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Theory of Mind Without a Language Model: Effects of Social Experience, Education and Language Exposure

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Theory of Mind Without a Language Model: Effects of Social Experience, Education and Language Exposure

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Abstract

Theory of Mind (ToM) abilities, i.e., the understanding that others have internal states that differ from one's own, and that these states guide behavior, are multiply determined. ToM abilities underlie later social and pragmatic abilities, grossly affecting later life experiences, particularly for deaf children. However, previous studies have not clearly identified the effects of language, hearing status, or other exogenous factors, such as education or executive function abilities, on ToM development. To disentangle these, we studied three understudied populations in Nicaragua: Homesigners, who have not acquired a conventional language but have developed gestural communication systems; users of Nicaraguan Sign Language, an emerging language (NSL Signers); and Unschooled Spanish Speakers. Comparing these groups can help uncover the relative contributions to ToM of social experience (available to all groups), membership in a linguistic community (NSL Signers and Unschooled Spanish Speakers only), and education (only NSL Signers), thus providing critical information that distinguishes among current theories, and that informs language planning and policy decisions supporting healthy development in deaf children.

Using a minimally verbal ToM protocol in which participants *experienced* two types of False-Belief (vs. being told of them): Unexpected Contents and Appearance/Reality; a minimally verbal Inhibitory Control task; two perspective-taking tasks; and a memory span task, we found that: 1) Language was most related to success on False-Belief measures of ToM as well as to transformational memory span tasks, while 2) Education was most related to success on conflict-Inhibitory Control tasks. Performance on non-transformational memory span tasks, non-conflict Inhibitory Control, and Perspective Taking did not differ across groups, suggesting that those without education or a language community nevertheless develop these cognitive abilities.

In sum, the results suggest a complex interaction among language, inhibitory control executive function, and education for Theory of Mind Development, and highlight language as a necessary factor.

1. Introduction

1.1. What is Theory of Mind and why is it important?

Theory of Mind (ToM), the ability to understand that others have beliefs and desires different from one's own beliefs, desires, or from what reality shows to be true, and the additional understanding that those beliefs and desires may in turn influence others' behavior (Wimmer & Perner, 1983, Baron-Cohen, Leslie & Frith, 1985, a.o.), is a foundational aspect of human social cognition. It allows us to understand others' intentions & behavior, and allows us to take others' perspectives and understand why someone else may not know what we know or see things the same way as we ourselves may.

ToM is not just about *understanding* others-- it has crucial implications for interpersonal *interactions*. That is, ToM's biggest impact is not only on the internal human experience (our observations and contemplations of others), but also in our external, daily interactions. For example, without a fully developed ToM, it is difficult to have a "normal" conversation in which two individuals cooperatively create common ground (e.g., Grice, 1989). Difficulties in this realm, such as providing too much or too little information in conversation, can affect others' perceptions. Knowing how much information to give, depending on your interlocutor, has its foundation in ToM abilities (Astington, 1990, Charman et al., 1998).

While the overall importance of ToM to human interaction is not argued, aspects of its developmental trajectory are (e.g. Wellman, Cross & Watson, 2001). In Figure 1, we see that ToM is not a single ability; to develop a mature ToM one develops a variety of abilities over time that culminate in very sophisticated interpersonal and communicative abilities, such as

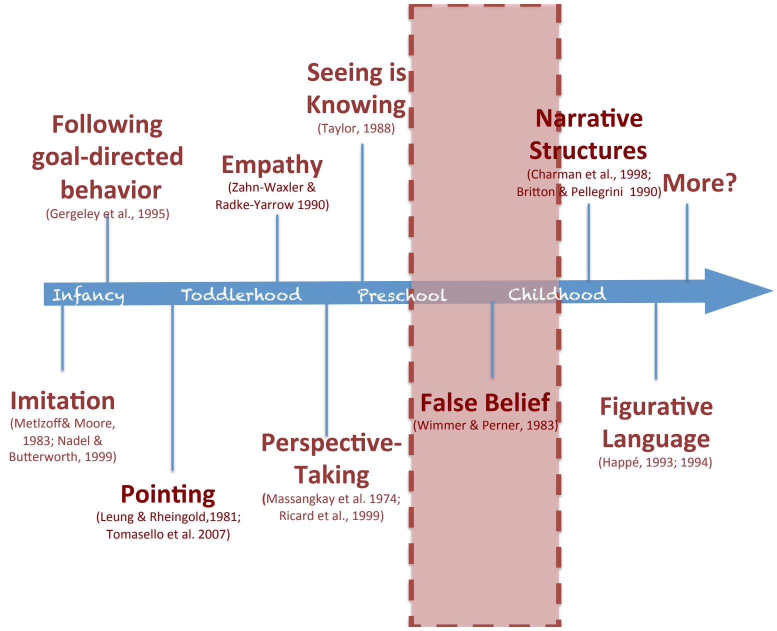

Figure 1: Milestones of various abilities relating to Theory of Mind.

the use of appropriate narrative devices and figurative language, e.g., sarcasm (Wellman & Liu, 2004; Peterson, Wellman & Slaughter 2012).

Interestingly, the earlier, nonverbal abilities are not usually the basis of debate; it is clear that infants can imitate other humans at a very early age (e.g., Meltzoff & Moore, 1983, Meltzoff & Decety, 2003, Nadel et al., 1999), and begin to follow points and other nonverbal communicative acts shortly thereafter (e.g., Leung & Rheingold, 1981, Phillips et al., 2002, Tomasello & Carpenter, 2007). Along the same lines, the later abilities are also not very hotly debated either; it is clear that one must have mastered at least some linguistic abilities in order to use that language for figurative speech acts. What *is* argued, however, is the moment at which language begins to play a crucial role in the conceptualization of others' thoughts, beliefs, and desires, and the understanding that others' behaviors are driven by their own thoughts, beliefs and desires, and finally, that that drive may result in behaviors that are different from one's own.

Some argue that the ability to understand others' thoughts and beliefs is available very early in life (e.g., Low, 2010, Onishi & Baillargeon, 2005, Meristo et al., 2012); while others

believe that this ability is not available until later in childhood, at about the age of four or five years (e.g., Wimmer & Perner, 1983). In either case, it is well documented that *overt* measures of Theory of Mind, i.e., those in which participants must explicitly make decisions, act on, or respond with language (as opposed to *covert*, or more implicit, measures that rely on first looks, looking time, or infant surprise response) are not usually passed until about 4 or 5 years, after significant language and social developmental gains have been accomplished by the child (e.g., de Villiers & Pyers 2002, Villiers & de Villiers, 2012, Wimmer & Perner, 1983). Because social and linguistic gains occur concurrently, it is difficult to disentangle the relative contributions of each in the development of ToM, and thus an active debate exists regarding which of these abilities is most implicated in the development of ToM. This active debate is reflected in two major theoretical camps.

1.2 Simulation Theories vs. Language-based Theories of ToM Development

1.2.1 The development of mature ToM abilities based in social experience

Social experiences undoubtedly are fundamental to typical and optimal human development. In the early experiences of a child, it is the interaction with his caregivers that lays the groundwork for later understanding about the world. Infants respond to caretakers' affect, for example, infants with depressed or anxious mothers later show different responses to happy, surprised or angry faces when compared to infants of mothers who were not anxious or depressed (Vanderwert et al., 2014). Later, social experiences underscore children's understanding of friendships and other relationships – both positively and negatively (e.g., Gottman et al., 1975, Selman, 1980, Smith & Rose, 2011). The obvious need for social interaction in human development has sparked many interesting fields of research regarding the importance of social experiences in shaping aspects of human cognition.

For example, some theorists suggest that it is the participation in social interactions which leads to our understanding of ourselves and others as social beings – it is the interaction which helps to shape the individual rather than the other way around. This *participatory sense-making* (De Jaegher & Di Paolo, 2007, De Jaegher et al., 2010) rejects even the construct of a Theory of Mind and suggests instead that there "is an explicit two-way link between individual and social processes, leaving open the possibility for individual cognitive skills to have dual or even purely social developmental origins" (De Jaegher & Di Paolo, 2007).

Other theorists suggest that social experiences provide us with information about others through our own experiences. Proponents of so-called *Simulation Theories* argue that life experience and social interactions are sufficient to scaffold mature ToM abilities, without the need for language (e.g., Goldman, 1992, Gordon, 1986, Nickerson, 1999). On this view, one's own experiences provide the foundation for ToM by serving as a template for understanding how others will behave in a given similar situation; these templates are updated as one gains more life experience.

These theories are argued primarily in the philosophical realm with little to no empirical data specific to the mechanisms of simulation (e.g., Gordon, 1986). However, recent neuroimaging research in the "mirror neurons" of non-human primates, which typically show responses in motor control regions when passively observing others' motoric behavior (e.g., Kohler et al., 2002) have also bolstered recent interest in Simulation Theories. Mirror neurons have been argued to possibly provide a neurologic clue to how humans could be "wired" for social interactions, and more importantly, as a neurologic basis for understanding other minds (e.g., Gallese & Goldman, 1998, Iacoboni, 2009) through reflection. In fact, studies using EEG

measures looking for mirror neuron activity in populations with known deficits in Theory of Mind abilities show decreased activity (Oberman et al., 2005) in anticipated mirror neuron networks, thus encouraging theories linking mirror neurons with Theory of Mind abilities (Gallese, 2007). Importantly, these neuroimaging studies, like most other neuroimaging studies, can only show neural firing in the presence of ToM-related stimuli, but do not explain explicit understanding and related abilities, i.e., the mechanisms relating these neural firings to ToM-related behavior.

According to most socially-based theories of ToM, but in particular the simulation theories, language *can* play a part in the development of ToM, primarily because language provides a way to interact more with others, providing opportunities to update one's knowledge more efficiently. In the end, however, it is the reflection on one's own experiences that primarily supports the understanding of other minds via a social scaffold.

1.2.2 The development of mature ToM abilities based in language experience

Other researchers argue that it is language development, and possibly specific linguistic structures, that is essential to the child's development of a mature ToM. Mental verbs (Gola, 2012, Howard et al., 2008, Pyers & Senghas, 2009) and complement clause structures (de Villiers & de Villiers, 2000, de Villiers & Pyers, 2002), for example, have been associated with the development of ToM abilities, as measured by the gold standard task for assessing ToM: the false belief task (FB) (e.g., Wimmer & Perner, 1983).

