a  24b 

Figure 24. Training trial 1, where the experimenter showed a video (24a) and drew an example path according to the path of the ball in the video (24b).

25a 

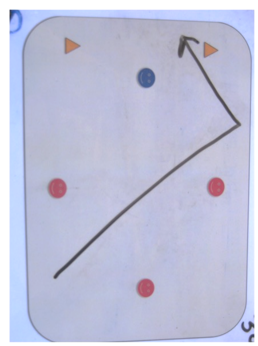
25b 

Figure 25. Training trial 2, where the participant watched a video of a ball travelling down a hallway (25a) and then the participant drew the path of said ball on the laminated sheet (25b).

perspective from the video to the laminated sheet – that is, if one held up the laminated sheet next to the video, one could directly “trace” the path of the plates or the bowl onto the sheet. The soccer videos were deemed “complex:” they had four instead of three participants, more trajectory changes, and required the participant to visually “translate” the perspective in the

video (see the "stimuli" line of Table 8) to the laminated sheet. This "translation," or change in perspective, required an understanding of the relative positions of the three men wearing red shirts, the dark blue shirt, and the orange cones and then required associating those to the red faces, blue faces and the orange triangles on the sheet. The laminated sheet for the "complex" soccer trials essentially represents an aerial view of the men in the soccer configuration. Participants were allowed to watch the videos as many times as they wanted; the researcher asked after playing the video if they wanted it repeated after playing the video. Once the participant was satisfied, s/he drew the path of the ball, plates, or bowl as needed. All layout responses were photographed and interactions were video recorded for offline coding.

Coding. Path sketches were coded as "correct," "Flipped/Rotated," or "other" (Tables 2,3). Correct sketches included not only the correct path but the correct direction. If a particular sketch did not include an arrow to confirm the direction of the path, videos were checked to confirm the participant drew the path in the correct order (as opposed to the opposite order, for instance). "Flipped/Rotated" paths are sketches that would essentially be correct if the laminated sheet were turned or flipped (Table 8). Only two path sketches were categorized as "Flipped/Rotated" – one from Cohort 1 and one from Cohort 2, both in Complex/Soccer types of trials. Sketches that were not Correct or Flipped/Rotated were coded as "Other[29]."

Results. Each participant received a score or 1 or 0 for each path sketched. Across two trials, each participant could receive a maximum score of 2 for the simple trials and 2 for the complex trials. The mean and mode per participant group is provided in Table 9.

---

[29] The code of "other" was chosen rather than "incorrect" because most path sketches that were not correct still contained correct elements that could not be analyzed at this time. For example, the "other" sketch in the dinner column in Table 2 has a correct segment from the rightmost person to the center, but it is missing the connection from the leftmost to the rightmost, and has an additional segment from the center to the leftmost.

Most participants, save for two in Cohort 1, scored perfect (2/2) scores in the Simple (dinner) trials. Individual *Complex* trial scores and group means are presented below in Figure 26. A marginal difference was found between Cohort 1 and the Codas (Mann-Whitney $U = 48.5$, $p= 0.093$, $n_{Cohort1}= n_{Codas}=8$), but no differences were found between Cohort 1 v. Cohort 2 (Mann-Whitney $U = 45.5$, $p= 0.1707$ $n_{Cohort1}= n_{Cohort2}=8$) or Cohort 2 v. Codas (Mann-Whitney $U = 29$, $p=0.795$, $n_{Cohort2}= n_{Codas}=8$).

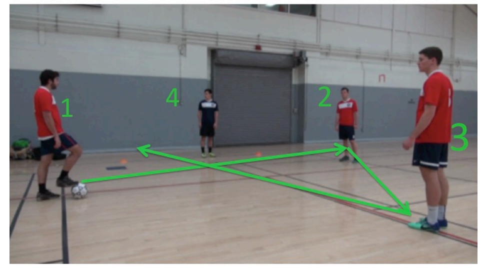
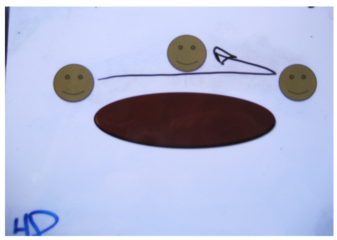
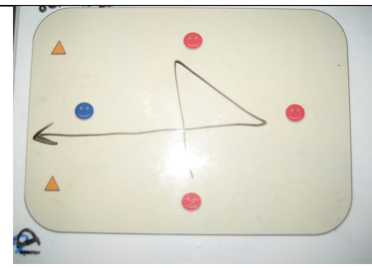
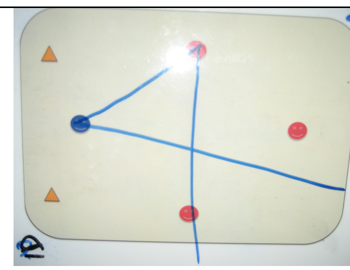
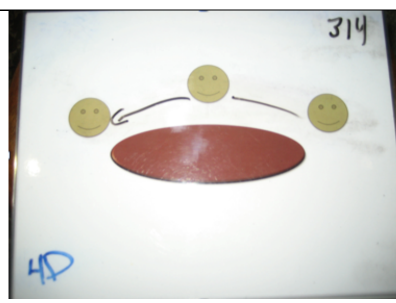
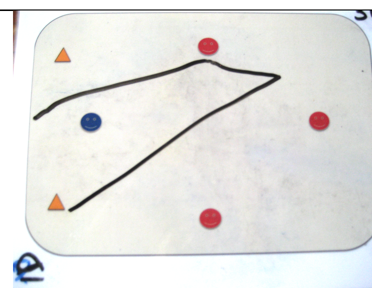
	Simple Fewer participants (3) Fewer direction changes (2) No change in perspective	**Complex** More participants (4) More direction changes (3) Change in perspective
		
Correct path marking		
Rotated/Flipped path marking	N/A	
Other path marking		

Table 8. Example trials and possible codes/outcomes for path markings by participant.

	Simple Mean (Mode) score correct out of a maximum of 2	**Complex** Mean (Mode) score correct out of a maximum of 2
Cohort 1	1.75 (2)	0.63 (0)
Codas	2 (2)	1.375 (1)
Cohort 2	2 (2)	1.375 (2)

Table 9. Mean and mode score per group per path type (Simple or Complex). The maximum score per participant is 2.

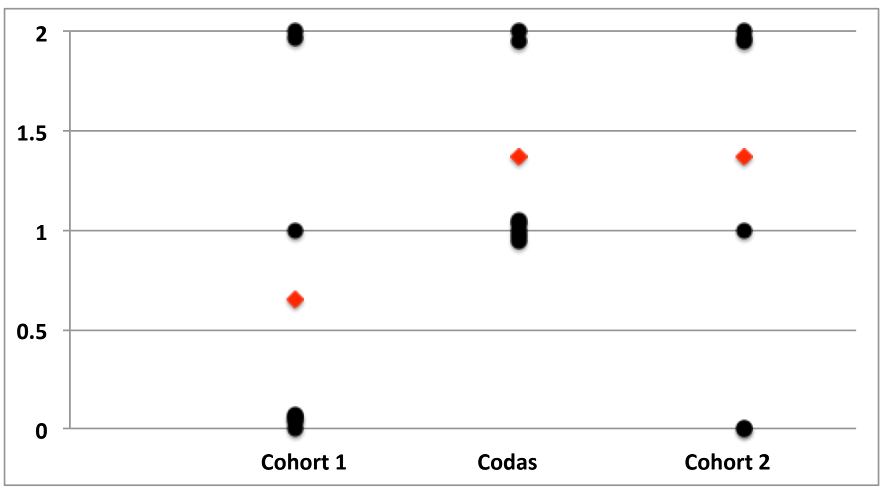


Figure 26. Individual (black circles) scores for correct layouts and group means (red diamonds). Cohort 1 had the lowest mode score of 0; the mode for the Codas was 1 and for Cohort 2 was 2.

Special cases.

Practice trials may predict difficulties with Simple encoding. Earlier in the description of the task, it was noted that only two participants needed additional feedback during training/ practice. Interestingly, they are the same two participants who got any trials wrong among the Dinner (simple) trials. Considering the task demands for the simple trials and the perfect scores

across all other participants, it is likely that these two participants may struggle not only with spatial relations but with encoding simple event information. On the surface, any irregular spatial productions may resemble those who struggle only with spatial language/spatial information, but the root of their difficulties may be general event encoding rather than spatially-specific information. We explore this further when we correlate scores on encoding are related to overall productions and interpretations in Chapter 6.

Difficulties with Complex trials. Two participants produced path sketches that were coded as Flipped/Rotated. These path productions were not on the same trial for both participants, but they were actually both on Complex type trials and both these participants scored perfectly on the Simple (dinner) trials. However, both these participants did *not* produce correct paths for the *other* Complex trial they participated in. It may be possible that they have a weak spatial encoding, either limited by or emerging with their language complexity (that being a less complex form of this new and quickly evolving language) and that they were only able to encode or attend to one, but not both aspects of the spatial information. That is, their paths show us that they were able to encode the general shape of the path, but not necessarily relate the positions of the actors in the video to the positions of the images on the sheet. This too will be explored further when scores on encoding are related to overall productions and interpretations in Chapter 6: Relating Productions, Interpretations and Encoding.

Discussion. A *path marking* encoding task was conducted to further explore the root variables influencing participants' consistent or inconsistent productions and interpretations. This task presented participants with Simple (fewer participants, easier translation from video to paper, fewer changes of location) and Complex (more participants, a more difficult translation from video to paper, more changes of location) trials to explore these variables. Simple trials were

passable by most participants across all three participant groups. Only two participants did not score perfectly on the Simple trials – these were the same two participants that required additional feedback during training; this points to the possibility that their ability to encode events goes beyond the encoding of relative spatial relationship and paths but to more generalized difficulties encoding events they observe.

Complex trials elicited more variable responses across all three groups. Cohort 1 participants struggled the most, with the most number of participants unable to correctly produce the paths depicted in the soccer videos. Cohort 2 and the Children of Cohort 1 (Codas) performed similarly overall (both had a mean of 1.375, but with some interesting differences. Cohort 2, for example, had the highest mode (2), showing that they had the most number of participants who scored perfect scores. However, Cohort 2 also had a wider range than the Codas, who had the same mean, but all Codas were at least able to pass one of the two Complex trials, whereas Cohort 2 had two participants who did not get either Complex trial correct (thus scoring a "0" overall).

Finally, the Complex trials also possibly provided a window into understanding the way that participants may understand or encode events; participants who were able to produce an essentially correct path, so long as the sheet were flipped or rotated, indicates that participants are attending to, or encoding, the path without attending to the relative locations of other things in the scene. This is akin to attending to the type of action in an event and producing that verb (e.g., GIVE or KICK), but not attending to or producing a consistent spatial layout for said event (e.g., to the right or to the left). Scores on Path Marking will now be related to sign production in next in Chapter 6: Relating Productions, Interpretations, and Encoding.

Chapter 6. Relating Productions, Interpretations, and Encoding

Studies 1-3 investigated the consistency of participants' *productions* of spatial modulations (both within and across participants), the consistency of their *interpretations* of others' spatial modulations, and participants' abilities to *encode* relevant spatial information. The following summarizes the results so far, by participant group:

Cohort 1: Cohort 1 *produced inconsistent* spatial modulations when describing spatial events and their *interpretations* were essentially split between *rotated* and *unrotated*, suggesting that their underlying grammar regarding spatial modulations/layouts is *unrestricted.* These Cohort 1 production and interpretation patterns replicate the performance of distinct Cohort 1 signers collected over 20 years ago, and reported in Senghas (2003). Cohort 1 consistently performed more poorly than the Codas or Cohort 2 signers on *encoding* tasks; however, this difference only reached significance for their ability to encode the *event* (vs. left-right direction, or path). Cohort 1 performed most poorly when producing the *path* of an event.

Cohort 2: Cohort 2 signers' *productions* showed a strong preference for spatial modulations reflecting a *rotated* spatial layout. Cohort 2's *interpretations* showed an interesting pattern in that they reserved essentially *unrestricted* interpretations for sentences produced by Cohort 1, but showed a preference for *rotated* interpretations when viewing sentences by Codas or other Cohort 2 signers. This is a partial replication of Senghas (2003), where Cohort 2 signers showed strong preferences for *rotated* productions and interpretations. Cohort 2 consistently performed better than Cohort 1 and as well or better than the Codas on *encoding* tasks; however, these differences only reached significance for encoding the *event,* where they were significantly better than Cohort 1 and performed similarly to the Codas.