The False Belief (FB) task is designed to elicit a response from the child participant by asking about another's beliefs given certain events. For example, in the *Smarties* task (An unexpected-contents task involving M&M-like candies; Gopnik & Astington, 1988), the child is shown a Smarties candy box and is asked what he thinks is in the box. Given the box's outward

appearance, it is a reasonable and likely response to say that there must be Smarties candies in the box. The child is then allowed to open the box (or is shown the contents of the box), at which point the child learns that there are actually other objects inside, such as multicolored paper clips. The box is then closed and the child may be asked again what he thinks is in the box for confirmation that he remembers that it actually contains paper clips, not Smarties. Then another character is introduced, often in the form of a puppet, who was not present for the initial interaction. The puppet is introduced to the child and the child is then asked what the puppet thinks is in the box. The child is considered to have passed if he says that the puppet will say there are Smarties in the box, showing that the child realizes that the puppet was not there for the reveal of what is actually in the box, and must be going on the box's outward appearance only. On the other hand, the child is considered to have failed the task if he responds that the puppet will think there are paper clips in the box (what is actually in the box, not some other random object). This is believed to be evidence that the child cannot separate his own thoughts, beliefs, or knowledge from those of others.

Other variants of the FB task include Appearance/Reality (A/R) tasks in which an object or scene appears to be one way, but in reality is not (e.g., fake food (Pyers, 2005)), and Change-of-Location tasks in which an object is placed in one location in the presence of a character, is moved while that character is out of sight, and then that character returns to retrieve the object (Wimmer & Perner, 1983). Arguments against the FB task as a measure of ToM say that the task is inherently linguistically based as it requires the understanding of a complex sentence (i.e., "What does Elmo think is in the box?" or "What will Elmo will say is in the box?"), and is thus actually a measure of language ability in ToM than true ToM *understanding* (e.g., Wellman, Cross & Watson, 2001).

However compelling arguments against the validity of the FB task are, general complexity in language is not the only determining factor in passing FB tasks. Hale & Tager-Flusberg (2003) found that training on sentential complements (e.g., “The boy said he kissed Grover.”), but not similarly complex relative clauses (e.g., “Bert hugged the girl who jumped up and down.”), improved children’s ToM performance on False Belief tasks relative to pre-training levels. Therefore, those advocating for language-based theories argue that it is some *aspect* of language that is central to normal ToM development, such as the presence of mental verbs in the child’s vocabulary (Howard et al., 2008, Gola, 2012, Pyers & Senghas, 2009, Shatz et al., 1983), or the complement clauses they oftentimes require (de Villiers & de Villiers, 2000, de Villiers & Pyers, 2002).

1.3 Executive Function (EF) and the development of ToM abilities

While language proficiency or access to rich social interactions are often debated as being the crucial element needed by a typically developing child to achieve understanding of other minds, there are nevertheless other abilities argued to be necessary in order to achieve higher-level ToM abilities, and in particular, to correctly maneuver a False Belief task. In addition to the early ToM-specific abilities (Figure 1) such as understanding intentionality (Behne et al., 2005, Gergely et al., 1995, Philips et al., 2002) and the ability to take another’s perspective (Piaget, 1956, Masangkay et al., 1974, Flavell et al., 1981), other general (not specific to ToM) cognitive abilities have been argued to be necessary for proper ToM development. These usually fall in the realm of the Executive Functions, and more specifically, Working Memory and Inhibitory Control.

The executive functions (EF) are a “heterogeneous collection of skills that, in various ways, aid in the monitoring and control of thought and action” (Carlson et al., 2002). These

skills mature as frontal lobe function matures, usually achieving adult levels by 25 years of age (Stuss & Knight, 2013), and are strongly implicated in Theory of Mind functioning as they aid in the processing of the information required to process a False Belief, or other higher-order ToM skills. Importantly, even when Theory of Mind abilities are considered to be available to very young infants, or even present at birth, theorists allow for ToM abilities to be limited or bolstered by EF abilities (Gordon & Olson, 1998).

EF has been investigated as part of ToM studies around the globe, showing that EF predicts ToM abilities over and above general intelligence (Carlson et al., 2002), can be used to predict later ToM abilities in development (Carlson et al., 2004), and can be assisted by the suggested EF bolstering that comes with bilingualism (Bialystok & Senman, 2004).

An additional important consideration for our purposes is the effect of educational experiences on EF development (and by extension, on FB performance). Some research shows a relationship between EF and education (e.g., Sabbagh et al., 2006), whereas others find no effect (Ostrosky-Solis et al., 2004). Because the populations of interest in the present studies vary greatly in their educational levels it is important to find ways to address the effects of educational experiences themselves, apart from the other factors that have been described earlier (see section 2 for rationale behind the current study design).

1.4 Deaf individuals as an informative population

The debate between linguistically- and socially- based arguments for ToM development continues because we still cannot easily disentangle the relative contribution of each of these factors in typically developing children: by 4-5 years of age, children have amassed enough social experience *and* acquired sufficient language to successfully navigate FB tasks, and implicit tasks (e.g., Onishi & Baillargeon, 2005, Low, 2010, Meristo et al., 2012) do not provide

enough evidence that the measured behavior is actually based on the understanding of others' internal beliefs. What is required to disentangle these factors is a population that shows normal development in one or the other ability (i.e., normal ability in social interaction without language development), and a task that provides behavioral measures of FB without relying on language to access that knowledge. We find this combination in deaf[1] children born to families who can hear and do not know sign language.

Ninety to 95 percent of deaf children are born to parents who can hear (Mitchell & Karchmer, 2004, Moores, 2001, Vaccari & Marschark, 1997). Given that most of these families do not know sign language and the child is not able to access the spoken language due to their hearing loss, the child may likely spend some time without any linguistic[2] input. They do, however experience typical social interactions and therefore still have opportunities to visually learn about affect, pointing, intentionality, and the like.

This study is not the first to investigate Theory of Mind development with deaf individuals, but it is only in the last two decades that the issue of language exposure has been raised. Crucially, researchers have become aware of the importance of separating Deaf children with Deaf parents (who experience early language exposure) from deaf children with hearing parents (who experience relatively late exposure to language[3]). Thus, contrary to previous

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[1] It is standard to use a capital "D" in "Deaf" when referring to a group of individuals with hearing loss who share cultural values, norms, political perspectives, and a language. A capital "D" will only be used with in the text when it is sure that those being referred to fit this definition. Note, even in the United States, not all persons with hearing loss are part of the Deaf community.

[2] Some aspects of human communication (i.e., the use of gesture) are still hotly debated as to whether they should be considered part of the linguistic system. For the purpose of this paper, "linguistic" refers to the communicative system used by the community.

[3] Note that there are hearing parents of deaf children who do choose to learn to sign as soon as they find out that their child is deaf. While this is not always the case (many hearing parents choose to have their child learn to speak and to use listening devices such as hearing aids or cochlear implants) (Mauldin 2011, 2012), the parents who do sign are still in the early stages of acquiring a sign language during a critical time in their deaf child's language development, and parents often do not become fluent

findings which found that deaf children are delayed as a group relative to similarly-aged children with normal hearing at ToM-related tasks (e.g., Lundy, 2002, Russell, 1998), we see that early language exposure (Meristo et al., 2012, Peterson, 1999, Woolfe et al., 2000), and likely specifically exposure to language referring to mental states (Moeller & Schick, 2006, Rhys-Jones & Ellis, 2000, Schick et al., 2007) eliminates this difference.

Moreover, a language benefit has been found for two unexpected groups: very young deaf children and within deaf children with deaf parents. Meristo and colleagues (2012) found that infants of about 17- 26 months of age with hearing parents who do not use a sign language experience delays in anticipating the actions of a character with a false belief as compared to counterparts with normal hearing (measured by anticipatory looking). Furthermore, Meristo and colleagues (2007) found that within a group of deaf children with deaf parents, differences can still be found for the rate of FB success depending on the child's educational environment (e.g., orally-based education with limited sign support vs. sign-based education with a rich sign community).

Therefore, the current series of studies aims to isolate *participation in a linguistic community* as a contributing factor to ToM success by using a minimally verbal, experiential False Belief task with individuals who have varying levels of access to others who share a language with them. Other potentially important factors are also tested, namely participants' abilities to understand others' visual perspectives, their working memory spans and inhibitory control abilities. These tasks are elaborated further in section 2.

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themselves. Thus, the input to the child from the hearing, signing parent is not as linguistically rich as it would be from a Deaf signing parent (Peterson, 1999).

2. Rationale for current study design

As part of the body of work investigating the communicative and cognitive effects of age of language exposure, there is a growing sub-field investigating the effects of no language exposure as well as the effects of exposure to an emerging language rather than to an established language[4]. Some of this work has focused on the language system itself, for example, the linguistic structures available in the sign systems of individuals with no language exposure (e.g., Brentari et al., 2012, Coppola & Newport, 2005, Goldin-Meadow, 2003); those using an emerging language (e.g., Coppola & Senghas, 2010, Coppola et al., 2013, Senghas, 2003, Senghas et al., 2004), and the development and comprehension of the system by those in the signers' communicative circles (e.g., Carrigan & Coppola, 2012, Richie et al., 2014,). Other work has examined the effect of a lack of language exposure, or exposure to an emerging language, on other aspects of cognitive development, such as number cognition (e.g., Spaepen et al., 2011) and ToM development (Morgan & Kegl, 2006, Pyers, 2005, Pyers & Senghas 2009,).

In the previous Theory of Mind work with an emerging sign language in Nicaragua that is less than 40 years old, researchers have found relationships between participants' language exposure and ToM abilities. For example, Pyers (2005) and Pyers and Senghas (2009) found differences in False Belief success between signing groups depending on the number of mental verbs in the lexicon, and their frequency of use, across different cohorts of signers. Thus, signers representing an older group of sign language users ("Cohort 1," see section 2.1.2 for a full description) who had been exposed to the language in its early stages did not have as many mental verbs in their productions as later, younger signers ("Cohort 2") who had been exposed to the language after it had evolved some (and who had Cohort 1 signers as their language models).

[4] Most spoken languages are considered to be established languages, as many of them (even what we now call "creoles") have a long history with many speakers of the language. Even American Sign Language, a relatively new language, has a 200-year history (Groce, 2009).

Work by Morgan and Kegl (2006) with deaf Nicaraguans[5] confirmed previous studies in the United States that success on Theory of Mind tasks is dependent on the age of exposure to a sign language (before or after the age of 10) and can also be correlated with the production of mental state language in narrative.

To add to this body of work, the current study proposes to extend our understanding of the relationship between language exposure and social experience with ToM-related abilities by looking at Homesigners, Nicaraguan signers, and Nicaraguan Spanish speakers who have little to no educational experiences (as a comparison group). By including these three specific groups, it allows us to more specifically isolate the effects of *not* participating in a linguistic community by contrasting participants who do and do not participate in a linguistic community and those who do and do not have the opportunity to receive educational experiences. This is of particular import, because for Cohort 1 signers, the very place they are introduced to a linguistic community is the same place they receive an education. The two experiences cannot be divorced for Cohort 1 participants, or, for that matter, for deaf children from families who do not sign.

2.1 The participants

2.1.1 Homesigners

As briefly mentioned above, homesigners are deaf individuals who are born to and raised by families who are not deaf and who don't know a sign language (Coppola, 2002, Coppola &

[5] Morgan and Kegl's participants are not divided into cohorts in the way that the NSL groups are for many of Senghas', Coppola's, and Pyers' studies. Morgan and Kegl's (2006) participants were from a city on the east (Atlantic) coast of the country (Bluefields), which is highly inaccessible from the western part of Nicaragua, the site of Managua, the capital. Bluefields can be easily reached only by plane, or by an arduous boat journey requiring multiple days. This distance from the capital means that the language was already well established and still developing in the Managuan deaf community by the time it reached Bluefields and there is likely no critical mass of deaf individuals in Bluefields to truly evolve the language in the way it has been evolving in Managua. Likely language change has been happening in Bluefields, but on a smaller scale, given a) the size of the community there, b) the amount of access the deaf individuals have to each other, c) the ages of the deaf community members in the area, and d) the relatively limited contact they have with individuals coming from Managua.

Newport, 2005, Goldin-Meadow, 2003, a.o.). Because they do not have access to the spoken language around them, they develop their own gestural-communicative systems called *homesign*. With the standardization of newborn hearing screening in the United States, it is not common anymore for deaf children to spend much time without any attempts to address their communication needs (although many spoken-language attempts are unsuccessful) (Mauldin, 2011, 2012).

In developing countries like Nicaragua, however, newborn hearing screening is not widely available, and so when a mother realizes her child is deaf, there are not many options for education, either using auditory means (e.g., a magnification system plus spoken language) or a sign language (Polich, 2005). Despite their lack of conventional linguistic input, *homesigners* in Nicaragua continue to use their gesture systems as their primary means of communication into adulthood. They do not appear to be socially impaired; they enjoy relatively typical social interactions with their hearing families, friends, and neighbors. While homesign is not a fully developed language, mature homesign systems exhibit a range of linguistic properties found in fully-developed languages such as the grammatical relation of subject (Coppola & Newport, 2005), and thus signifies an emerging language system without the fully developed structure of established languages. Thus, Homesigners represent a group with little to no exposure to conventional linguistic input, as well as little to no educational experience (Table 1).

2.1.2 Nicaraguan Sign Language: An emerging language

One of the main advantages of research with recently emerging languages is the opportunity to measure the effects of absent or atypical linguistic input and the linguistic and cognitive benefits conferred by participating in a linguistic community. Like Homesigners, Cohort 1 signers of Nicaraguan Sign Language (NSL) (the first group of signers to begin

creating the language at a newly re-established center for special education in Managua during the late l970s to early 1980s), did not have access to linguistic input transmitted vertically, that is, from a pre-existing language model. However, Cohort 1 signers did engage in language genesis with their peers (horizontal transmission) (Senghas et al., 2005).

NSL signers of all cohorts (cohort 1 and the subsequent children who entered the school later, representing cohorts 2, 3, and so on) interact with many other users who use the system as a primary language, i.e., members of the Deaf community in Managua, and are thus part of a linguistic community. Homesigners, by comparison, rely on using their gesture systems with hearing people their entire lives -- hearing people who only use these gestures with the homesigner and never with each other. In other words, the benefit of the horizontal transmission experienced by cohort 1 signers is absent from the homesigners' experience because there is no network of gesturers/signers to contribute to language genesis. Empirical and computational evidence suggests that the rich interconnections among users that characterize typical sociolinguistic communities are essential for developing some aspects of linguistic structure, e.g., a conventionalized lexicon (Richie et al., 2014).[6]

Another significant difference between Homesigners and Cohort 1 signers is the fact that Cohort 1's (and subsequent cohorts') introduction to the linguistic community is situated within an educational or vocational context (Polich, 2001, Senghas et al., 2005). As it is for most deaf children born to parents who do not already know a sign language, it is the schools that provide *both* educational and primary linguistic experiences through peer interactions. This will be explained further in the context of the next group, the unschooled hearing Spanish speakers in

[6] Further, each homesigner's mother does not share the system even with the homesigner-- despite having used it over a very long period of time (Carrigan & Coppola, 2012). By these criteria, the homesigner, hearing family members and friends who use homesign, and their patterns of interaction do not constitute a linguistic community (even a small one), whereas the Cohort 1 signers *do* constitute a linguistic community.

section 2.1.3.

To reiterate, the primary reason for including Cohort 1 signers as a comparison group to homesigners to see the effects of having a *linguistic community* on ToM abilities (Table 1). As mentioned, there is precedence for investigating ToM abilities in Cohort 1 signers; the current study has adapted a task previously used by Pyers (2005), allowing for results from the current study to be compared with previous results on the same task. In this task, Cohort 2 outperformed Cohort 1 overall (Pyers, 2005), with Cohort 1 signers having moderate success on Appearance/ Reality items and no success with Unexpected Contents items. To clarify, although both Appearance/ Reality and Unexpected Contents tasks are both considered False Belief tasks, success on one may not guarantee success on the other. This makes the Pyers (2005) results more interesting: recall that Cohort 1 had no language model -- there was no older group of interlocutors from which to learn their language, nor anyone within the peer group who had had access to a conventional language model. Additionally, Cohort 1 participants were tested in adulthood, eliminating the possibility that additional ToM abilities could later develop given enough time. Therefore, two questions could be asked: 1) Could the ability to succeed at Appearance/ Reality tasks be available to humans regardless of the language input they receive (or not), thus leading to a difference in success on Appearance/ Reality tasks as compared to Unexpected Contents tasks? Or perhaps, could participation in a linguistic community be enough to scaffold this ability, regardless of how developed the language is (i.e., the existence and frequency of the use of mental verbs, complex clauses, or consistency of grammatical structures within and between users of the language)?

2.1.3 Unschooled Nicaraguan Spanish Speakers

As mentioned, like most deaf children born to hearing parents who do not know a sign language,

the vast majority of NSL signers in past and present studies gained access to their linguistic community via educational settings (Polich, 2001). Thus, we cannot separate having a linguistic community from education in either NSL signers (who have both) or Homesigners, who have neither. Thus Unschooled Spanish Speakers are introduced (Table 1). They represent individuals who have full access to a language community but have little to no education. Unfortunately it is virtually impossible to find a group of participants to test the opposite circumstances from the Unschooled Spanish Speakers – this would require participants who fully interact in an educational setting (and thus enjoy the benefits of education) without having any exposure to language in or out of the classroom.

Note that the Unschooled Spanish Speakers do not have educational experiences for anticipated reasons: the family businesses needed the extra hands. Four of the five unschooled hearing participants were full-time agricultural workers; the fifth worked making tortillas for the family business. Their lack of education primarily resulted from economic restrictions and the distance to the nearest school.

2.2 Recruitment methods

Participants were recruited either as part of a long-standing, ongoing research relationship with the research group (for homesigners and NSL signers), or, for the Unschooled Spanish Speakers, via community contacts in rural areas.

Participant Characteristics				Participation in Study			
Group (N)	**Mean Age** (range)	**Linguistic community**	**Educational experience** (mean, range)	**Perspective Taking**	**False Belief**	**Executive Function**	**Working Memory**
Adult Homesigners N=4	31.5y (26–35y)	No	Very little[7] (0.5y, 0-1.5y)	✔	✔	✔	✔
Adolescent Homesigners N=3	11.3 (10-12y)	No	Little (3y, 0.8-5y)	✔		✔	✔
NSL Cohort 1 N=6	41y (35-45y)	**Yes**	**Yes[8]** (10.5y, 6-13y)	✔	✔	✔	✔
Unschooled Spanish Speaking Adults N=5 or 6[9]	31.5y (19-47y)	**Yes**	Very little (0.7y, 0-3y)	✔	✔	✔	✔
Unschooled Spanish Speaking Adolescents N=2	12.5 (9-16y)	**Yes**	None (0y)[10]	✔		✔	✔

Table 1: Summary of participant group characteristics.

[7] Homesigners' education constitutes *any* attempt at education (see Appendix A). While these attempts may not contribute to *language* learning, there may still be benefits that have not been captured to date, such as in EF.

[8] No secondary school was then available to NSL signers; most attended elementary school until ~16 years of age (6th grade), and some later attended a vocational school. Typical school days in Nicaragua tend to be ½-day (Polich, 2001), thus the reported mean of 10.5 years is not comparable to similar years of schooling in the U.S.

[9] One USS adult participated *only* in the FB task and not in the remaining tasks, therefore for the EFB there are six USS but in the remaining studies there are five.

[10] The parents/guardians of the USS Adolescents reported *no* educational experiences for their children. We had to take them at their word, but realize this may not actually represent the reality of their experiences. A lack of education is still common in rural areas of Nicaragua-- education has been emphasized in recent legislative activities and is valued generally, but families sometimes either cannot afford transportation to school and/or cannot afford to lose the

2.3 Current study tasks

2.3.1 Visual Perspective Taking

A visual perspective-taking task is first introduced to test a key precursor to later, more abstract, Theory of Mind abilities. This task essentially asks a) whether a participant understands *that* another individual can have a different experience than their own and b) whether the participant can *mentalize* or *visualize* what the other may be seeing. This is a task with a long history in developmental psychology (see section 3.1 for a more thorough description), and is generally accepted as a developmental precursor to later Theory of Mind abilities.

Courtin and Melot (2005) suggest that it is the visual perspective taking abilities required by many sign language structures (French Sign Language (LSF), for their purposes) that aid Deaf children with Deaf parents in developing ToM abilities. However, the ability to understand others' perspective is available very early on in typically developing hearing children as well (Flavell, 1981, 1984, Masangkay, 1974) and resides along the continuum of ToM abilities as an important precursor to the FB task (Figure 1). To date, we have no clear evidence of what perspective taking abilities are available to those with *no* language exposure. Perspective taking tasks are thus included in this study to investigate a) the relationship of language exposure to perspective taking, and b) whether life experience (even without a language) boosts perspective-taking abilities.