Children of Cohort 1: While the Codas' productions of spatial modulations were inconsistent, they consistently used *unrotated* productions to a greater degree than their own parents, and the strength of their preference did not differ significantly from that of their parents or Cohort 2 signers, falling somewhere in the middle. These results seem to reflect Codas' limited ability to improve on the input they received from Cohort 1, relative to the degree to which Cohort 2 improved on the same Cohort 1 input. Of all three groups, the Codas demonstrated the most flexibility in their *interpretations,* assigning *unrestricted* interpretations equally to the productions of all three groups. This supports one of two possibilities that are not necessarily mutually exclusive: (1) that the Codas do not interact with Cohort 2 enough (or at all) to realize that Cohort 2 signers differ in their use of NSL as compared to Cohort 1, and/or (2) the Codas' own knowledge of NSL isn't developed enough to support recognition of differences among other signers. While this was not checked explicitly, it is unlikely that the Coda reports of interacting with their parents' friends included interacting with Cohort 2 signers. This is mainly because the two cohorts are about 10 years apart in age and that age gap may have lead to different circles of friends. Future work will follow up on this.

Finally, the Codas' *encoding* performance differed somewhat from both Cohort 2 and Cohort 1 in ways particular to the type of item. For items testing *event* and *path,* the Codas performed similarly to Cohort 2 signers, whereas for *direction* they fell between Cohort 1 and Cohort 2.

While these results are very interesting on their own, our main questions center on the Codas' performance as they relate to the input they received, given their lack of linguistic peers. Here I propose and evaluate three hypotheses informed by Hoff's (2006) review of social effects on language development. Hoff suggests that in addition to social contexts (such as the presence

or absence of peers), individual communicative pressures and opportunities play a significant role in language acquisition and regularization, whether with peers, siblings, or parents. Even if we find evidence of a universal language-acquisition or language-deriving ability in all children, the child's environment may yet play a significant role in their realization. This evidence is clear when we think of extreme cases, such as homesigners – who are still heralded as evidence of innate language-creation abilities (e.g., Siegler et al., 2014). However, it becomes less clear when we consider Codas or Heritage speakers who theoretically receive "enough" input to derive a fluent, native language.

There is clearly a contradiction in the theories and approaches available so far in language acquisition studies. For instance, studies with heritage speakers argue that their lack of exposure to varied speakers explains their lack of full acquisition of the home language (e.g., Gollan et al., 2015). However, laboratory studies with children given relatively little exposure (as compared to heritage speakers) to novel languages show they can extract new linguistic rules from what they are provided (e.g., Hudson Kam & Newport, 2009; Saffran, Aslin, & Newport, 1996). So which is it? It may be both, or neither. It is possible that all children can extract novel rules given inconsistent, ambiguous or equivocal information, especially in the sociolinguistic vacuums represented by laboratory settings. It is equally possible that environmental factors, such as the number of interlocutors or who those interlocutors are, plays a role in the formation of linguistic rules and/or how those rules are realized in the language-learning child.

Therefore, I propose the following three hypotheses, explain them in detail below, and offer analyses evaluating their explanatory power regarding the current findings:

(1) Participants' *encoding* abilities will correlate with their own strength of preference for *production* of spatial modulations.

(2) The Codas' preferences for *unrotated* productions will be predicted by their parents' *encoding* abilities rather than by their parents' production patterns. In other words, for the Codas, the pressure to accommodate their parents' struggles with spatial information will override any direct "learning" or extrapolation of rules based on their Cohort 1 parents' productions.

(3) The Coda children's pattern of *interpretations* will relate to their (Cohort 1) parent's pattern of *productions* rather than their parent's pattern of *interpretations.*

Hypothesis 1: Participants' encoding abilities will correlate with their own strength of preference for production of spatial modulations.

For this analysis, I took the encoding value with the most variability in performance, that is, *encoding event – first response.* Recall that Cohort 1 differed significantly from both Codas and Cohort 2 signers on *encoding event- first response*. Given the differences in strength of *production* preference, where Cohort 2 showed significantly stronger preferences than Cohort 1, and the Codas falling in between, I hypothesized that these two measures were related. Figure 27 shows the relationship between *encoding event- first response* and *strength of production* preference.

Surprisingly, no relationship was found between *encoding event- first response* and *strength of production* preference (Spearman's r_s= 0.074, p= 0.976, two tailed, given arcsine transformed proportions correct per participant), suggesting two possibilities: (1) there truly is no relationship between understanding and recalling spatial events and the regularity with which you use spatial modulations to describe those spatial events, or (2) a third, unexplored variable, serves as a moderator, masking the relationship. Some participants score at ceiling in each task,

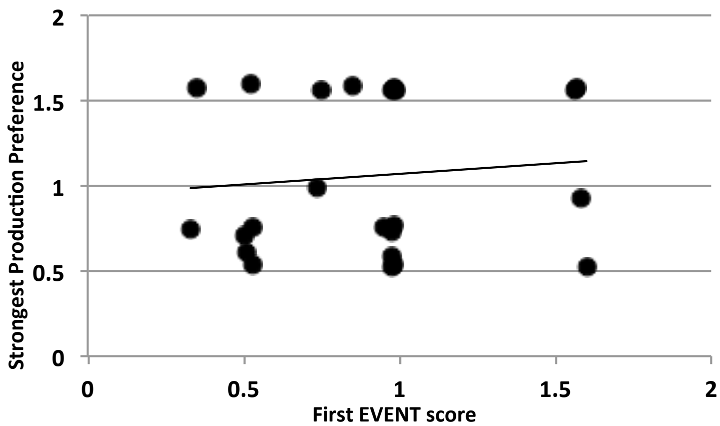


Figure 27. The correlation between participants' scores on their first response to questions relating to the *event* in the encoding task (Study 3) and the strength of their preferred production type for spatial modulations (Study 1). All original proportions were arcsine transformed. No correlation was found between these two factors (Pearson's r= 0.083, *p*= 0.700, r^2 = 0.007, two tailed).

though only two show a perfect score (1.00) for *encoding* as well as a perfect 1.00 on their strength of preference, representing a perfectly consistent use of a spatial layout -- in these cases, both were *rotated*.

For Hypotheses 2 and 3 I direct the reader to the set of 9 family-wise tables at the end of this chapter (Tables 10-18). These tables offer qualitative comparisons for each Parent-Child pair that address Hypotheses 2 and 3[30]. Here I suggest some possibilities to be explored further, either qualitatively or if it becomes possible, quantitatively.

Hypothesis 2: The Codas' preferences for *unrotated* productions will be predicted by their parents' encoding abilities rather than their parents' production preferences.

Examining the family-wise charts, the first pattern that emerges is the following: for 6 of the 9[31] Parent-Child pairs, the parent struggles with *encoding direction* and the child prefers

---

[30] I chose to analyze these data qualitatively due to the very small sample sizes and the possibility of multiple factors warranting substantial multi-level regressions or mixed modeling analyses to disambiguate the contributions of each factor.

[31] There were 8 Codas and 8 Cohort 1 participants, but one family had one child with two parents and another family had one parent with two children. Pairing them makes 9 parent-child pairs.

unrotated productions (Pairs 1, 2a, 2b, 3, 5, 7). Interestingly, of the three that do not show this pattern, one (pair 4) shows the opposite pattern, which still supports this hypothesis: the mother shows excellent *encoding* skills, and the child produced 100% *rotated* spatial modulations. Furthermore, in pair 4, the mother's own *productions* are inconsistent. While this could suggest that the child in pair 4 regularized the inconsistent productions made by her mother, please also refer to pair 3, where again, we see the hypothesized pattern in which the parent struggles with encoding and the child shows a preference for *unrotated* productions. What is most interesting here (especially juxtaposed with family pair 4) is that the mother in pair 3's productions are highly consistently *rotated* (100 percent), yet her child shows a preference for *unrotated* productions.

Another interesting qualitative example arose from the now-adult child of family 4. During the productions task, at one point I asked for clarification on a particular production, and I asked the Coda participant simultaneously in NSL and Spanish to clarify if the ball in the soccer stimuli went to the right, the left, or straight ahead, without using the words in Spanish for *right, left,* or *straight ahead.* I only indicated with my hands the path and repeated "this way, this way, or this way." Strikingly, the Coda participant responded with "*to the right*" in spoken Spanish but simultaneously moved her hands to her own *left*. In other words, if she were speaking to a Spanish speaker, the Spanish speaker would have taken it to mean to their own right. However, the indication to her own left with her hands could be interpreted in a *rotated* or an *unrotated* manner, depending on the grammatical system of the receiver. For example, a Cohort 2 signer would likely interpret this expression as *rotated,* meaning that the ball would have gone to their own left – contrary to the spoken Spanish that they cannot hear. The combination of the spoken Spanish "*to the right*" and the NSL production of the path to the *left*

of the signer provides a clue: the Coda intended for the gesture to be interpreted in an *unrotated* manner: to *your right,* not to your left, if you were to take my perspective (as would be necessary for a *rotated* interpretation). The Coda was indicating the direction with her hands similarly to the way that aerobics instructors do: they say "right hand" and lift their own left hand, mirroring their class. This reduces the cognitive load on the listener and puts more load on the producer; the listener just mirrors what they see but the producer has to take into account the listener's perspective. Why would the Codas do this? I suggest that the use of spatial modulations reflecting an *unrotated* layout may be easier for Cohort 1 signers to understand, given their current scores on *encoding* (see the parents' scores in Tables 10-18 below), and previous results showing that Cohort 1 struggles with spatial descriptions and relations (e.g., Pyers, Perniss, & Emmorey, 2015; Pyers, Shusterman, Senghas, Spelke, & Emmorey, 2010). Here I suggest that the children of Cohort 1 implicitly accommodate these difficulties by using *unrotated* layouts, taking on the burden of rotating for their parents' (and other Cohort 1 signers') understanding.

Hypothesis 3: The Coda children's pattern of *interpretations* will relate to their (Cohort 1) parent's pattern of *productions* rather than their parent's pattern of *interpretations*.

Just as the parents' productions do not likely guide their child's choice of *rotated* or *unrotated* spatial modulations (the child's productions), the parents' *interpretation* patterns likely exert less of an influence on their own child's *interpretations.* I suggest that the child's *interpretation* performance is a reaction to the varied and inconsistent productions they encounter from the Cohort 1 signers with whom they interact. This pattern emerges in the family pair charts in two possible ways: (1) the child's *interpretations* pattern like his/her parents' *productions*, or (2) the parents' *productions* are inconsistent and the child shows great flexibility in their interpretations by choosing *unrestricted* interpretations.

I would like to highlight family pair 3 as an example of the mismatch between a child's own production and interpretation patterns. Here the mother's productions are strongly *rotated;* while the child's interpretations are split between *unrestricted* and *rotated*, the child never selects an *unrotated* interpretation, despite preferring *unrotated* productions herself. It is possible, then, that the proportion of *rotated* to *unrestricted* interpretations made by the child result from the proportions of interactions she has with that parent versus with other Cohort 1 signers. That is, interactions with varied signers beyond her own parents and their inconsistent patterns of productions and intended meanings may influence this Coda's own interpretations.

The only family pair (out of nine) whose patterns do not support Hypothesis 3 is family pair 6b, where the child's interpretations do not include any *rotated* choices (the child has primarily *unrestricted* interpretations, with a few *unrotated*). However, the mother's productions do include *rotated* productions. This family may be an outlier, or the strength of the child's *unrestricted* interpretations may outweigh any others, or the child's (undocumented) interactions with Cohort 1 participants besides his/her own mother may have influenced the child's interpretations.

In sum, the pattern of evidence across Studies 1-3, and the observed relationships between their results support the following interpretations: (1) individual children (without peers) will attempt to regularize somehow, by imposing regular choices in their own productions (strength of preference, Study 1), but (2) in the absence of peers and in the face of inconsistent interlocutors, the desire for clear communication overwhelms any inclination to impose regularity or to create a fundamental grammatical rule. Recall that Codas' *only* NSL interlocutors are their Cohort 1 parents, who are not only inconsistent in their input to the child, but also inconsistent in the way they understand and interpret others (including the child).