2.3.2 False Belief

The false belief task is chosen here as the measure of interest because of its unique place in the development of ToM-related abilities for typically developing children. As we can see in Figure 1, ToM as a general ability relates to many low- and

high-level abilities along a typical developmental trajectory. Interestingly, the low-level abilities (to the left of the FB task) are primarily nonverbal abilities that are measured using nonverbal approaches, and the high-level abilities (to the right of the FB task) are primarily verbal abilities, and are measured using language. It is the FB task that presents a unique position in that it could be grouped as a non-verbal (and thus potentially social) ability, *or* it could be primarily verbal, and grouped as such. Using a *nonverbal* false belief task would eliminate the participants' expressive language ability within the task as the pivotal factor for success and would instead highlight the participant's ability to understand others thoughts.

2.3.3 Executive Functions

Two Executive Function tasks are introduced, testing Working Memory (WM) and Inhibitory Control (IC). These have been included for three reasons: 1) they have been previously implicated in ToM success - specifically FB success (e.g., Carlson et al., 2002, 2004, Sabbagh et al., 2006) for their contribution to the ability to suppress one's own knowledge of the reality of the situation in order to favor the other individual's (incorrect) belief; 2) there as yet is no body of research investigating EF abilities within Homesigners and NSL signers and 3) we can compare results within this study to previous studies investigating the effects of education on executive function abilities (e.g., Ostrosky-Solis et al., 2004).

2.4 Procedures for conveying task instructions

While all tasks in the current studies were chosen because they could be conducted nonverbally, we gave instructions in a specific language when possible to maximize participants' understanding of the task instructions and procedure (i.e., spoken

Spanish was used with the hearing participants and NSL was used with the NSL signers). Gestural communication was used with the homesigners. Thus, the choice was made to prioritize comprehension of task instructions over standardization of the protocol. No script could have been written to meet the needs of this communicatively diverse group of participants, and completely nonverbal (solely gestural) tasks proved to be cumbersome and confusing for some hearing participants.

2.5 Current study predictions

2.5.1 Perspective Taking

Given that perspective taking abilities are available to children rather early in life (Flavell, 1981, 1984, Masangkay, 1974), no differences were predicted between homesigners, NSL signers, and Unschooled Spanish Speakers. Given the average ages of the participants, the current study cannot disentangle the effects of general life experiences on Perspective Taking abilities.

2.5.2 False Belief

Homesigners, who do not participate in a linguistic community, and thus are unlikely to have developed the linguistic structures that support FB understanding, were not predicted to succeed. Prior results (Pyers, 2005) suggested that some NSL Signers would succeed. Given that the Spanish speakers are adults with typical developmental histories, they were expected to succeed.

2.5.3. Executive Functions

2.5.3.1 Inhibitory Control

Given previous work on Inhibitory Control in unschooled, low socioeconomic status populations (Ostrosky-Solis et al., 2004), and previous work showing that deaf

children in oral education environments eventually "catch up" to hearing counterparts (Shusterman, et al., 2012), no difference was expected between groups.

2.5.3.2 Working Memory

As of yet, there is not enough research on working memory in homesigners (or a similar group) to provide a prediction of the base rate of success. Given previous suggestions that Working Memory is a necessary ability for the success of False Belief tasks (Gibson, 1998), it was possible that the same would hold true in this study, on the other hand, other studies find *no* contribution of Working Memory above and beyond that of language to the success of False Belief (Astington & Jenkins, 1999, Slade, 2005). Given that homesigners have *no* language model or linguistic community, it was then possible that they could actually benefit from a contribution from Working Memory without the aforementioned influences of language on False Belief success.

3: Study 1: Perspective Taking

3.1: Introduction

As we consider how crucial having a mature Theory of Mind is to everyday social interaction, it becomes clear that this is not an ability which develops quickly, or even at a specified age, but rather over time. There are important steps along a developmental continuum that build up to a mature understanding of others' thoughts, beliefs and desires. Many take the understanding of False Belief (the understanding that someone can have a belief about the world which is untrue, given one's own understanding and/or reality) to be the key measure of Theory of Mind development, but in order to understand that another can have a *false* belief, one must understand that others have beliefs, or at least experiences of the world which are different than one's own.

In his seminal work, Piaget (1956) showed that it was not until middle to late childhood that children could pass his "mountain task," in which a child is presented with a 3D display of three mountains of varying heights and distances from the child. The child was asked what the view would look like from differing points around the display. Piaget concluded that children could not understand others' perspectives (and by relation, others' minds) until middle to late childhood (Flavell, 1985).

Masangkay and his colleagues (1974) extended Piaget's work showing that if the task is simplified by using two-dimensional pictures or single familiar 3D objects, preschool children can succeed. Masangkay et al.'s work shows that the understanding that others may see things that one cannot see themselves (Perspective Taking Level 1), and that the understanding that another's view of the same object may not be the same as one's own (Perspective Taking Level 2) is available to children much earlier than previously argued by Piaget. Flavell and colleagues (1981) further defined this ability to show that Level 1 understanding is developmentally prior to Level 2, and that the distinction between Level 1 and Level 2 cannot be easily overcome by training; that is, the progression to Level 2 is not trivial in that training does not help the child develop Level 2 understanding.

By placing Perspective Taking abilities on a developmental timeline, we see its relation to other abilities related to the understanding of others (Figure 1), and we also see that Perspective Taking is a developmentally earlier ability along the Theory of Mind developmental timeline. It is reasonable, then, to test Perspective Taking in our population of interest, to answer the question: ***Is the ability to understand another's visual perspective language-dependent?*** Perspective taking has not been tested directly

in deaf populations without cognitive impairments (see Shield (2010) for perspective taking in deaf children with Autism Spectrum Disorders). While it could be argued that previous work by Masangkay et al. (1974) and Flavell et al. (1981) show that children without mature language abilities[11] can take others' perspectives, these children still had years of language exposure which may have provided them with enough information about the world and others' perspectives to scaffold the development of perspective.

Deaf individuals with *no* language exposure, but sufficient *life experience* provide us with a way to control for language as the key factor in the understanding of others' perspectives. As an additional element, unschooled hearing Spanish speaking adults and children were tested to be sure that Socio-Economic Status (SES) and/or educational experiences were not contributing to success on this task, since the children in Masangkay et al. (1974) and Flavell et al. (1981) were all from middle class families and oftentimes were recruited from nursery schools.

3.2: Participants

All participants were Nicaraguan: 7 deaf Homesigners (4 adults (HS); M_{age}= 31.5y, Range = 26-35y and 3 adolescents (HS-A) M_{age}= 11.3y, Range = 10-12y), 6 deaf signers from Cohort 1 (M_{age} = 41y, Range = 35- 45y), representing NSL's earliest users (NSL Signers), and 7 hearing Unschooled Spanish Speakers (5 adults (USS); M_{age}= 28.5y, Range = 19-39y and 2 adolescents (USS-A) M_{age}= 12.5y, Range = 12-16y). The Unschooled Spanish Speaking adults and adolescents represented a group who, like homesigners, had little to no education, but who, like the NSL signers, were part of a linguistic community (Table 1).

[11] Assuming that mature language abilities are defined by mature discourse abilities, such as narrative coherence or cohesion (e.g., Karmiloff-Smith, 1985), which have been found to mature by about the age of 8 or 9 years old.

3.3: Materials and Procedure

Perspective-taking abilities were tested using two tasks, a two-dimensional, or "Level 1" task, and a 3-dimensional, or "Level 2" task (see Masangkay et al. (1974) or Flavell et al. (1981) for evidence for two developmentally distinct abilities).

3.3.1 Level 1 perspective taking.

Level 1 perspective taking abilities were tested using two-dimensional stimuli, namely two images printed on 8" x 11" laminated sheets, which were placed back-to-back. First, both images were shown to the participants, and participants were asked to identify the objects (Figure 3). This was done for two reasons – first, it familiarized the participants with the images, and second, it created common references between the participant and the experimenter. This was particularly important because homesigners each have their own idiosyncratic means of communication, and the experimenter may not be familiar with their reference for "wheelbarrow," for example.

All the images chosen were familiar items in Nicaragua, varying in nature from humans to animals to inanimate tools. All the images have previously been successful in Nicaragua, as these images represent a subset of images used in Richie et al.'s (2014) lexicon elicitation task.

Four sets of images were presented: Cat/Hat, Wheelbarrow/Fishing Rod, Cow/Girl, and Pitcher/Chicken. For each of the aforementioned sets, after familiarization and naming of the images, one image was presented to the participant and the other faced the experimenter. The experimenter then asked: "What do *you* see?" and "What do *I* [the experimenter] see?" (see Table 2 and Figures 2–3). Both perspective questions were asked for each set, and each set was flipped so that the participant had an opportunity to

Experimenter sees	Participant sees	Question	Anticipated Response
Cat	Hat	What do you see?	Hat
Cat	Hat	**What do I see?**	Cat
** Images are then switched**			
Hat	Cat	**What do I see?**	Hat
Hat	Cat	What do you see?	Cat

Table 2: Sample interaction for Cat/Hat. Crucial perspective questions are presented in bold text.

Figure 2: Images of cat and hat used in Perspective Taking Level 1. Each image appears on one side of a laminated sheet.

Figure 3: Experimenter and participant engaged in Perspective Taking Level 1 task.

see every image (Table 2). Feedback was only provided during the first pair of images, Cat-Hat, if needed, to clarify the instructions.

3.3.2 Level 2 perspective-taking.

Level 2 perspective-taking abilities were tested using three-dimensional stimuli, namely three familiar objects: a toy duck, a mug with identifiable sides (a hand design on one side and a handle), and a toy truck (Figure 4). Each object was presented to the participant on a "lazy susan" so that it could be rotated easily either by the experimenter

or the participant. Testing was done with the lazy susan on a surface between the participant and the experimenter[12]. Front/back perspectives were tested first with all objects, then side views were tested. Like in Level 1, participants were asked "What do *you* see?" and "What do *I* [the experimenter] see?" (Table 3 and Figure 5). Participants were presented with an 8" x 11" laminated sheet displaying the four possible perspectives of the object being tested (Figure 5). Participants could respond either by selecting the correct image or by describing the correct perspective (e.g., "You see the back of the duck" or "You see the duck's feet."), however the experimenter encouraged the participant to choose the correct image whenever possible for clarity in coding and for consistency across participant groups, particularly for the homesigners, who may solely rely on selecting images. The experimenter re-asked the question for insufficiently descriptive responses such as "You see the duck." The duck object was used for familiarization with the task, and feedback and practice were employed if the participant seemed to have trouble with the task. Strategies for explaining the task included

Figure 4: The three objects tested in Perspective Taking Level 2: Duck, Mug, and Truck.

[12] In some testing situations, the camera positioning and seating arrangements were such that the experimenter could sit "across" from the participant (they faced each other), but the table for the task was not between them (i.e., the experimenter and the participant sat on the same side of a large round table, but turned to face each other and positioned the task items on an area of the table between them (Figure 6)).

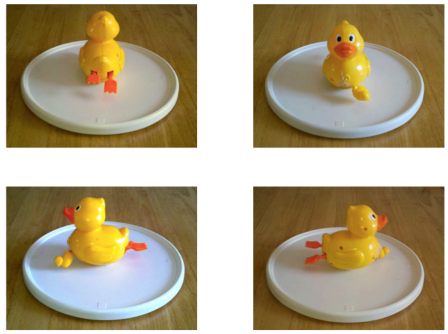


Figure 5: Sample answer array, and the four perspectives tested in Perspective Taking Level 2.

Experimenter sees	Participant sees	Question	Anticipated Response
Back of duck	Front of duck	What do you see?	Front of duck
Back of duck	Front of duck	**What do I see?**	Back of duck
** Object is then rotated 180 degrees**			
Front of duck	Back of duck	**What do I see?**	Front of duck
Front of duck	Back of duck	What do you see?	Back of duck

Table 3: Sample interaction for Front/Back trials of object: duck. Crucial perspective questions are presented in bold text.

Figure 6. Images of participants engaged in "duck" trial.

switching seats with the participant, either the experimenter or the participant rotating the object on the lazy susan, and the experimenter describing what she sees and asking the participant to find that picture in the array.

3.4: Results

The Level 1 Perspective Taking (two-dimensional images) trials were coded for correct responses: Wheelbarrow/Fishing Rod, Cow/Girl, and Pitcher/Chicken (practice trials were excluded). Only the first response was coded for accuracy, unless the

participant immediately corrected him/herself, for a total of three possible correct answers to the *experimenter's* perspective.

All participants scored at 100 percent accuracy for all Level 1 Perspective-Taking trials and thus no differences were found between participant groups, or as an effect of either age of language exposure or years of educational experiences.

Level 2 Perspective Taking (three-dimensional objects) was coded for accuracy across non-practice trials (Mug and Truck). The front/back perspective trials were tested and coded separately from the side-view perspectives, for a total of four possible correct answers each (a total of eight possible correct across all front/back and side-view). Only the first response for the *experimenter's* perspective was coded for accuracy, unless the participant immediately corrected him/herself.

Spearman's correlations were conducted to assess the association between years without exposure to language and score on the Perspective Taking task (Figures 7 – 10). Years without exposure to language was measured as current age for the Homesigners (M_{age}=22.85, range= 10-35y), as they have not yet been exposed to a formal linguistic system. The age of entry into the schooling system for the Cohort 1 signers ($M_{age\text{-}of\text{-}entry}$ = 4.76) was considered to be their number of years without a language, and this value was zero for the Unschooled Spanish Speakers, as they were exposed to a fully developed linguistic system from birth.

No relationship was found between lack of exposure to language and score on Level 2 Perspective taking for either front/back or side-view trials (Front/Back $r_S[18] = -0.36$, $p = 0.11$; Side-View $r_S[18] = -0.14$, $p = 0.53$, Figures 7 and 8).

The second question at hand is whether experience in educational settings may have an impact on Perspective Taking abilities. As mentioned, most of the participants in previous studies (Masangkay et al., 1974, Flavell et al., 1981) who were able to succeed on Perspective Taking Level 2 tasks were recruited from educational programs (local nursery schools). While language may not be a key factor in developing Perspective Taking skills, it could have been that the structured environment and types of interactions available (the types and number of conversations with peers) may scaffold these abilities.

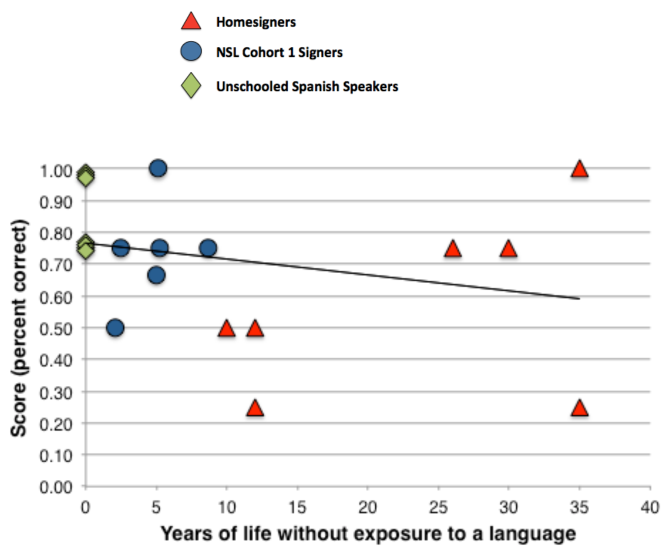


Figure 7: Perspective Taking of 3D objects - Front/Back perspective. Number of years without exposure to a language was not associated with scores on Front/Back 3D objects.

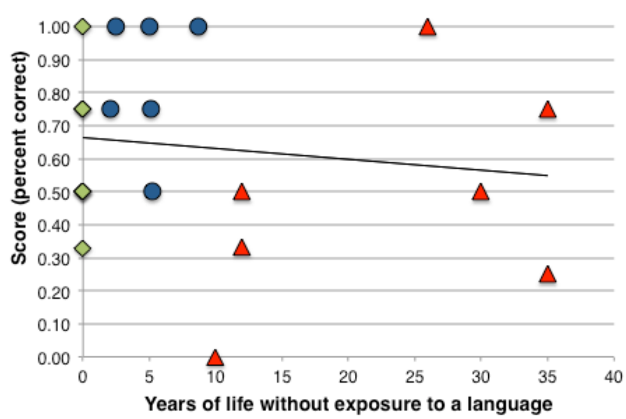


Figure 8: Perspective Taking of 3D objects - Side View. Number of years without exposure to a language was not associated with perspective taking ability of 3D objects - side view.

In our populations, however, educational experiences did *not* predict Perspective Taking Level 2 abilities for either the Front/Back perspectives or the Side-view perspectives (Front/Back $r_S[18] = -0.34$, $p = 0.14$; Side-View $r_S[18] = 0.22$, $p = 0.33$, Figures 9 and 10).

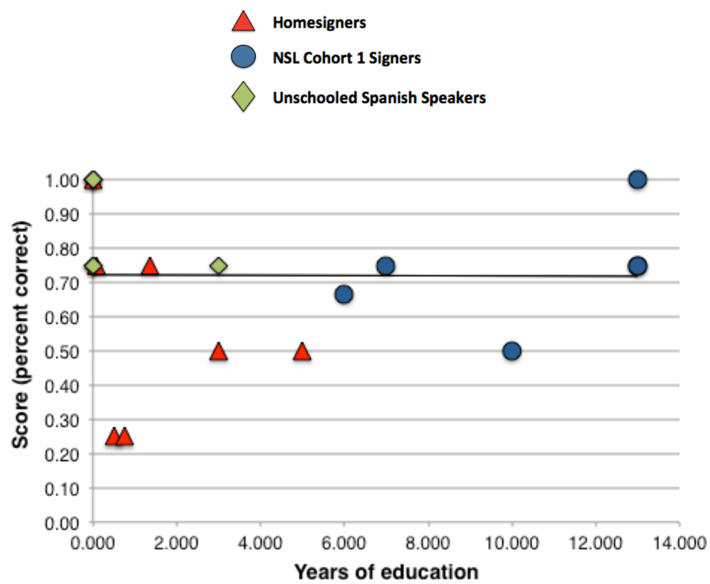


Figure 9: Perspective Taking of 3D objects - Front/Back perspective. Number of years of education was not associated with scores on Perspective Taking Front/Back tasks.

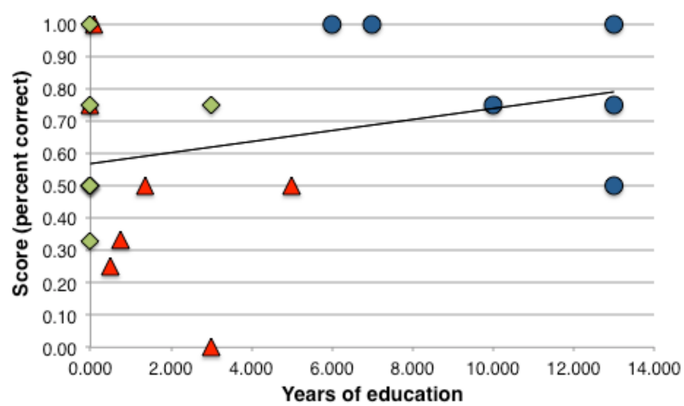


Figure 10: Perspective Taking of 3D objects - Side view. Number of years of education was not associated with scores on the Perspective Taking - side view of a 3D object task.

3.5 Discussion

The results show that both Level 1 and Level 2 Perspective Taking abilities are available regardless of exposure to a language or educational experiences. Under either condition, participants show that they understand that another individual can see things that they themselves cannot (Level 1), and that perspectives of objects simultaneously visible to themselves and others may nonetheless give rise to differing visual experiences (Level 2) (Flavell et al. 1981). In fact, for many participants in Level 1 and some in Level 2, the task was easy enough that participants often volunteered the Experimenter's perspective before the Experimenter could ask the question.

It is still clear, however, that Level 2 is harder than Level 1, given the fact that all participants scored perfectly on Level 1 but not on Level 2. This difficulty, however, doesn't seem to relate systematically to either language exposure or education.

So what do we make of the individuals who scored poorly on Level 2? First, we could consider a comparison of scores to chance-- for Level 2, chance performance is 25% (1/4 of the available perspective options: Front, back, Left side, Right side). Given this cutoff, only one participant scored below chance levels, although others hover around chance (three for side view: two homesigners and one NSL signer, and two on front/back, both homesigners). It is notable that the USS participants, while they did not score perfectly, were also not scoring as close to chance as these homesigners and NSL signer did.

This pattern of data might be also be interpreted as evidence of two distinct abilities: first, the *understanding* that another's experience or perspective may be different from your own, and second, the ability to *mentalize,* or actually take the other's

perspective. Even if the participant is *incorrect* in his or her prediction, the fact that they do not choose *their own* perspective seems to constitute evidence that an individual *understands* that another person has a different perspective from their own.