What may be happening is this: the parents are inconsistent in their *productions* and they are also inconsistent in their *interpretations,* especially if their primary interlocutors are other inconsistent Cohort 1 signers who consistently struggle with spatial information (*encoding*). The children, who do not struggle as much with spatial *encoding,* may recognize this and use this as a motivation for linguistic/ communicative consistency. Namely, Codas realize that producing consistently *unrotated* productions may help their parents succeed more often in correctly interpreting spatial language, given the lighter cognitive load of interpreting an *unrotated* layout (Pyers et al., 2015). This leads to a mixed result: the Codas develop a quasi-consistent rule (*produce unrotated layouts*, but don't expect consistency from other signers (*unrestricted interpretations))*. But this pattern is unexpected given that other (Cohort 2) signers who received the same vertical input from Cohort 1 in a peer interaction context. What remains to be seen is whether the Codas have other means of consistently expressing argument structure, for example, word order. Regardless, it is an invaluable finding that (1) the codas *do* use space when producing NSL descriptions of spatial events and (2) codas exhibit consistency in their uses of space, even if their pattern is unexpected given the observed patterns in Cohort 2 signers.

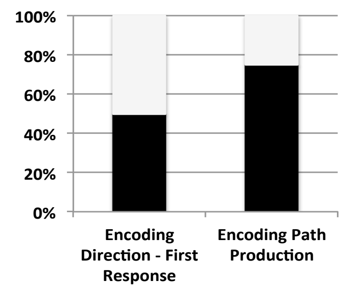
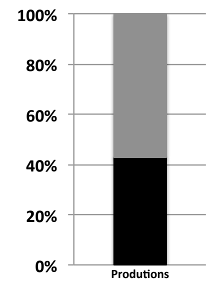
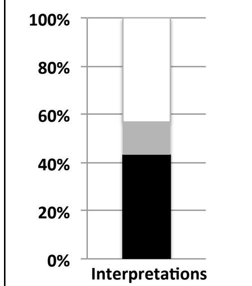
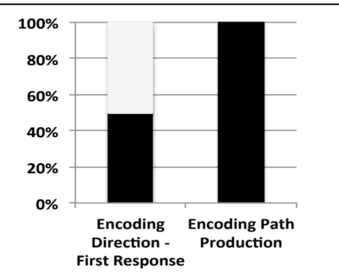
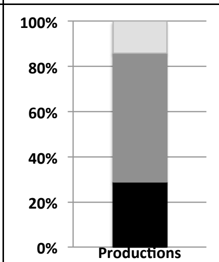
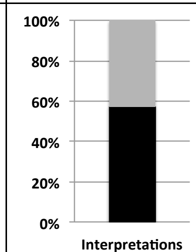
Family Number	Participant, Year of entry (Age at test)	Encoding Incorrect Correct	Productions No direction Unrotated Rotated	Interpretations None/Other Unrestricted Unrotated Rotated	Individual Summaries
1	Parent, 1974				• *Encoding:* Direction and path both poor • *Productions:* No layout preference (inconsistent) • *Interpretations*: There is a slight preference for *rotated*; but frequent errors suggest interpretations are essentially *unrestricted*.
	Child (pre-teen)				• *Encoding:* Direction poor but path at ceiling. • *Productions:* Preference for *unrotated*, occasional *no direction* • *Interpretations:* Interpretations are essentially *unrestricted*.
	Parent-Child Comparisons	Similar on *Encoding Direction*; child better on *Path*.	*Production* ratios similar; child adds *No direction.*	Parent makes many more *interpretation* errors than child; Parent - slight preference for *rotated* interpretations, Child- *unrestricted.*	**OVERALL** • Both parent and child are inconsistent in their productions and interpretations; both parent and child may struggle with *encoding direction*, leading to interpretation errors. • **Neither has created a grammatical rule governing spatial modulation.**

Table 10. Relationships among encoding, production, and interpretation patterns for Family 1 (Parent-Child Pair 1).

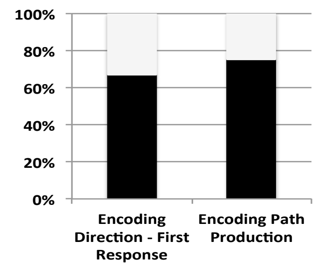
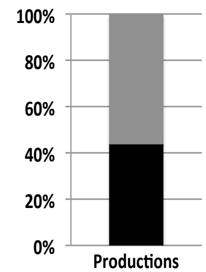
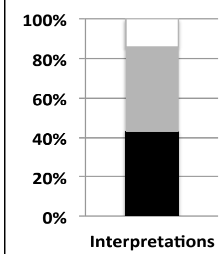
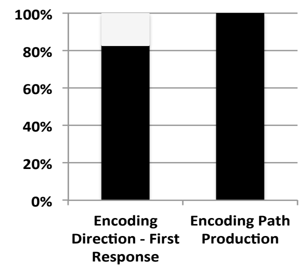
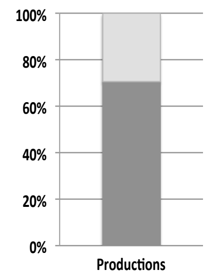
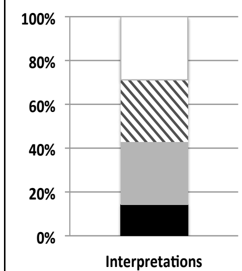
Family Number	Participant, Year of entry (Age at test)	Encoding Incorrect Correct	Productions No direction Unrotated Rotated	Interpretations None/Other Unrestricted Unrotated Rotated	Individual Summaries
2a	Parent, 1978				• *Encoding:* Direction and path both difficult • *Productions:* No layout preference (inconsistent) • *Interpretations*: Essentially *unrestricted;* some errors (none/ distractor).
	Child (adult > 25)				• *Encoding:* Few errors. • *Productions:* Preference for *unrotated* layout; occasionally *no direction* • *Interpretations:* Essentially *unrestricted*; some interpretation errors (none/ distractor).
	Parent-Child Comparisons	Child better for *direction* and *path*.	Despite almost equal use of *Unrotated*, only Child shows a layout preference; only Mother uses *Rotated*	*Both* essentially unrestricted in interpretations; both make errors.	**OVERALL** • Child better at encoding, more regular in productions. • Both are essentially unrestricted in their interpretations, though possibly for different reasons (parent as a consequence of *encoding* struggles, child as a consequence of inconsistent productions from parent). • **Neither has created a grammatical rule governing spatial modulation.**

Table 11. Relationships among encoding, production, and interpretation patterns for Family 2a (Parent-Child Pair 2).

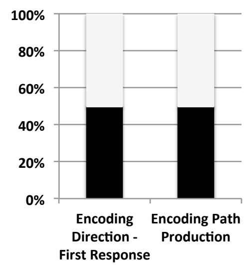
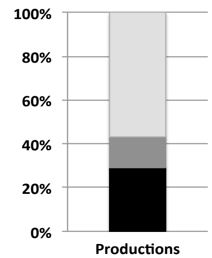
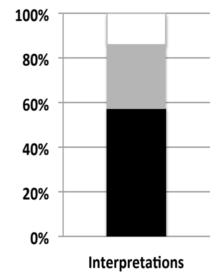
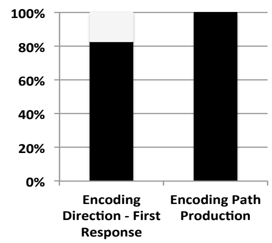
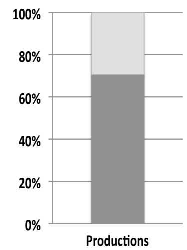
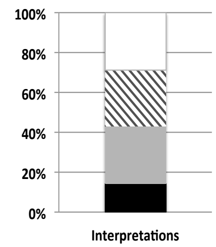
Family Number	Participant, Year of entry (Age at test)	**Encoding** Incorrect Correct	**Productions** No direction Unrotated Rotated	**Interpretations** None/Other Unrestricted Unrotated Rotated	**Individual Summaries**
2b	Parent, 1974				• *Encoding:* Direction and path both poor • *Productions:* Majority use no space; no layout preference (inconsistent). • *Interpretations*: Essentially *unrestricted* (slight preference for Rotated)*;* some errors (none/ distractor).
	Child (adult > 25)				• *Encoding:* Few errors. • *Productions:* Preference for *unrotated* layout; occasionally *no direction.* • *Interpretations:* Essentially *unrestricted*; some errors.
	Parent-Child Comparisons	Child better for *direction* and *path*.	Both Child and Stepfather produce with *No Direction.* Only child shows preference for *Unrotated.*	Both are essentially unrestricted in interpretations; stepfather prefers *rotated* slightly.	**OVERALL** • Child better at encoding, more regular in productions. • Both essentially unrestricted in interpretations, though possibly for different reasons (parent due to *encoding* struggles, child responding to inconsistent productions from parent). • **Neither has created a grammatical rule governing spatial modulation.**

Table 12. Relationships among encoding, production, and interpretation patterns for Family 2b (Parent-Child Pair 3).

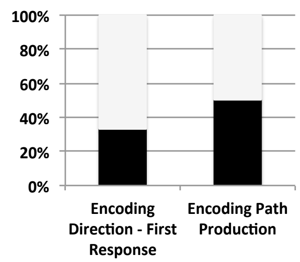
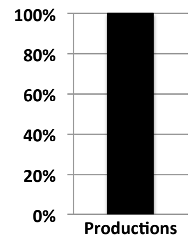
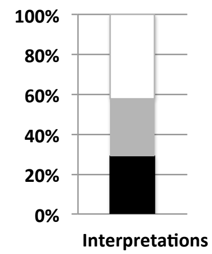
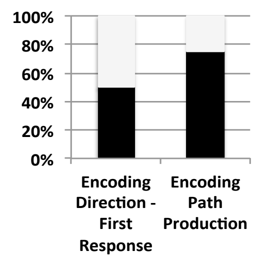
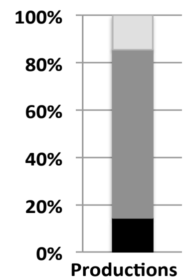
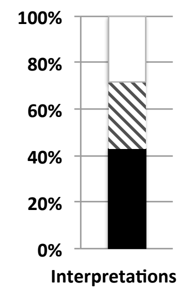
Family Number	Participant, Year of entry (Age at test)	Encoding Incorrect Correct	Productions No direction Unrotated Rotated	Interpretations None/Other Unrestricted Unrotated Rotated	Individual Summaries
3	Parent, 1974				• *Encoding:* Direction and path both poor. • *Productions:* 100% *rotated* (consistent). • *Interpretation*: Essentially *unrestricted;* significant errors (none/ distractor).
	Child (adult 20-25)				• *Encoding:* Poor for Direction; OK for Path. • *Productions:* Strong preference for *unrotated* layout; occasionally *no direction.* *Interpretations:* Flexible; some errors. Never chooses *unrotated*, despite a preference for *unrotated* productions.
	Parent-Child Comparisons	Child only slightly better for *direction* and *path.*	Parent, Child patterns differ strikingly. Parent's *encoding* struggles may cause child to accommodate in *productions.*	Both make interpretation errors. Child includes *unrestricted* choices, mother is *unrestricted* (half *rotated* and half *unrotated).*	**OVERALL** • Child slightly better at encoding, more regular in productions. • Parent essentially *unrestricted* in her interpretations. • Child is *unrestricted* but may have *rotated* interpretations given mother's *rotated* productions. • **Neither has created a grammatical rule governing spatial modulation.**

Table 13. Relationships among encoding, production, and interpretation patterns for Family 3 (Parent-Child Pair 4).

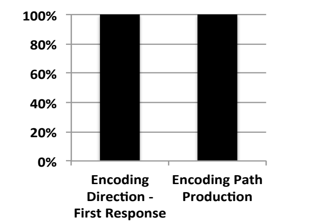
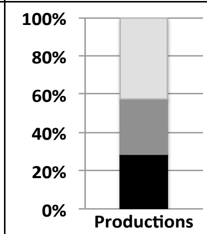
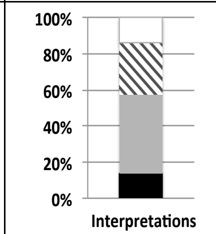
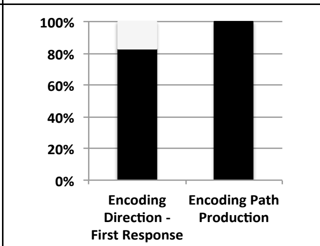
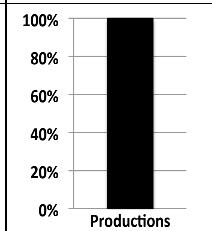
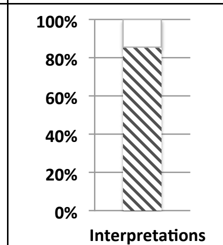
<table>
<tr><th>Family Number</th><th>Participant, Year of entry (Age at test)</th><th>Encoding
Incorrect
Correct</th><th>Productions
No direction
Unrotated
Rotated</th><th>Interpretations
None/Other
Unrestricted
Unrotated
Rotated</th><th>Individual Summaries</th></tr>
<tr><td rowspan="3">4</td><td>Parent, 1974</td><td></td><td></td><td></td><td>Encoding: Direction and path at ceiling.
Productions: No layout preference (inconsistent).
Interpretations: Essentially unrestricted; few errors (none/ distractor).</td></tr>
<tr><td>Child (teenager)</td><td></td><td></td><td></td><td>Encoding: Direction and path both good.
Productions: Strong preference for rotated layout.
Interpretations: Strongly unrestricted, despite strong preference for rotated productions; few errors.</td></tr>
<tr><td>Parent-Child Comparisons</td><td>Both do well on encoding direction and path.</td><td>Parent/Child do not pattern similarly. Child strongly prefers rotated productions despite inconsistent input.</td><td>Child prefers unrestricted choices, mother is also essentially unrestricted.</td><td>OVERALL
Mother's success with encoding may support regularly rotated productions by child.
Parent essentially unrestricted in her interpretations.
Child's interpretations are unrestricted, likely due to the parent's inconsistent productions.
Neither has created a grammatical rule governing interpretations of spatial modulations; however, the child's productions are very consistent.</td></tr>
</table>

Table 14. Relationships among encoding, production, and interpretation patterns for Family 4 (Parent-Child Pair 5).

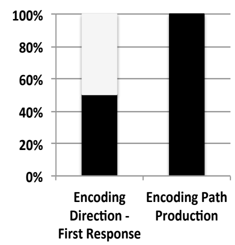
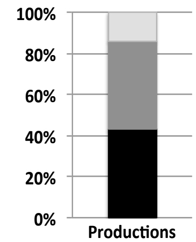
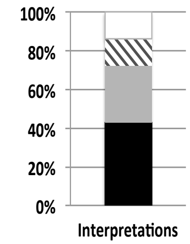
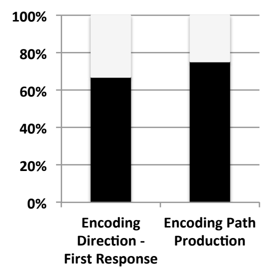
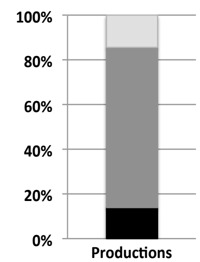
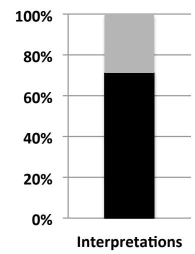
Family Number	Participant, Year of entry (Age at test)	Encoding Incorrect Correct	Productions No direction Unrotated Rotated	Interpretations None/Other Unrestricted Unrotated Rotated	Individual Summaries
5	Parent, 1977				• *Encoding:* Direction poor; path at ceiling. • *Productions:* No preference (inconsistent). • *Interpretations*: Essentially *unrestricted;* few errors.
	Child (pre-teen)				• *Encoding:* Several errors on both direction and path. • *Productions:* Strong *unrotated* preference; occasional *no direction.* • *Interpretations*: Preference for *rotated* despite preferring *unrotated* productions; no errors.
	Parent-Child Comparisons	Both struggle with *direction;* child struggles somewhat with *path*.	Child prefers *unrotated* productions; parent has no preference.	Mother essentially *unrestricted* (balanced for *rotated* and *unrotated)*. Child slightly prefers *rotated.*	**OVERALL** • Mother's struggles encoding *direction* may elicit regularly *unrotated* productions from child. • Parent essentially *unrestricted* in her interpretations. • Child has slight preference for *rotated* interpretations, but has good number of *unrotated* interpretations, calling the preference into question. • **Neither has created a grammatical rule governing spatial modulation for interpretations, but child pattern suggests a production rule.**

Table 15. Relationships among encoding, production, and interpretation patterns for Family 5 (Parent-Child Pair 6).

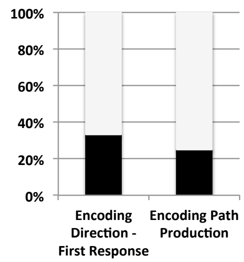
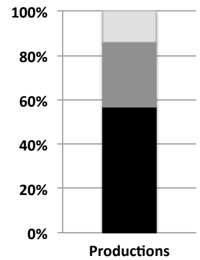
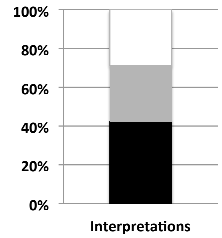
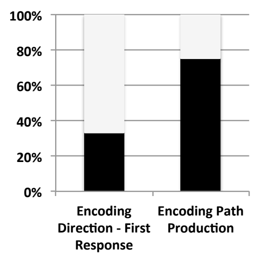
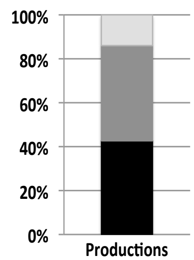
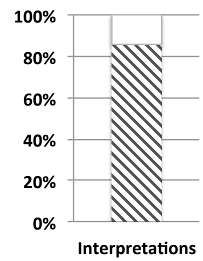
Family Number	Participant, Year of entry (Age at test)	Encoding Incorrect Correct	Productions No direction Unrotated Rotated	Interpretations None/Other Unrestricted Unrotated Rotated	Individual Summaries
	Parent, 1981				• *Encoding:* Direction and path both poor. • *Productions:* Slight *rotated* preference; occasional *no direction* (inconsistent). • *Interpretations*: Essentially *unrestricted;* several errors.
6a	Older Child1 (teenager)				• *Encoding:* Direction poor; path better. • *Productions:* Balanced between *rotated* and *unrotated* productions (inconsistent). • *Interpretations*: Strongly *unrestricted;* few errors.
	Parent-Child Comparisons	Both struggle with *direction;* parent clearly struggles with *path,* child struggles somewhat with *path*.	Parent and Child almost identical; Child produces *unrotated* slightly more than parent.	Mother essentially *unrestricted*; Child clearly *unrestricted.*	**OVERALL** • Mother's struggles with *encoding* may elicit inconsistent productions from child. • Parent essentially *unrestricted* in her interpretations. • Child clearly *unrestricted* in his interpretations. • **Neither has created a grammatical rule governing spatial modulation.**

Table 16. Relationships among encoding, production, and interpretation patterns for Family 6a (Parent-Child Pair 7).

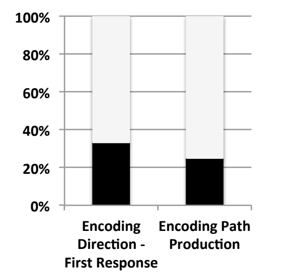
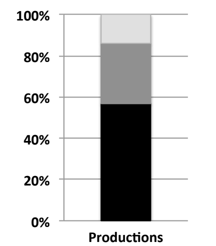
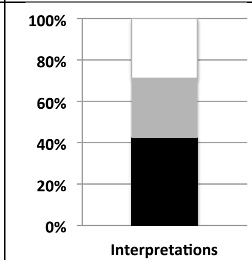
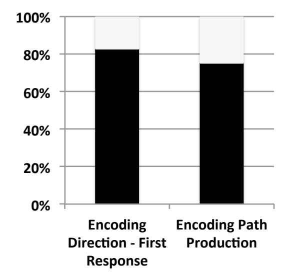
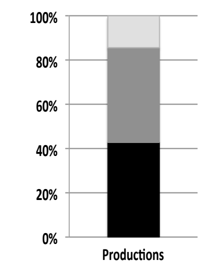
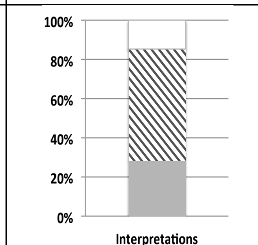
<table>
<tr><th>Family Number</th><th>Participant, Year of entry (Age at test)</th><th>Encoding
Incorrect
Correct</th><th>Productions
No direction
Unrotated
Rotated</th><th>Interpretations
None/Other
Unrestricted
Unrotated
Rotated</th><th>Individual Summaries</th></tr>
<tr><td rowspan="3">6b</td><td>Parent, 1981</td><td></td><td></td><td></td><td>Encoding: Direction and path both very poor.
Productions: Slight rotated preference; occasional no direction (inconsistent).
Interpretations: Essentially unrestricted; several errors.</td></tr>
<tr><td>Younger Child2 (pre-teen)</td><td></td><td></td><td></td><td>Encoding: Few errors on direction and path.
Productions: Slight unrotated preference; occasional no direction (inconsistent).
Interpretations: Majority unrestricted, with some unrotated choices; few errors.</td></tr>
<tr><td>Parent-Child Comparisons</td><td>Child better than parent at encoding both direction and path.</td><td>Parent and Child both inconsistent. Child produces unrotated slightly more than parent.</td><td>Mother essentially unrestricted (balanced for rotated and unrotated). Child clearly unrestricted in interpretations.</td><td>OVERALL
Mother's struggles with encoding may elicit inconsistent productions from child.
Parent essentially unrestricted in her interpretations.
Child clearly unrestricted in her interpretations.
Neither has created a grammatical rule governing spatial modulation.</td></tr>
</table>

Table 17. Relationships among encoding, production, and interpretation patterns for Family 6b (Parent-Child Pair 8).

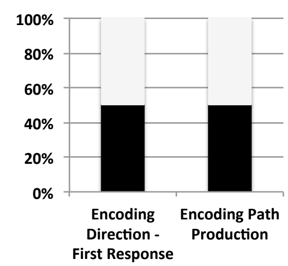
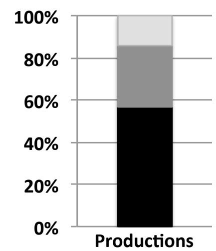
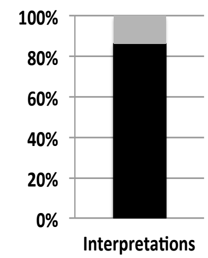
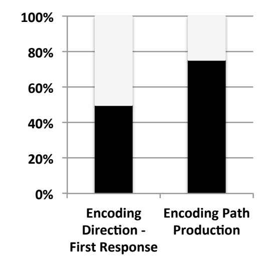
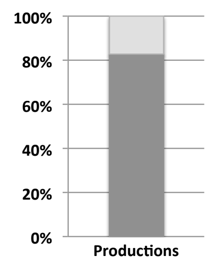
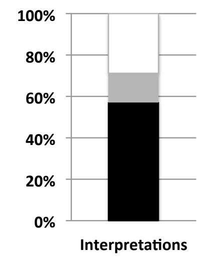
<table>
<tr><th>Family Number</th><th>Participant, Year of entry (Age at test)</th><th>Encoding
Incorrect
Correct</th><th>Productions
No direction
Unrotated
Rotated</th><th>Interpretations
None/Other
Unrestricted
Unrotated
Rotated</th><th>Individual Summaries</th></tr>
<tr><td></td><td>Parent,
1984</td><td></td><td></td><td></td><td>• Encoding: Direction and path both poor.
• Productions: Slight rotated preference; occasional no direction (inconsistent).
• Interpretations: Strong unrotated preference.</td></tr>
<tr><td>7</td><td>Child
(pre-teen)</td><td></td><td></td><td></td><td>• Encoding: Direction poor; many path errors.
• Productions: Strong unrotated preference; occasional no direction.
• Interpretations: Rotated preference despite strong preference for unrotated productions; some errors.</td></tr>
<tr><td></td><td>Parent-Child Comparisons</td><td>Both struggle with direction; Parent struggles with path more than Child.</td><td>Parent inconsistent; Child prefers unrotated.</td><td>Both parent and child prefer rotated interpretations; child's preference is weaker.</td><td>OVERALL
• Mother's struggles with encoding may elicit unrotated productions from child.
• Parent prefers rotated interpretations, with some preference for rotated productions.
• Child's preference for rotated interpretations weaker than mother's.
• Mother may have a burgeoning grammatical rule for spatial modulation; child does not (but production consistent).</td></tr>
</table>

Table 18. Relationships among encoding, production, and interpretation patterns for Family 7 (Parent-Child Pair 9).