A post—hoc review of incorrect answers revealed that for the Front/Back perspective, 4 out of 7 homesigners, 3 of 6 NSL signers and 2 of 6 Unschooled Spanish Speaking (adults and children) consistently chose the picture that corresponded to *their own* perspective when they were asked about the *experimenter's* perspective, instead of one of the other perspectives (Side-view-Left or Side-view-Right). This pattern possibly sugggests that participants who answered in this way may have had a hard time even realizing that the experimenter had a different perspective from their own. However, the Side-view perspective results offer a more interesting interpretation. While the adult homesigners did *not* solely choose their own perspective as their (incorrect) answer in the side-view tasks, the (incorrect) answers they chose were always of the *front* of the item. This was also the case for only one NSL signer. The rest of the NSL signers' incorrect responses for the side-view were of their *own* perspective. It could be, perhaps, that in lieu of a good strategy for mentalizing another's perspective, the default could be to go for the "iconic" or forward-facing image of the object. The data here are too small to run statistical analyses—recall that this breakdown is *of the incorrect choices*: the responses that are left after first removing the correct choices from what was a small sample to begin with. Further work could investigate the question of the makeup of incorrect choices using a larger sample size.

Poor overall performance on Level 2 could also be accounted for by the difficulty that some participants may have had in understanding the task in the first place. While a

variety of strategies for explaining the task were employed, the experimenter's strategy of getting up and switching seats with the participant to demonstrate different perspectives was concentrated entirely within the deaf participant groups (Homesigners and NSL cohort 1 signers), although it was not used with every deaf participant. This could mean that deaf participants genuinely had a harder time understanding the task, but it also could mean that the experimenter found this to be the most efficient means of explaining the task. Further analysis of the videos is required to evaluate these possibilities.

Interestingly, for the Unschooled Spanish Speakers, novel means of solving the perspective questions arose. One particularly striking strategy was to talk through one's own perspective and therefore conclude the experimenter's. A paraphrased (and interpreted) solution to the Truck (side-view) question is as follows: "Hmm. I see the driver's side here, so you must be looking at the passenger side, and the passenger's side [picture] is here." Obviously language helped this participant in some way – language allowed him to hold in memory labels for each side ("driver's" vs. "passenger's" side) and then allowed him to articulate that *before* depending on the answer array for possible perspectives.

Another interesting linguistic, or communicative, note is that oftentimes sign language verbs expressing *seeing* are "directional verbs," that is, they can be modified to encode the object that is being seen (Sandler & Lillo Martin, 2006). Thus, it could be said that in the <u>gestural</u> or linguistic question posed by the experimenter, the experimenter could be unintentionally indicating the "answer" by indicating the side of the object closest to her either using a directional verb ("see X" or by pointing as part of the gestural question "What do I see?", and therefore, what her perspective is. If this were the case,

however, one would assume that the signers or homesigners would have some sort of an advantage in this task, which does not seem to be the case.

In sum, we see that Perspective Taking Skills are available to individuals regardless of their language background or educational experiences, but also that neither kind of experience guarantees success on this task. What should we make of the life experiences of individuals who do not succeed on Perspective Taking Level 2? Are they limited to the Perspective Taking Skills of a 2 – 3 year old typically developing child? It is more likely that the *understanding* exists, without the ability to actually *mentalize* the other perspective. Further investigations would need to be conducted (perhaps the same task but with more participants) to identify factors relating to success in Perspective Taking Level 2 for understanding vs. mentalization as well as to factor out other contributing factors.

4. Study 2: False Belief

4.1 Introduction

Over the last two decades, studies have shown that it is not the experience of being deaf itself, but the consequent delay in language exposure that causes a "delay" in the deaf child's ability to succeed at False Belief tasks (Courtin & Melot, 2005, Meristo et al., 2012, Moeller & Schick, 2006, Morgan & Kegl, 2006, Peterson, 1999, Rhys-Jones & Ellis, 2000, Schick et al., 2007, Woolfe et al., 2000,). What these studies have shown is that ToM abilities are *delayed* commensurate with the degree of delay in sign language exposure. But what if the child is *never* exposed to a language? Does ToM never progress past a certain point? This thesis takes as its central question the following: ***Can life experiences apart from language, or visuo-social experiences, provide enough***

information about others' thoughts, beliefs and desires to scaffold ToM development without the need for linguistic input?

This study is designed to complement previous work in Nicaragua (Pyers, 2005, Pyers & Senghas, 2009) by extending the populations studied to those who have had no exposure to signed or spoken language. Pyers (2005) and Pyers & Senghas (2009) worked with Nicaraguan signers, showing that the older members of the community (Cohort 1) who had no language models (no vertical transmission) but who had rich peer-to-peer linguistic experience (rich horizontal transmission) (Senghas et al., 2005) performed worse on a false belief task than the next cohort of signers (Cohort 2). Note that Cohort 2 signers had Cohort 1 as their language models; horizontal peer-to-peer interactions and their young age allowed them to surpass the language vertically transmitted to them through their interactions with Cohort 1 signers (their older peers).

Cohort 1, however, was not completely incapable of passing the FB tasks. They were *less* able to do so, and were more likely to pass Appearance /Reality FB tasks (4/8 participants) than to pass Unexpected Contents FB tasks (0/8 participants) (Pyers, 2005). ***Could it be that some aspects of FB understanding (such as the understanding about Appearance-Reality) are more readily available through social/ life experiences?***

The goal of this study is to investigate the possible contributions of social experience to the development of ToM. Hearing, Spanish-speaking participants with little to no schooling are included as a comparison group to Cohort 1, who have experience both in a linguistic community and with educational settings.

4.2: Participants

The participants were the adult participants from Study 1, with one additional

Unschooled Spanish speaking adult. All participants were Nicaraguan: 4 Homesigners (HS), 6 signers from Cohort 1, representing NSL's earliest users (NSL Signers), and 6 Unschooled Spanish Speakers who, like homesigners, had little to no education, but who, like the NSL signers, were part of a linguistic community (Table 1).

4.3 Materials and Procedure

In traditional FB tasks experimenters provide task instructions, content, and prompts using language, and participants respond verbally. Thus, a truly non-verbal FB task was needed to avoid any in-task linguistic requirements. Additionally, alternative FB tasks which are usually deemed "non-verbal" still have elements which require experience with activities typical of middle-class homes and educational contexts. For example, the picture-completion task used with NSL signers in Pyers & Senghas (2009) was not successful with Nicaraguan homesigners, and may also present issues for unschooled hearing Nicaraguans, who similarly may not appreciate the convention of sequentially presented still images representing continuous events in a narrative (as in storybooks). In our design, we strove to eliminate language from both the task instructions and task demands, and therefore used an experiential FB task adapted from Pyers (2005), described below.

Each participant was given first-hand *experience* with Appearance-Reality (A/R) and Unexpected Contents (UC) false belief situations. They then participated in a *prediction* game in which they earned money for making correct predictions. The procedure is described in great detail because the incremental, implicit understanding of the task instructions, and how participants should respond, are essential to our commitment to a minimally verbal procedure that fairly assesses the theory of mind

abilities of homesigners in particular. Table 4 summarizes the three phases and 14 trials that each participant saw, first for the experience, then again for the prediction condition.

4.3.1. Phase 1: Stickers:

The goal of Phase 1 was twofold. The *experience* condition familiarized participants with the process of choosing items from an array, and (nonverbally) demonstrated that a choice on a particular trial may be obvious (such as in an array of three originally identical stickers, one pristine, and the other two crumpled or ripped), or a choice might be based on preference (e.g., two different-colored smiley face stickers). In the *prediction* condition, the sticker phase provided the understanding that: 1) sometimes it is easy to predict someone else's behavior (obvious choice trials), 2) sometimes it is hard (individual preference trials), and 3) correct predictions earn them a small monetary reward (5 Córdobas per correct prediction (max. 70 Córdobas or US$2.75) across all trials (a healthy incentive given typical local incomes[13]).

4.3.2 Phase 2: Appearance/ Reality

In the Appearance/Reality phase, the participant saw three plates holding 1, 2, and 4 cookies. Unbeknownst to the participant, the four "cookies" were very convincing ceramic composite replicas. The experimenter encouraged each participant to indicate the "best" plate. For the homesigners, this was done by pointing at the participant, and then to the three plates of cookies, followed by a thumbs-up gesture with a questioning look. All participants chose the plate with four cookies during their experience phase; when encouraged to try a cookie, they discovered that the cookies were not real. The cookies were returned to their original array and the question or gestures were repeated, this time

[13] This monetary incentive was approved under University of Connecticut IRB # H10-306.

to test the participant's knowledge that the cookies were fake (thus the plate with 2 cookies should be chosen as the "best").

4.3.3 Phase 3: Unexpected Contents:

In the Unexpected Contents condition, the participant was presented with one of two arrays: paper, a glass, a lock, and a candle *or* a notebook, a mug, a lockbox and a box of cigarettes (Table 4). The participant was then presented with a series of tools and was asked to indicate which object in the array each tool is used with. First, the participant was presented with a pen, and had to match it with an object (paper or notebook). Upon choosing the paper, the participant was asked to make a mark on the paper. The participant was then presented with a pitcher of water and asked to match it to an object (the glass or mug). Upon choosing, the participant was asked to pour water into the vessel. Third, the participant was presented with the matchbox (containing a key, but no matches), and again asked to match it to an object (in the False Belief trial, the participant should choose the candle or cigarettes, but in the knowledge trial, the participant should know that the matchbox contains a key and choose the lock or lockbox). Upon choosing the candle or cigarettes, the participant was encouraged to light the candle or a cigarette, and subsequently discovered that the matchbox contained a key, not matches. The array was then switched (i.e., paper to notebook, etc.) but the three tools (pen, pitcher, and matchbox) were left in view of the participant, so he or she could see that no one, including the experimenter, touched them. The entirety of the Unexpected Contents condition was repeated, now with the participant knowing what was in the matchbox, matching tools to their objects. Note, the key trial is the matchbox trial, during which the participant should demonstrate his or her knowledge that the matchbox contained a key

(instead of matches), and thus should be matched with the lock/lockbox, not the candle/cigarettes. In the *prediction* phase (i.e., when the participant is predicting the choices of a confederate), the first two tools (pen, pitcher of water) set the participant up for the tool-matching paradigm, while the third (matchbox containing a key) presented first a false belief, then a test of knowledge.

Figure 11: Participant engaged in the experiencer phase of the False Belief task.

Figure 12: Participant engaged in the Predictor phase of the False Belief task.