Chapter 7. General Discussion and Conclusion

This series of studies investigated the relative contribution of linguistic peers on the acquisition of a grammatical rule for using *rotated* or *unrotated* spatial layouts in an emerging language. These findings contribute to our understanding of the extent to which individual children can construct grammatical rules in the face of inconsistent input. This work may also illuminate the language-making capacities and the social interactional structures underlying typical language acquisition. Three groups of Nicaraguan Sign Language (NSL) signers representing two phases of the language's development were asked to *produce* short sentences, *interpret* others' short sentences, and demonstrate how well they could remember and produce (i.e., *encode*) relevant spatial information.

Cohort 1 summary. Cohort 1, the older group of signers, represents the first phase of the language's development. Study 1 showed that Cohort 1 signers produced inconsistent space-meaning mappings when describing events in which it would be informative to be consistent regarding rightward or leftward modulations to signs[32]; these findings partially replicated Senghas (2003). In a further replication of Senghas (2003), Cohort 1 signers were also relatively flexible in their interpretations of others, equally interpreting others' spatial modulations as reflecting a *rotated* or *unrotated*[33] spatial layout. Cohort 1 signers also made more interpretation *errors*, the underlying causes of which were explored by the *encoding* task. In the *encoding* task, I asked Cohort 1 signers

[32] While it would also be informative to the listener to use another means of indicating source and goal or agent and patient/recipient, such as word order, it is telling that the signers do use spatial modulations in their productions, though inconsistently. For example, Cohort 2 signers likely view spatial modulations as informative, as indicated by Cohort 2's interpretations of the Coda productions. Cohort 2 signers tend to interpret Coda productions as *rotated,* when they are in fact most likely *unrotated.* Future analyses will examine the word order in the productions of all three groups to find other sources of agent/recipient or source/goal information.

[33] Cohort 1's interpretations were equally *rotated* or *unrotated*, though they were more inclined than Cohort 1 signers, for a response to any single item, to choose one or the other. This is qualitatively similar to choosing an *unrestricted* response (i.e., for a single answer saying that both *rotated* and *unrotated* are possible interpretations), although it is quantitatively different as represented by the figures in Study 2.

to answer short yes/no memory questions asking about events they had just watched. They demonstrated difficulty in encoding the correct *event* (e.g., kicking vs. dribbling), with recalling the *direction* of a spatial event, as well as in reproducing the *path* of an object as it had moved in the video clip. This pattern of results indicates that difficulties in *producing* descriptions of spatial events or *interpreting* others' descriptions of spatial events may stem from an inability to recall the relevant information[34].

Cohort 1 then formed the language models, or vertical input, for two younger groups: (1) Cohort 2 NSL signers; deaf individuals approximately ten years younger in age and who arrived at the school for the deaf approximately ten years after Cohort 1 first started at the school, and (2) their own hearing children who were exposed to and started learning their parents' sign language from birth (Codas) but who report never using the sign language with any same-age deaf or hearing signers. Cohort 2 and the Coda Children of Cohort 1 therefore represent two groups in the second phase of the development of the language who experience varying sociolinguistic environments.

Codas vs. Cohort 2 Signers. Of interest for our purposes are the meaningful differences between Cohort 2 and the Children of Cohort 1 in terms of exposure to language and their interactions using the language. Cohort 2 signers are all deaf signers who use NSL as their primary and dominant language. While Cohort 2 signers were all born to families who can hear and who did *not* know or learn NSL, Cohort 2 had the benefit of vertical input from Cohort 1 and horizontal input from each other *while at school* (i.e., for limited hours in the day and only certain days of the week). This vertical

---

[34] While it is possible that difficulties with encoding could lead to consistent productions for what a particular signer (incorrectly) believes to be true, the end result is likely the same – weak encoding in general is likely to result in chance (50/50) recollections of the actual direction (rightward or leftward), and therefore result in a pattern of production equally likely to be *rotated* as *unrotated*.

input began only after they actually started attending school, which was on average after the age of 4 (M=4.4y; range=3.1y – 7.25y). The Coda children of Cohort 1 had early (from birth), intense (every day, most waking hours), long-term (all-day between ages 0 – 5, and before/after school thereafter) exposure to their parents' and parents' friends' (other Cohort 1 signers') signing. However, no Coda reported signing with same-age peers (either deaf or hearing). Even those Codas with siblings (including one pair of siblings who participated in the current studies) reported using spoken Spanish with each other, and only using NSL with their parents and parents' friends, over a host of topics and in various situations. A reasonable concern is the frequency of use of NSL and even more so, the diversity of interlocutors to whom the Codas are exposed (e.g., Gollan et al., 2015). Gollan et al. (2015) argue that a diversity of exposure predicts better language in the heritage language. However, two of their primary methods of reaching this conclusion are addressed in this study. First, their maximum number of interlocutors in the heritage language reported by their participants is 9, including both parents. While the experimenters did not directly ask Codas for the total number of signers with whom they interacted, all Codas reported signing with Deaf adults other than their parents about a wide variety of topics, indicating a wide diversity of exposure. Gollan's argument is that exposure to various signers provides exposure to various topics and ways of conversing. The fact that the Codas speak with individuals other than their parents about things such as "getting married" or "other cultures" addresses this argument by showing that the Codas are exposed to signers other than their parents (i.e., their total number of deaf interlocutors must be 3 or greater) and about a wide variety of topics – the main point made by Gollan et al. 2015.

Additionally, Gollan et al. (2015) used a 33-item vocabulary task to assess proficiency in both the dominant and heritage language. Participants scored an average of 72% correct (maximum score 100%) in one heritage language (Chinese) and 61% correct (maximum score 90%) in Spanish. Here we used a 52-item vocabulary task[35] on which the Codas fared at least as well as Cohort 1 on NSL vocabulary (Coda group mean of 82%; maximum score 100%). Codas also scored well on the corresponding Spanish vocabulary (group mean of 88%; maximum score 100%). Obviously the Codas in the current study form a smaller sample size than that of Gollan et al. (2015)'s study. Given this performance, I am confident that the Coda children of Cohort 1 represent a group with vertical, but no horizontal language input, and that they possess enough knowledge of NSL and exposure to varied signers to address the question at hand.

The question then is whether vertical input alone is sufficient to spark regularization of inconsistent patterns in language input. Would the Coda children of Cohort 1 regularize the inconsistent productions produced by their parents? So far the answer is both yes and no. Study 1 showed that Cohort 2 was still significantly more regular in their choice of spatial modulation when they chose to use space than was Cohort 1. Study 1 also showed that the Coda children of Cohort 1 fell somewhere in between; that is, while Cohort 1 and Cohort 2 differed significantly, the Codas did not differ significantly from either group, placing their performance somewhere between Cohort 1 and Cohort 2. While we cannot say that they regularized the choice of spatial

[35] The two vocabulary tasks differed in their methods. Gollan et al. (2015) elicited productions of the heritage language via a picture naming task (MINT), whereas the vocabulary task in the current study was a vocabulary recognition task, similar to the Peabody Picture Vocabulary Task (PPVT), in which the vocabulary item is presented and the participant selects the matching picture. It could be argued that the PPVT or TVIP is an easier task because it is easier to recognize a vocabulary item than it is to retrieve and produce it. Future work will attempt to elicit vocabulary items from the Codas, using the MINT or another picture naming task normed for various cultures and languages.

modulation to a measurable degree as compared to their input, it seems as if they were headed in that direction.

Relations among Encoding, Production, and Interpretation. The patterns that emerge when considering the interactions among *encoding, production*, and *interpretation* performance suggest contributions specific to individual abilities[36] as well as via participation in a network of linguistic peers. This evidence stems from the performance of the Cohort 1 parents on the *encoding* task, which influence their own *productions* and *interpretations,* and then a type of domino effect on the performance of their child(ren). First, Cohort 1 signers may be inconsistent in their *productions* because they struggle with *encoding* spatial information from the scene to be described. This inconsistency, therefore, is likely a byproduct of their struggles with spatial cognition (also evidenced elsewhere, e.g., Pyers et al., 2010). These inconsistent productions not only offer variable language models; on top of that, Cohort 1 cannot be relied on to <u>understand</u> rotated space well. Thus, the Codas may accommodate their parents by producing *unrotated* spatial modulations in order to make comprehension easier for their parents – that is, by eliminating the need for their parents to do the mental rotation or mental perspective taking (i.e., Theory of Mind) necessary to interpret *rotated* productions. The consequent consistency in the Coda children's productions may not be a direct result of their parents' input (as in a typical input-output relationship), but rather a response driven by pragmatic considerations.

---

[36] Whether the abilities of individual learners stem from an innate language capacity (e.g., Chomsky, 1959) or a type of learning mechanism (e.g., Aslin, Saffran & Newport, 1998; Saffran, Aslin & Newport, 1996, a.o.), is beyond the scope of the current studies. However, it is certainly a topic for further study as it pertains to individuals without linguistic peers who receive inconsistent input.

Furthermore, Study 2 found that the Coda children were the most willing to apply *unrestricted* interpretations to others' productions, regardless of the group the signer was from (Cohort 1, Cohort 2, or Coda). Again, their parents' struggles with *encoding* spatial information may have caused the children to keep their interpretations of others' productions open, because it was likely never clear whether their interlocutor intended a *rotated* or *unrotated* layout. Because the Codas never interact with linguistic peers, they have no choice but to extend this flexible interpretation to others (the only other deaf people they reported interacting with are also Cohort 1 signers who are likely inconsistent in their spatial modulations).

Influence of Spanish bilingualism on Codas. I would like to highlight a major difference (among several) between Cohort 2 signers (who clearly regularized the input they received) and the Codas (who did not). The Codas, while exposed to their parents' inconsistent signing for intense periods, did *not* have the benefit of a peer network to possibly provide some regularity in NSL. However, they *did* benefit from exposure to an established, regular language – spoken Spanish. Their experiences with successful interactions in Spanish from an early age (most Codas reported at least one hearing person in the household during their childhood), juxtaposed with the inconsistent input from their parents, may have triggered a pragmatic response in the children. Namely, Codas' constant and cumulative attempts to find the most readily understandable language to communicate with their parents and other Cohort 1 signers may have resulted in their lack of regularization due to varied attempts at making the message clear to their Cohort 1 interlocutors.

In this way, the Codas' extensive experience communicating successfully in Spanish may have inadvertently hindered their abilities to regularize their parents' inconsistent input because they know what it is like to have successful exchanges using clear (regularized) language. It is fortunate for these children to be bilingual and have had these experiences, but unfortunately for us in our aims to disentangle certain aspects of language acquisition. Even the children who participated in previous language learning studies (e.g., previously referenced studies by Hudson-Kam & Newport) were already fluent speakers of at least one other language (i.e., English). The benefits of this language competence include understanding that grammars exist; an impetus to seek out those regularities, and understand and use pragmatic norms. Given this, I suggest that regularly experiencing successful communication in Spanish enabled the Codas to implicitly link the use of a regular (grammaticized) system with clear(er) communication and (more) successful interaction, and enabled them to achieve that in their interactions. However, these aims are somewhat at odds with each other: their own preferences for productions aim for clear communication, but they cannot rely on their interlocutors to be as regular or to interpret them as regularly. Therefore, Codas leave their interpretations of others open to any and all possibilities, and aimed to achieve clear communication at the cost of regularizing their productions.

Other Considerations

While the aims of this study were to establish whether peer interactions contribute to the regularization of this particular grammatical form in NSL, several related questions warrant consideration. They are: (1) What benefits might a peer group offer that a child cannot get from an adult network?; (2) How might these results apply to the

regularization of other aspects of language?; and (at least) (3) How does bilingualism affect the current results? I will address each of these three questions below.