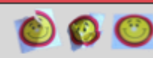
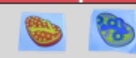
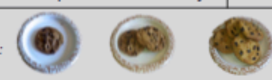
Trial	Goal(s)	Prompt	Visual Stimuli	Anticipated response
Stickers/Choice Training:		Sample Obvious Choice array: 		Sample Individual Preference array: 
1	Some decisions/ predictions are easy	Which is best?	Obvious choice array	Undamaged sticker
2			Obvious choice array	Undamaged sticker
3	Some decisions/ predictions depend on preferences		Individual preference array	Either sticker
4			Individual preference array	Either sticker
5			Obvious choice array	Undamaged sticker
6			Individual preference array	Either sticker
Appearance/Reality:		Plate with 4 cookies contains fake cookies: 		
7	Experience False Belief	Which is best?	1, 2, 4 cookies on plates	Plate with 4 cookies
8	Test Knowledge		1, 2, 4 cookies on plates	Plate with 2 cookies
Unexpected Contents:		Tool: Matchbox (contains key) 	Sample Object array: 	
9	Introduce tool/object matching routine	What does this (tool) go with?	Pen (tool)	Notebook (object)
10			Pitcher	Cup
11	Experience False Belief		Matchbox (containing key)	Candle
12			Pen	Notebook
13			Pitcher	Cup
14	Test Knowledge		Matchbox (containing key)	Lock

Table 4: The phases and individual trials that each participant saw, once as an experiencer and then once as a predictor of a confederate's choices. All relevant ordering possibilities were counterbalanced.

To reiterate, after experiencing the entire task, and more importantly, directly experiencing the false beliefs, each participant participated in all trials again, but this time as a *predictor* of another's choices (Figure 12) – a confederate who was a member of the research team but who had not previously participated in any aspect of this task. The participant indicated the item the confederate would choose, before the confederate actually made a selection, by marking a set of laminated sheets containing images of all the arrays.

4.4 Results

A participant had to correctly predict the confederate's choices in both the Appearance/ Reality and Unexpected Contents conditions to pass the task overall (see Figure 13), light and dark red bars, for proportion of participants passing each subtest). For the Appearance/ Reality condition, a participant passed if they predicted that the

confederate would choose the plate with 4 (fake) cookies; participants failed this task if they predicted that the confederate would choose the plate with two cookies. For the Unexpected Contents condition, a participant passed if they predicted that the confederate would match the matchbox to the item to be lit (i.e., the cigarettes or the candle), and failed if they predicted that the confederate matched the matchbox to the item that needed a key (i.e., the lock or the lockbox). None of the Homesigners, who lack a linguistic community, passed; however, immersion in a linguistic community did not guarantee passing for NSL signers and Unschooled Spanish Speakers. In sum, for Appearance/ Reality, no homesigner passed, 3 out of 6 NSL signers passed (50%), and 4 out of 6 of the Unschooled Spanish Speakers passed (67%). For Unexpected Contents, no homesigner passed, 1 out of 6 NSL signers passed (16%), and 3 out of 6 Unschooled Spanish Speakers passed (50%) (Figure 13).

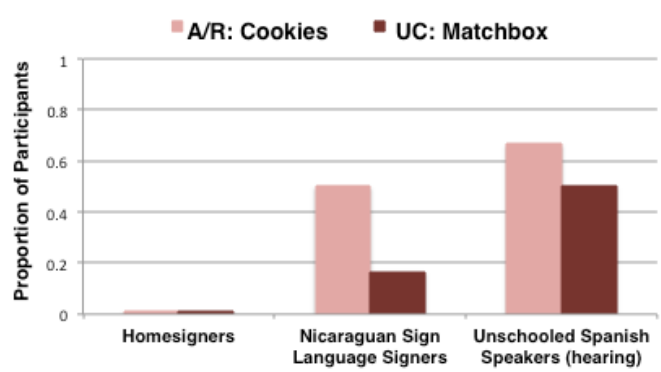


Figure 13: Proportion of each group that *passed* each task. No participant passed the Unexpected Contents condition without also passing Appearance/Reality, thus the scores for Unexpected Contents were the same as passing the task overall.

Despite the difficulty that some of the Spanish speakers had with the task, the Spearman's rho revealed a significant inverse relationship between the amount of time an individual lacked a linguistic community and Appearance Reality score ($r_S[14] = -0.51$, $p = 0.038$) and Unexpected Contents score ($r_S[14] = -.48$, $p = 0.049$). The Spearman's rho

failed to reveal a statistically significant relationship between education and either FB task (Appearance /Reality: $r_S[14] = .11$, $p = .680$; Unexpected Contents: ($r_S[14] = .06$, $p = 0.813$).

To increase our understanding of the relationship between language, social experiences, education and False Belief understanding, participants were given scores of 0, 1, or 2, depending on whether they passed none, one, or both False Belief phases respectively. This was their *overall* score. Years without a linguistic community significantly related to overall scores ($r_S[14] = -.56$, $p = 0.024$), but years of educational experience was not ($r_S[14] = 0.06$, $p = 0.829$) (Figures 14 and 15).

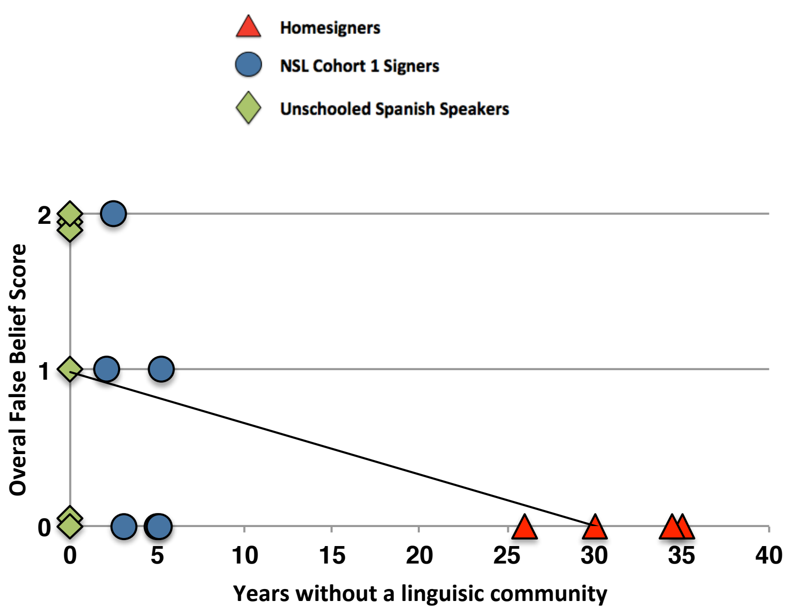


Figure 14: Years without a linguistic community was significantly and negatively related to overall False Belief scores.

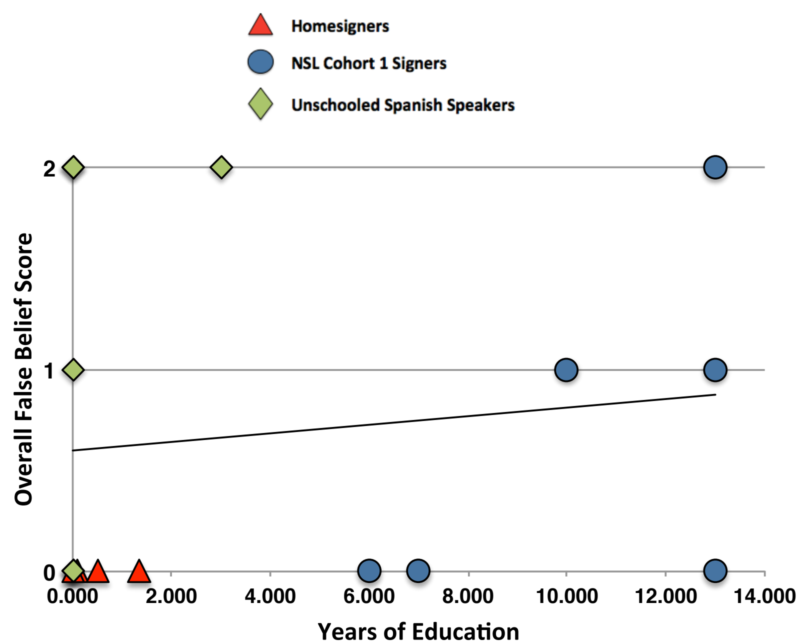


Figure 15: Years of educational experience was not related to overall False Belief scores.

4.5 Discussion

4.5.1 Effects of linguistic community and education

In sum, as strength of linguistic community increased (with Homesigners having the weakest, and hearing Nicaraguans the strongest), the passing rate for both conditions of the False Belief task increased significantly. Notably, hearing Nicaraguans did not universally pass either task, in conflict with the prediction that membership in a linguistic community (and consequent exposure from birth to an established language) would enable passing. These results not only demonstrate a positive relationship between participation in a linguistic community and success on the FB task; they also refute the Simulation Theorists' position (e.g., Goldman, 1992, Gordon, 1986) that life experiences are enough to promote understanding of others' beliefs. If it were the case that life experiences were sufficient, as they argue, then all three groups (including the homesigners) should have been able to predict the confederate's choices with ease.

It is also notable that typically developing, hearing, American five- year-olds usually pass what would be considered more linguistically complex False Belief tasks. While some variation exists cross-culturally, cross-linguistically, and across varied socioeconomic backgrounds (Chasiotis et al., 2006, Cicchetti et al., 2003, Liu et al, 2008, Noble et al., 2005, Shahaeian, 2014, Shatz et al., 2003, Slaughter & Perez-Zapata, 2014) in the average age of passing these types of false belief, with the upper age limit of about 9 years old for some linguistic groups (e.g., Slaughter & Perez-Zapata, 2014), we note that the children in these studies do eventually pass sometime in childhood, and their struggles with the False Belief task do not persist into adolescence. Specifically, these children are younger than the participants in this study[14] and therefore presumably have less life experience to draw from than do the homesigners. All of the children studied across these cultures, however, do have the benefit of participation in a linguistic community *plus* the benefit of (some) educational experience, usually.

While education did *not* predict passing rates for our participant groups, it is likely that education level and language interact for typically developing American children, as well as for the current participants. This is suggested by the fact that the four individuals who passed both tasks (who received an overall score of "2" – one NSL signer and three Spanish speakers) have certain traits that either give them an advantage linguistically or "educationally." More specifically, the one NSL signer who scored a "2" represents the youngest of his cohort of signers. He spends a lot of time with members of the next cohort (Cohort 2, who uses a more grammatically complex form of NSL than Cohort 1 does (e.g., Senghas, 2003, Senghas et al., 2004, 2005) and is likely to

[14] With the exception of one nine-year-old adolescent participant who did not participate in the False Belief task, but contributed to the Perspective Taking and Executive Function tasks.

have access[15] to the mental state language that Cohort 2 uses more often than Cohort 1 members would (Pyers & Senghas, 2009). Therefore, he has a boost of the linguistic kind. The three Spanish speakers, however, who had full and early access to a linguistic community, but who did not have formal education are nevertheless "leaders" – two are the equivalent of foremen on their farms and the third is a small business owner. While we cannot disambiguate whether, for instance, these individuals already had some sort of skills that led them to become the leaders they are now, or whether being put in the position of being a leader helped them develop these ToM abilities.