The benefit of peers. First, what benefits might a peer group offer that a child cannot get from an adult network? For this, I look to proposals regarding the myriad factors contributing to language emergence (e.g., Meir, Sandler, Padden & Aronoff, 2010; Senghas, 2005). The factors include (among others), the number of interlocutors, the contribution of context (or not having a shared context), societal attitudes toward deafness and sign language (for the emergence of new sign languages in particular), and the role of gesture (again particular to sign language emergence). In this series of studies, I aimed to control some of these variables; for example, all Coda participants *did* report interacting with deaf signers other than their own parents, resulting in a larger (though not extensive) sociolinguistic network. Of particular interest is not necessarily the size of the network but *who makes up the network* - adults or peers? Future studies could measure the extent of this (Coda to adult) network by asking more specific language background questions (e.g., asking participants to recall the name(s) of their parents' deaf friends). One could then evaluate whether network size correlates with Codas' strength of regularization, in order to see whether, given a sizeable *adult* network, whether the Codas would in fact, regularize. Conversely, one could investigate *smaller* networks of peers – perhaps, for instance, those deaf children attending small schools in rural areas of Nicaragua who do not have contact with many peers outside their region. Perhaps the size of the network doesn't matter so long as it is made up of the "right" combination of vertical and horizontal input? In that case, with inconsistent or semi-consistent input, and

a limited peer network, the deaf children in rural areas with small networks should contribute to the regularization of the language as well.

One possibility regarding how a peer network might contribute to the conventionalization of language (and in particular for this use of spatial modulation) is the way in which peers influence each other cognitively and/or linguistically. Earlier, I suggested that Codas' pragmatic desire for clear communication when interacting solely with individuals (Cohort 1 parents) who did *not* have grammaticized rules for production and interpretation likely hampered Codas' efforts to regularize (when they may have regularized otherwise). Early work by Piaget suggested that children develop in part via interactions with other children (DeLisi & Golbeck, 1999). These interactions with peers give children experiences in figuring out moral or cognitive conundrums without the societal pressures of interacting with an adult. In this scenario children may "argue" with each other, and in arguing their own perspectives and listening to other children's perspectives, come to appropriate conclusions (that an adult may have been able to offer through direct, but less efficient, instruction). In fact, children are more apt to mimic each other in language use when arguing (Killen & Naigles, 1995). This, and other means of mimicking or coming to consensus among same-age children (e.g., Labov, 2012) may contribute to more efficient regularization among peers for any single child in the group (such as Cohort 2 signers) as compared to others who only interact with adults and not with peers (such as the Coda children of Cohort 1).

In the current instance of linguistic regularization, the presence of a peer group could also change the proportion of individuals who the child interacts with that are inconsistent or irregular from strongly irregular interactions to interactions where the

child can meet another child at the same level and "hash out" their linguistic differences in a way that is not available when interacting with adults. This hypothesis does not discount the contributions of the adults; indeed the adults serve as the primary input to the children, and possibly narrow the set of grammatical choices available. But the children, working among themselves, provide their own regularization to that input. A child embedded in a peer network will conventionalize more rapidly than a child without a peer network.

One way to test this (albeit with difficulty) would be to look at deaf children who receive only inconsistent vertical input without the benefit of *any* peers. For example, deaf children are commonly "mainstreamed" into public school settings with hearing, English speaking peers, but they often do not socialize much with those peers (Antia, 1982; Antia & Kreimeyer, 2003). Comparing deaf children with sign as their primary language (unlike the Codas) who have varying degrees of interaction with signing peers could help us disentangle these factors. This comparison would be particularly revealing because many mainstreamed deaf children interact solely (or primarily) with hearing sign language interpreters or hearing teachers of the deaf whose *second*, *late-acquired* language would likely present inconsistent input to the child.

Application to other parts of language. This series of studies examined the regularization of an element of Nicaraguan Sign Language that was beyond what Cohort 1 was able to regularize themselves given peers but without the benefit of linguistic input. Here I showed that their children, with linguistic input but without peers, did not improve much on that irregular input. Further, what was regularized was done so in an unexpected way (*unrotated* rather than *rotated*), given previous findings (Senghas, 2003), current

Cohort 2 results, as well as observed preferences across other sign languages (Pyers et al., 2015). In contrast, Cohort 2, with peers and given similar irregular vertical input, did regularize that element in the expected way. However, as-yet-unexplored aspects of NSL grammar might not require peer interaction to become regularized. Recall in Table 1 (repeated below as Table 11), I presented two other groups who lack peers but who nevertheless show interesting patterns of developing linguistic structure. First, *homesigners*, who lack both input and linguistic peers, do show evidence for the grammatical relation of subject (Coppola & Newport, 2005). Additionally, heritage language speakers, who experience rich input but who do not have linguistic peers, show relatively resilient verbal morphology even if their nominal morphology suffers (e.g., in Russian (Kagan, 2005) and in other languages (Benmamoun et al., 2013)).

	Surfeit of peers (usually assumed, but not usually explicitly explored)	**Scarcity of peers**
Rich language input	• Typical language conditions	• Heritage Language speakers
Inconsistent language input	• Development of Pidgins to Creoles • "Simon"	• Hearing, signing children of NSL Cohort 1
No language input	• Emerging Language, such as Nicaraguan Sign Language, Cohort 1	• Homesigners

Table 19. (Reproduced from Table 1 in Chapter 1.) This table summarizes the interactions between the presence of peers and the richness of the linguistic input in the environment. The hearing, signing (Coda) children of Cohort 1 represent a unique population who receives a fair amount of inconsistent language input, but lacks same-age linguistic peers with whom to use that language.

Furthermore, heritage language *signers* (hearing children of deaf parents, who also receive rich sign language input) pattern like heritage speakers in their strengths and weaknesses across phonology, morphology and syntax (word order). Some variability

arises, for instance, in the resilience of types of morphology (Chen Pichler et al., 2017). Because elements of NSL are still evolving (for instance, the use of *r-loci*-like reference in signing space (Kocab et al., 2015)), it is unclear how peers might influence this particular use of *rotated* and *unrotated* spatial modulations. Future work should investigate differences and similarities between the Children of Cohort 1 and Cohort 2 on other aspects of NSL grammar.

Codas are inherently bilingual. Finally, there is the question of bilingualism. Of course, any time a child is exposed to more than one language, his "input space" for any particular language is reduced (e.g., Chen Pichler et al., 2015; Gathercole & Thomas, 2009). The same applies to the Children of Cohort 1, who learned NSL and Spanish simultaneously – indeed this is the very thing that made them an ideal comparison group for Cohort 2. By virtue of the context of their bilingualism they did not have linguistic peers. What is interesting is that like homesigners (no linguistic peers and no input), the Codas *do* seem to move toward improving on their input, but not to the same degree that Cohort 2 did given essentially the same input. In this way, then, they are like the Heritage Speakers (and signers) who experience a multitude of external pressures on their language dominance, such as the language(s) used for education/academics, the societal perspectives on the language, and the sheer number of interlocutors using the non-heritage (later, dominant) language (Benmamoun, Montrul, & Polinsky, 2013; Van Deusen-Scholl, 2003).

As stated earlier, this bilingual experience may have afforded the Codas a pragmatic benefit in that they could compare their communicative experiences with

Cohort 1 signers to their experiences with Spanish speakers and understand what it is to have a successful interaction. In principle, this could have pushed them to regularize in ways that Cohort 2 did not, and to remain flexible in their interpretations of others. While this access to an established language and its speakers offered a communicative benefit, it was not necessarily a linguistic benefit in that it may have hindered their establishment of a codified grammatical rule for spatial modulation.

There may also be as-yet-measured influences of bilingualism on the Codas' productions. For instance, having been exposed to Spanish and Spanish word order, they may expect to use word order more than spatial modulation to communicate who gave what to whom. However, in this case, because no participant used lexical terms for spatial relations (e.g., "the woman on her right"), such statements would be ambiguous, given that all vignettes depicted actors of one sex (i.e., the dinner table scenes depicted three women and no men, and vice versa for the soccer vignettes). One way to disambiguate referents would be to be more descriptive about the actor's appearance, since all actors had small variations in their dress, hairstyle or facial features. For example, one participant produced a description such as "The woman with the green headband gave…" Future work will analyze word order to see if, for instance, individuals who are inconsistent in their use of space might be consistent in their word order. If they are, then we can conclude that they don't necessarily expect the spatial modulation to be informative in terms of thematic role, because that information is consistently encoded by the word order. That analysis, while interesting and informative on its own, does not diminish the impact of the current results, and would only bolster the finding that the use of spatial modulation, while regularized by Cohort 2 given input from Cohort 1 (and with

peers), is not regularized by the Codas, given similar input and in the absence of linguistic peers. The effects of multilingualism are complex, to say the least, and much work remains to tease apart the effects of social environment, interactions with others, influence of siblings, and other factors (e.g., Hoff, 2006).

Production – Comprehension asymmetries. A final intriguing phenomenon uncovered by the present study, and requiring further investigation, is the Codas' production-comprehension asymmetry (Hendriks, 2014); that is, the fact that the Codas are more regular in their productions than in their interpretations. While it is typically theorized that asymmetries between production and comprehension usually manifests as better comprehension than production, that is not necessarily always the case, evidenced by children's adult-like *productions* of, yet inconsistent *comprehension* of pronouns (Hendriks, 2014). While the current projects present an asymmetry of sorts between regular productions and irregular interpretations (comprehension), I would caution the reader to consider the difference between regularization in the context of an emerging language (with no target language established) as compared to most other language acquisition work in which a target adult language structure has been established and identified. Future work should investigate this further, to see if similar asymmetries exist in other aspects of the Nicaraguan Codas' language production and interpretation, especially given, for example, structures that are established in Cohort 1 signing already, and/or whether similar asymmetries for similar elements of the language exist for other heritage signers.

In all, Studies 1 -3 of this dissertation, and the interactions among them, have demonstrated a likely contribution of a linguistic peer network on the regularization of

spatial modulations in Nicaraguan Sign Language. However, peer interactions alone are not sufficient to drive this regularization (cf. NSL Cohort 1), and neither is rich vertical input alone (cf. Heritage Language speakers) (Hoff, 2006). Working with the first generation of hearing signers of an emerging language can help us understand better the contributions of the individual child as well as the contributions of that child's linguistic peer network.

Conclusion

Children *are* amazingly good at learning language, and they are also proficient at learning many other things, such as how to make themselves clearly understood in communication, either by selecting the appropriate language in bilingual contexts (e.g., Au & Guzman, 1990), by accommodating their interlocutors in arguments (e.g., Killen & Naigles, 1995), and many other means. The current set of studies showed that children who experience inconsistent vertical input from adults and *no* input from linguistic peers will regularize the inconsistent input in ways that accommodate their inconsistent interlocutors. This result takes into account both the child's tendency and ability to seek regularities in their input and incorporate them into their own productions, but also factors in the unique sociolinguistic setting of the child in this environment. These results underscore and affirm previous laboratory findings that children do find and/or impose regularities on irregular input (e.g., Hudson Kam & Newport, 2009) in a natural language setting. It also contributes to the body of knowledge regarding heritage language users, namely that the number of interlocutors influences grammatical attainment (e.g., Gollan et al., 2015), but that there may be a strong influence from the type of interlocutors that make up the sociolinguistic environment of the child. Further investigation is needed to

disentangle the relative contributions of adult vs. child interlocutors on the rate and extent of language acquisition and regularization.

Finally, the major impact of this paper is on the child who may be at risk for not gaining any language at all – a deaf child born to a hearing family who does not sign. These deaf children represent 90–95% of all deaf children in the US (Mitchell & Karchmer, 2004) and they face many challenges to adequate language acquisition. These findings suggest that, in order for language development, and indeed, development more generally, to proceed appropriately, deaf children need 1) early access to language that is readily understood—for most deaf children this is their country's sign language; and 2) sufficient and regular interaction with peers using the sign language.

References

Antia, S. D. (1982). Social Interaction of Partially Mainstreamed Hearing-Impaired Children. *American Annals of the Deaf*, *127*(1), 18–25. http://doi.org/10.1353/aad.2012.1184

Antia, S. D., & Kreimeyer, K. H. (2003). Peer interactions of deaf and hard-of-hearing children. *Oxford Handbook of Deaf Studies, Language, and Education*, *1*, 164-176.

Arends, J., Muysken, P., & Smith, N. (1994). *Pidgins and creoles: An introduction* (Vol. 15). John Benjamins Publishing.

Aronoff, M., Meir, I., Padden, C., & Sandler, W. (2004). Morphological universals and the sign language type. *Yearbook of Morphology 2004*, 19–39. Retrieved from http://www.springerlink.com/index/kq8678024l342721.pdf

Aronoff, M., Meir, I., & Sandler, W. (2005). The paradox of sign language morphology. *Language, 81*(2), 301–344.

Aslin, R. N., Saffran, J. R., & Newport, E. L. (1998). Computation of conditional probability statistics by 8-month-old infants. *Psychological Science, 9*(4), 321-324.

Au, T. K., & Glusman, M. (1990). The principle of mutual exclusivity in word learning: To honor or not to honor? *Child Development, 61,* 1474–1490.

Bauer, A. (2014). *The use of signing space in a shared sign language of Australia* (Vol. 5). Sign Language Typology Series, Walter de Gruyter GmbH & Co KG. https://www.degruyter.com/view/serial/179904

Benmamoun, E., Montrul, S., & Polinsky, M. (2013). Heritage languages and their speakers: Opportunities and challenges for linguistics. *Theoretical Linguistics, 39*(3–4), 129–181. http://doi.org/10.1515/tl-2013-0009

Bickerton, D. (1981). *Roots of language.* Karoma. *Ann Arbor*, *10*, 268-284.

Bloom, L., & Tinker, E. (2001). *The intentionality model and language acquisition* (Vol. 66). Boston: Blackwell.

Bull, T. (1998). *On the edge of deaf culture.* Alexandria, VA: Deaf Family Research Press.

Carrigan, E. M., & Coppola, M. (2017). Successful communication does not drive language development: Evidence from adult homesign. *Cognition*, *158*, 10-27.

Chen Pichler, D., Reynolds, W., Palmer, J. L., Quadros, R. D., Kozak, L. V., & Lillo-Martin, D. (2015). Heritage signers: Bimodal bilingual children from deaf families. In *Proceedings of the Conference on Generative Approaches to Language Acquisition (GALA).*

Chomsky, N. (1980). *Rules and representations*. Oxford: Basil Blackwell.

Coppola, M. E. (2002). The emergence of grammatical categories in home sign: Evidence from family-based gesture systems in Nicaragua. PhD. Dissertation, University of Rochester.

Coppola, M., & Newport, E. L. (2005). Grammatical subjects in home sign: Abstract linguistic structure in adult primary gesture systems without linguistic input. *Proceedings of the National Academy of Sciences of the United States of America, 102*(52), 19249–19253.

Coppola, M., & Senghas, A. (2010). The emergence of deixis in Nicaraguan signing. In D. Brentari (Ed.), *Sign Languages: A Cambridge Language Survey* (pp. 543–569). Cambridge: Cambridge University Press.

Coppola, M., E., Spaepen, and S. Goldin-Meadow. (2013). Communicating about number without a language model: Number devices in homesign grammar. *Cognitive Psychology,* (67), 1-25. *doi: 10.1016:j.cogpsych. 2013.05.003*

De Beuzeville, L., Johnston, T., & Schembri, A. (2009). The use of space with indicating verbs in Auslan: A corpus-based investigation. Sign Language & Linguistics, 12(1), 53–82.

De Lisi, R., & Golbeck, S. L. (1999). Implications of Piagetian theory for peer learning. In A. O'Donnell & A. King (Eds.), *Cognitive perspectives on peer learning* (pp. 3-37). Hillsdale, NJ: Erlbaum.

Emmorey, K., Klima, E., & Hickok, G. (1998). Mental rotation within linguistic and non-linguistic domains in users of American Sign Language. *Cognition, 68*(3), 221–246. http://doi.org/10.1016/S0010-0277(98)00054-7

Emmorey, K., Borinstein, H. B., Thompson, R., & Gollan, T. H. (2008). Bimodal bilingualism. *Bilingualism: Language and Cognition*, *11*(1), 43-61.

Emmorey, K., & Tversky, B. (2002). Spatial perspective choice in ASL. *Sign Language & Linguistics*, *5*(1), 3-26.

Engberg-Pedersen, E. (1993). *Space in Danish Sign Language: The semantics and morphosyntax of the use of space in a visual language.* SIGNUM-Press.

Fisher, C., Gleitman, H., & Gleitman, L. R. (1991). On the semantic content of subcategorization frames. *Cognitive Psychology*, *23*(3), 331-392.

Fodor, J. A. (1983). The modularity of mind: An essay on faculty psychology. MIT Press.

Gagne, D. L., & Coppola, M. (2017). Visible social interactions do not support false belief development in the absence of linguistic input: Evidence from deaf adult homesigners. *Frontiers in Psychology*, *8*, 837.

Gallaway, C., & Richards, B. J. (Eds.). (1994). *Input and interaction in language acquisition*. Cambridge University Press.

Gathercole, V. C. M., & Thomas, E. M. (2009). Bilingual first-language development: Dominant language takeover, threatened minority language take-up. *Bilingualism: Language and Cognition*, *12*(2), 213-237.

Goldin-Meadow, S. (2005). What language creation in the manual modality tells us about the foundations of language. *Linguistic Review, 22*(2–4), 199–225. http://doi.org/10.1515/tlir.2005.22.2-4.199

Gollan, T. H., Starr, J., & Ferreira, V. S. (2015). More than use it or lose it: The number-of-speakers effect on heritage language proficiency. *Psychonomic Bulletin & Review*, *22*(1), 147-155.

He, A. W. (2010). The Heart of Heritage: Sociocultural Dimensions of Heritage Language Learning. *Annual Review of Applied Linguistics, 30,* 66–82. http://doi.org/10.1017/S0267190510000073

Hendriks, P. (2014). *Asymmetries between language production and comprehension*. Dordrecht: Springer.

Hoff, E. (2006). How social contexts support and shape language development. *Developmental Review, 26*(1), 55–88. http://doi.org/10.1016/j.dr.2005.11.002

Hoff-Ginsberg, E., & Shatz, M. (1982). Linguistic input and the child's acquisition of language. *Psychological Bulletin, 92*(1), 3.

Holm, J. A. (1989). *Pidgins and Creoles: Volume 2, Reference Survey (Vol. 2).* Cambridge University Press.

Hudson Kam, C. L., & Newport, E. (2005). Regularizing Unpredictable Variation: The Roles of Adult and Child Learners in Language Formation and Change. *Language Learning and Development, 1*(2), 151–195. http://doi.org/10.1207/s15473341lld0102_3

Hudson-Kam, C., & Newport, E. L. (2009). Getting it right by getting it wrong: When learners change languages. *Cognitive Psychology, 59*(1), 30–66. http://doi.org/10.1016/j.cogpsych.2009.01.001.

Hymes, D. (1971). Sociolinguistics and the ethnography of speaking. In E. Ardener (Ed.), *Social anthropology and language (pp. 47-93). London: Routledge.*

Isakson, S. K. (2016). Heritage Signers: Language Profile Questionnaire. Master's of Arts in Interpreting Studies (MAIS) Theses. Paper 27.

Johnston, T., & Schembri, A. (2007). *Australian Sign Language (Auslan): An introduction to sign language linguistics*. Cambridge University Press.

Kagan, O. (2005). In support of a proficiency-based definition of heritage language learners: The case of Russian. *The International Journal of Bilingual Education and Bilingualism, 8*(2-3), 213-221.

Killen, M., & Naigles, L. R. (1995). Preschool children pay attention to their addressees: Effects of gender composition on peer disputes. *Discourse Processes*, *19*(3), 329-346.

Kocab, A., Pyers, J., & Senghas, A. (2014). Referential shift in Nicaraguan Sign Language: a transition from lexical to spatial devices. *Frontiers in Psychology*, *5*.

Küntay, A. C., & Şenay, İ. (2003). Narratives beget narratives: Rounds of stories in Turkish preschool conversations. *Journal of Pragmatics*, *35*(4), 559-587.

Labato, L. (2017). Signs of the Times: A Cross-Cultural Exploration of Deaf Education and Human Rights in Nicaragua. Master's Thesis, University of Connecticut.

Labov, W. (2012). What is to be learned: The community as the focus of social cognition. *Review of Cognitive Linguistics. Published under the auspices of the Spanish Cognitive Linguistics Association 10*(2): 265-293.

Lenneberg, E. H. (1967). The biological foundations of language. *Hospital Practice*, *2*(12), 59-67.

Liddell, S. K. (2000). Indicating verbs and pronouns: Pointing away from agreement. *The Signs of Language Revisited: An Anthology to Honor Ursula Bellugi and Edward Klima,* 303–320.

Lifeprint.com: http://www.lifeprint.com/

Lillo-Martin, D., & Klima, E. (1990). Pointing out differences: ASL pronouns in syntactic theory. In S. D. Fischer & P. Siple (Eds.), *Theoretical Issues in Sign Language Research, Volume 1: Linguistics* (pp. 191–210). Chicago: University of Chicago Press.

Lillo-Martin, D., & Meier, R. P. (2011). On the linguistic status of "agreement" in sign languages. *Theoretical Linguistics, 37*(3–4), 95–143. http://doi.org/10.1016/j.biotechadv.2011.08.021.Secreted

Lynch, A. (2008). The linguistic similarities of Spanish heritage and second language learners. *Foreign Language Annals, 41*(2), 252–281. http://doi.org/10.1111/j.1944-9720.2008.tb03292.x

Marcus, G. F. (1993). Negative evidence in language acquisition. *Cognition, 46*(1), 53-85.

Meir, I. (2002). A cross-modality perspective on verb agreement. *Natural Language and Linguistic Theory, 20*(2), 413–450.

Meir, I., Sandler, W., Padden, C., & Aronoff, M. (2010). Emerging sign languages. In *Oxford Handbook of Deaf Studies, Language and Education, Vol. 2* (pp. 267–280). http://doi.org/10.1093/oxfordhb/9780195390032.013.0018

Mitchell, R.E., & Karchmer, M.A. (2004). Chasing the mythical ten percent: Parental hearing status and signing among deaf and hard of hearing students. Sign Language Studies, 4(2), 138-163.

Montrul, S. (2004). Subject and object expression in Spanish heritage speakers. A case of morpho-syntactic convergence. *Bilingualism: Language and Cognition 7*: 125–142.

Montrul, S. (2010). How similar are adult second language learners and Spanish heritage speakers? Spanish clitics and word order. *Applied Psycholinguistics, 31*(1), 167. http://doi.org/10.1017/S014271640999021X
Montrul, S. (2011). Morphological Errors in Spanish Second Language Learners and Heritage Speakers. *Studies in Second Language Acquisition, 33*(2), 163–192. http://doi.org/10.1017/S0272263110000720
Montrul, S. A. (2012). Is the heritage language like a second language? *EUROSLA Yearbook, 12*(2006), 1–29. http://doi.org/10.1075/eurosla.12.03mon
Montrul, S., & Polinsky, M. (2011). Why not heritage speakers? Unpublished Manuscript.
Morgan, G., & Kegl, J. (2006). Nicaraguan Sign Language and Theory of Mind: The issue of critical periods and abilities. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 47*(8), 811–819. http://doi.org/10.1111/j.1469-7610.2006.01621.x
Newport, E. L. (1990). Maturational constraints on language learning. *Cognitive Science*, *14*(1), 11-28.
Newport, E. L. (1999). Reduced input in the acquisition of signed languages: Contributions to the study of creolization. In M. DeGraff (Ed.), *Creolization, diachrony, and language acquisition*. Cambridge, (pp. 161–178). Cambridge, MA: The MIT Press.
Naigles, L. (1990). Children use syntax to learn verb meanings. *Journal of Child Language*, *17*(2), 357-374.
Newport, E. L., & Aslin, R. N. (2004). Learning at a distance I. Statistical learning of non-adjacent dependencies. Cognitive Psychology, 48(2), 127–162. http://doi.org/10.1016/S0010-0285(03)00128-2
Oller, D. K., & Eilers, R. E. (Eds.). (2002). *Language and literacy in bilingual children* (Vol. 2). Multilingual Matters.
Padden, C. (1988). Interaction of morphology and syntax in American Sign Language. New York: Garland.
Padden, C., & Humphries, T. (1990). *Deaf in America.* Harvard University Press.
Padden, C., Meir, I., Aronoff, M., & Sandler, W. (2010). The grammar of space in two new sign languages. In D. Brentari (Ed.), *Sign Languages: A Cambridge Language Survey.* New York: Cambridge University Press.
Palmer, J. L. (2015). ASL Word Order Development in Bimodal Bilingual Children: Early syntax of hearing and cochlear-implanted Deaf children from signing families. Ph.D. dissertation. Gallaudet University, Washington D.C.
Pellegrini, A. D., Galda, L., Flor, D., Bartini, M., & Charak, D. (1997). Close relationships, individual differences, and early literacy learning. *Journal of Experimental Child Psychology*, *67*(3), 409-422.
Perniss, P., Zwitserlood, I., & Özyürek, A. (2015). Does space structure spatial language?: A comparison of spatial expression across sign languages. *Language*, *91*(3), 611-641.
Pesco, D., & Crago, M. (1996). “We Went Home, Told the Whole Story to Our Friends”: Narratives by Children in an Algonquin Community. *Journal of Narrative and Life History*, *6*(4), 293-321.
Pizer, G., Walters, K., & Meier, R. P. (2013). “We communicated that way for a reason”: Language practices and language ideologies among hearing adults whose parents are deaf. *Journal of Deaf Studies and Deaf Education, 18*(1), 75–92.
Polich, L. (2005). *The Emergence of the Deaf Community in Nicaragua*. Gallaudet University Press.

Preece, A. (1992). Collaborators and critics: the nature and effects of peer interaction on children's conversational narratives. *Journal of Narrative and Life History*, *2*(3), 277-292.
Pyers, J. E., & Senghas, A. (2009). Language promotes false-belief understanding: Evidence from learners of a new sign language. *Psychological Science, 20*(7), 805–812. http://doi.org/10.1111/j.1467-9280.2009.02377.x
Pyers, J. E., Shusterman, A., Senghas, A., Spelke, E. S., & Emmorey, K. (2010). Evidence from an emerging sign language reveals that language supports spatial cognition. *Proceedings of the National Academy of Sciences of the United States of America, 107*(27), 12116–12120. http://doi.org/10.1073/pnas.0914044107
Pyers, J. E., Perniss, P., & Emmorey, K. (2015). Viewpoint in the Visual-Spatial Modality: The Coordination of Spatial Perspective. *Spatial Cognition & Computation*, *15*(3), 143-169.
Reynolds, W. & Palmer, J. (2014, June). Codas as heritage learners. Presented at CODA International, Codazona, Tempe, AZ.
Richie, R., Yang, C., & Coppola, M. (2014). Modeling the emergence of lexicons in homesign systems. *Topics in Cognitive Science*, *6*(1), 183-195.
Rothman, J. (2009). Understanding the nature and outcomes of early bilingualism: Romance languages as heritage languages. *International Journal of Bilingualism*, *13*(2), 155-163.
Saffran, J., Aslin, R. N., & Newport, E. L. (1996). Statistical Learning by 8-month old infants. *Science, 274*(5294), 1926–1928. http://doi.org/10.1126/science.274.5294.1926
Sandler, W., & Lillo-Martin, D. (2006). *Sign language and linguistic universals.* Cambridge University Press.
Senghas, A. (1996). Children's Contribution to the Birth of Nicaraguan Sign Language. Dissertation Abstracts International, B: Sciences and Engineering.
Senghas, A. (2003). Intergenerational influence and ontogenetic development in the emergence of spatial grammar in Nicaraguan Sign Language. *Cognitive Development, 18*(4), 511–531. http://doi.org/10.1016/j.cogdev.2003.09.006
Senghas, A. (2005). Language emergence: Clues from a new Bedouin sign. *Current Biology*, *15*(12), R463-R465.
Senghas, A., & Coppola, M. (2001). Children creating language: How Nicaraguan sign language acquired a spatial grammar. *Psychological Science, 12*(4), 323–328. http://doi.org/10.1111/1467-9280.00359
Senghas, A., Coppola, M., Newport, E. L., & Supalla, T. (1997). Argument Structure in Nicaraguan Sign Language: The Emergence of Grammatical Devices. *Proceedings of the 21st Annual Boston University Conference on Language Development*, 550–561. Somerville, MA: Cascadilla Press.
Senghas, A., Kita, S., & Özyürek, A. (2004). Children Creating Core Properties of Language: Evidence from an Emerging Sign Language in Nicaragua. *Science, 305*(5691), 1779–1782. http://doi.org/10.1126/science.1100199
Senghas, R. J., Senghas, A., & Pyers, J. E. (2005). The emergence of Nicaraguan Sign Language: Questions of development, acquisition, and evolution. In J. Langer, C. Milbrath, & S. T. Parker (Eds.), *Biology and knowledge revisited: From neurogenesis to psychogenesis*, 287-306. Mahwah, NJ: Lawrence Erlbaum Associates.
Siegler, R. S., DeLoache, J. S., Eisenberg, N., & Saffran, J., (2014). *How Children Develop*. Macmillan.

Sheldon, A. (1996). You can be the baby brother, but you aren't born yet: Preschool girls' negotiation for power and access in pretend play. *Research on Language and Social Interaction, 29,* 57–80. Singer.

Singleton, J. L., & Newport, E. L. (2004). When learners surpass their models: The acquisition of American Sign Language from inconsistent input. *Cognitive Psychology, 49*(4), 370–407. http://doi.org/10.1016/j.cogpsych.2004.05.001

Smith, R. L., & Rose, A. J. (2011). The "cost of caring" in youths' friendships: Considering associations among social perspective taking, co-rumination, and empathetic distress. *Developmental Psychology, 47*(6), 1792–1803. http://doi.org/10.1037/a0025309

Soltan, U. (2013). Remarks on heritage language grammars and their implications for linguistic theory. *Theoretical Linguistics, 39*(3–4), 241–250. http://doi.org/10.1515/tl-2013-0016

Supalla, S. (1991). Manually coded English: The modality question in signed language development. *Theoretical Issues in Sign Language Research, 2,* 85–109. http://doi.org/10.4319/lo.2013.58.2.0489

Tomasello, M. (2010). *Origins of human communication.* MIT Press.

Van Deusen-Scholl, N. (2003). Toward a Definition of Heritage Language: Sociopolitical and Pedagogical Considerations. *Journal of Language, Identity, and Education, 2*(3), 211–230. http://doi.org/10.1207/S15327701JLIE0203

Van Hoek, K. (1996). Conceptual Locations for Reference in American Sign Language. In G. Fauconnier & E. Sweetser, (Eds.) *Spaces, Worlds, and Grammar,* 334. Chicago: University of Chicago Press.

Williamson, A. (2015). Heritage learner to professional interpreter: Who are deaf-parented interpreters and how do they achieve professional status? Master's of Arts in Interpreting Studies (MAIS) Theses. Paper 22.

Appendix A: Language Use Questionnaire (English Translation)

Family and friend language use questionnaire

1) From the time of your birth to the age of 10, who lived in your home, and did they sign or speak Spanish? (please list, use back of sheet for more space)

Name	Deaf or hearing?	Language (s)

a)
b)
c)
d)
e)
f)
g)
h)

2a) I understand my mother's signing…

Never 1 2 3 4 5 Always

2b) I understand my father's signing…

Never 1 2 3 4 5 Always

3a) How often do you feel your mother understands your signing?

Never 1 2 3 4 5 Always

3b) How often do you feel your father understands your signing?

Never 1 2 3 4 5 Always

4a) Did/ do you have deaf friends your age? ___ yes ___ no

If yes…

4b) Did they go to school? ___ yes ___ no

If yes, where? ____

4c) Do they use the same signs as you? ___ yes ___ no

If no, what did they use? ____________________________________

4b) How often did you sign with them?

Never 1 2 3 4 5 Daily

6a) Did/ do you sign with your family members who can hear? ___ yes ___ no

If yes…

6b) How often did you sign with these hearing family members?

Never 1 2 3 4 5 Daily

6c) Please explain (e.g., when far away, when it's a secret…)

7) How often did deaf people visit your home?

Never 1 2 3 4 5 Daily

8) How often did you sign with these deaf people?

Never 1 2 3 4 5 Daily

9) How often were you asked to interpret?

Never 1 2 3 4 5 Daily

10) Please indicate any situations where you have interpreted:

__ Medical/ doctor's office for you
__ Medical/ doctor's office for your deaf parent
__ Medical/ hospital for you
__ Medical/ hospital for your deaf parent
__ School / meeting with teachers
__ At the market
__ When buying other things
__ Church
__ Weddings
__ Funerals
__ At the movies
__ With landlords
__ Employment/ work place
__ Conversations with hearing family members

__ Conversations with neighbors
__ When strangers come to the house (selling things, other)
__ With the police/ legal situations
__ For news from the Television or the Radio
__ Simple phone calls (to family, friends)
__ University courses
__ Complicated phone calls (employment problems, money problems)

Please indicate what topics you regularly have used sign to talk about:

	When you were a child (less than 10 years old)		Since you turned 10	
	With parents	With other signers	With parents	With other signers
Neighborhood news				
Sibling's problems				
Family news				
Personal body issues				
Government / National news				
Chemistry				
Having a boyfriend/girlfriend				
Laundry				
Mealtimes/ food				
Illnesses				
Work				
School / teachers at school				
School/ homework				
School/ gossip				
Getting married				
Climate change				
Different cultures				
Shopping				
Religion/ church				
Work/ Their employment				
Canal Project				
Family finances				

Appendix B: Family Social Perspective Taking questionnaires (English Translations)

Child version (Child answering about interactions with his/her parent)

1. I try to look at my parent's side of a disagreement before I make a decision.
0 1 2 3 4
Does not describe me at all Describes me very well

2. I sometimes try to understand my parent better by imagining how things look from her/his perspective.
0 1 2 3 4
Does not describe me at all Describes me very well

3. If I'm sure I'm right about something, I don't waste much time listening to what my parent has to say about it.
0 1 2 3 4
Does not describe me at all Describes me very well

4. When I talk to my parent, I tend to focus on my own thoughts rather than on what my parent might be thinking.
0 1 2 3 4
Does not describe me at all Describes me very well

5. I can pick up quickly if my parent says one thing but means another.
0 1 2 3 4
Does not describe me at all Describes me very well

6. My parent tries to look at my side of a disagreement before they make a decision.
0 1 2 3 4
Does not describe me at all Describes me very well

7. My parent sometimes tries to understand me better by imagining how things look from my perspective.
0 1 2 3 4
Does not describe me at all Describes me very well

8. If my parent is sure he/she is right about something, he/she doesn't waste much time listening to what I have to say about it.
0 1 2 3 4
Does not describe me at all Describes me very well

9. When my parent talks to me, he/she tends to focus on his/her own thoughts rather than on what I might be thinking.
0 1 2 3 4

Does not describe me at all Describes me very well

10. My parent can pick up quickly if I say one thing but mean another.

0 1 2 3 4

Does not describe me at all Describes me very well

Parent version(Parent answering about interactions with his/her child)

1. I try to look at my child's side of a disagreement before I make a decision.

0 1 2 3 4

Does not describe me at all Describes me very well

2. I sometimes try to understand my child better by imagining how things look from her/his perspective.

0 1 2 3 4

Does not describe me at all Describes me very well

3. If I'm sure I'm right about something, I don't waste much time listening to what my child has to say about it.

0 1 2 3 4

Does not describe me at all Describes me very well

4.When I talk to my child, I tend to focus on my own thoughts rather than on what my friend might be thinking.

0 1 2 3 4

Does not describe me at all Describes me very well

5.I can pick up quickly if my child says one thing but means another.

0 1 2 3 4

Does not describe me at all Describes me very well

6. My child tries to look at my side of a disagreement before they make a decision.

0 1 2 3 4

Does not describe me at all Describes me very well

7. My child sometimes tries to understand me better by imagining how things look from my perspective.

0 1 2 3 4

Does not describe me at all Describes me very well

8. If my child is sure he/she is right about something, he/she doesn't waste much time listening to what I have to say about it.

0 1 2 3 4

Does not describe me at all Describes me very well

9. When my child talks to me, he/she tends to focus on his/her own thoughts rather than on what I might be thinking.

0 1 2 3 4

Does not describe me at all Describes me very well

10. My child can pick up quickly if I say one thing but mean another.

0 1 2 3 4

Does not describe me at all Describes me very well