Finally, it is also of note that the passing rates differed for Appearance /Reality and Unexpected Contents, suggesting that these subtasks tap different aspects of False Belief understanding, as previously suggested by Pyers (2005).

4.5.2. Ensuring comprehension of the task

We can be confident that participants, including the homesigners, understood the FB task based on its design and from the research team's years of experience working with these individuals on a variety of language and cognitive tasks. Unlike traditional FB tasks, the current task instructs via *experience* rather than verbally - while language was used for those who had it, it was not the key testing factor – no predictions had to be put in the form of a sentence and the experiences spoke for themselves: the task phases gave participants experiences prior to making predictions– the very experiences that a Simulation Theorist would expect to scaffold predictions about another's choices.

The sticker phase provided the experience of making easy vs. hard (preference) choices, and then participants experienced earning or not earning incentives for correct

[15] These materials unfortunately did not elicit sufficient mental state language to evaluate the association between the *production* of mental state terms and False Belief success.

predictions. An additional control is built into the Unexpected Contents phase: a correct prediction of candle/cigarettes (for the matchbox) could come about in three ways: 1) the participant actually understood the other person's FB; 2) they forgot what was actually in the box and were just responding based on appearances (the matchbox calls for the candle), or 3) they didn't understand the task, and simply answered on the basis of the appearance of the box. However, in our dataset, whenever a participant did *not* succeed, they erroneously predicted the lock/lockbox to be the item that the matchbox calls for, thus showing that they 1) remembered what was in the matchbox (a key) and assumed that the confederate *also* must know that there is a key in the matchbox. Again, this is evidence that they had not forgotten what was in the box and were actually trying to predict the tool match (as opposed to choosing some other object in the array because they didn't understand the task). Moreover, the homesigners never indicated that they thought they were being fooled. To ensure trust, items for the FB task were never moved from the participant's sight.

In sum, the task design ensures that participants understood the task because it (1) instructs via experience rather than language; (2) gives participants experiences before making predictions; (3) includes training items for easy vs. hard (preference) choices; (4) builds in memory checks; and (5) provides monetary incentives for correct predictions. Regardless of how well individual participants comprehended the task, no participant group universally passed, showing that no factor (education, participation in a linguistic community, or life/ social experiences) guarantees passing. Overall, the best predictor of success on the task was participation in a linguistic community, and life experiences were shown (by the homesigners' failure to pass either FB phase) to *not* scaffold FB success.

5. Studies 3 and 4: Executive Function

5.1 Introduction

When studying the development of Theory of Mind abilities we should consider not only the relative contributions of language experience and social experiences, but also executive functioning abilities (which also may be influenced by life experiences such as social or linguistic input) (see section 1.3 for a definition and discussion of the Executive Functions).

Two executive function (EF) skills in particular have been tested as part of the current research program. The first EF study investigates Inhibitory Control (IC), the ability to inhibit one piece of information or rule, in favor of another, and the second investigates Working Memory (WM), or the ability to encode information and later transform that information for one's use and their respective relations to language and education. To our knowledge this study is the first to investigate EF abilities in these groups.

Both IC and WM have been hypothesized to lend a hand in ToM development (particularly for the FB task) for seemingly obvious reasons. First, WM allows us to encode the information of the reality of the situation and/or what we believe to be true, and the transformational aspect of WM allows us to update our knowledge as we learn what we may have thought to be true to not be true (the realization of our own false belief), and to encode the new reality (Carlson et al, 2002). IC then provides us with the ability to suppress what we now know to be true in favor what must be true for another individual given *their* reality. This goes beyond simply understanding *that* others have their own thoughts and beliefs to a level of processing that then can *imagine*, or *mentalize*

the other's reality and predict behavior according to one's own assumptions of that other person's reality.

5.2 Study 3: Inhibitory Control

5.2.1 Introduction

Inhibitory Control (IC) Executive Functioning abilities were tested in our populations using a simple mixed congruent/incongruent task adapted from Shusterman et al. (2012) that required minimal verbal instruction and required only a behavioral response (vs. a verbal response). This task was chosen because it has been used with young deaf populations in the United States, and because the conflict of rules parallels a FB trial: one must suppress one rule (or truth) for another.

This study aims to answer the following question: ***Is the ability to inhibit one rule in favor of another, and more specifically, is the ability to switch between rules dependent on one's language experience or educational experiences?***

5.2.2 Participants

All participants were the same as in Study 1: Perspective Taking.

5.2.3 Materials and Procedure

The experimenter sat across from the participant, with two 6"-diameter light-buttons on the table between them (Figure 14). In the instruction portion, the experimenter donned a black or white glove on her right hand and gesturally or verbally instructed the participant that when she tapped a button with that hand, the participant was to tap the same button. This was demonstrated for each of the two buttons. The participant then received two more practice trials with feedback, one for each of the buttons. The experiment had three testing phases (Table 5): 1) Right hand; 2) Left hand;

3) Both hands (Figure 14). In the first testing phase, the experimenter tapped the buttons with her right hand in a prescribed pattern (3 times on the left, 3 times on the right, 6 times total), and the participant had to tap the same button as the experimenter each time.

In phase 2, a new rule was introduced, and the experimenter used her left hand instead of her right hand. The left hand "rule" was that whichever button was tapped, the participant had to tap the *other* button. Laterality of glove color was counterbalanced across participants (i.e., if the right hand had had a black glove in phase 1, then the left hand had the white glove). A few practice trials with feedback were followed by 6 test trials, as in phase 1.

In the third phase *both* gloved hands (one black and one white), tapped the buttons (Figure 16). Both rules from phase 1 and phase 2 continued to apply: when the right hand tapped a button, the participant still had to tap the *same* button; likewise, when the left hand tapped a button, the participant had to tap the *other* button. Note that the glove color/ hand did not change from the control phases. Phase 3 contained 12 trials, with four possible hand/button combinations. All participants, including the homesigners, clearly understood the rules (see results for Phases 1 and 2 below); in fact, homesigners enjoyed the task so much that they afterward donned the gloves themselves to play with others as a diversion.

Figure 16: Participant receiving gestural instructions for Phase 3 of the Inhibitory Control task.

Phase	Task
1) White glove rule 	Participant must tap the SAME button as experimenter
2) Black glove rule 	Participant must tap the button NOT tapped by experimenter
3) Both gloves / Mixed rules  	Participant must switch between the two rules

Table 5: The three phases of the Inhibitory Control task, along with the glove color and task rule(s).

5.2.4 Results

All participants scored well above chance (50%) on control phases 1 and 2 (right & left hands alone, with a switch in between), (Homesigners' mean =90%, NSL Cohort 1 signers' mean =95%, Unschooled Spanish Speakers' mean =86%), showing they understood the task. The phase of interest is the <u>third</u> phase, which required the participants to <u>maintain two conflicting instructions</u> – to either tap the *same* or the *other* button, depending on the hand being used/glove color.

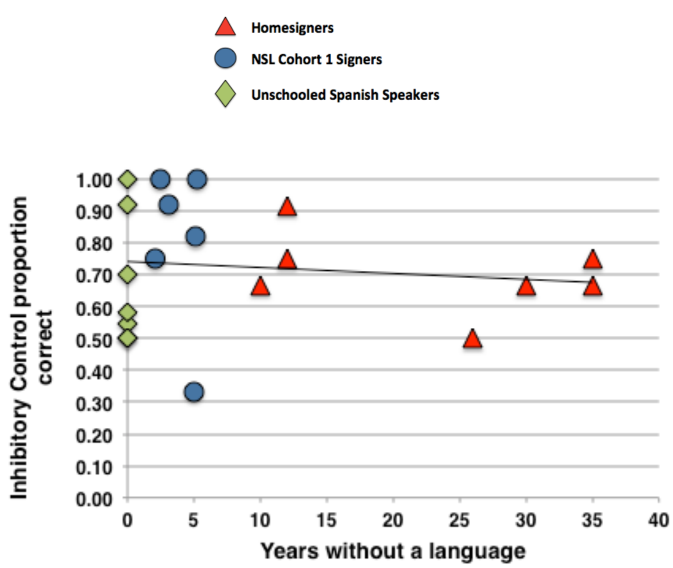


Figure 17: Years without a language was not associated with success on the Inhibitory Control task (r_S[18] = 0.041, *p* = 0.86).

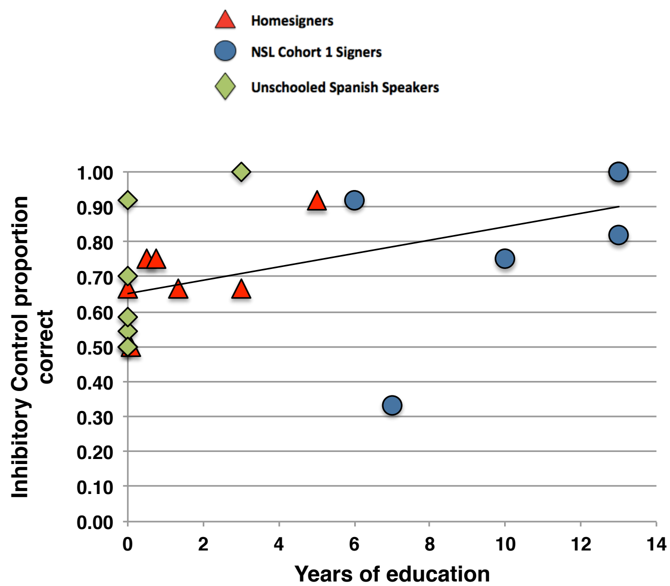


Figure 18: Years of educational experience was significantly associated with Inhibitory Control scores (r_S[18] = 0.54, *p* = 0.014).

Figures 17 and 18 present individual IC scores as predicted by years without language exposure (Figure 17) or years of educational experience (Figure 18). Spearman's nonparametric analyses showed no relationship between a delay in language exposure (years without a language) and IC score ($r_S[18] = 0.041$, $p = 0.86$). A significant relationship was found, however, between years of educational experiences and IC score ($r_S[18] = 0.54$, $p = 0.014$).

5.2.5 Discussion

The fact that NSL Signers, the only group with significant educational experiences, tended to score higher than the other two groups, along with our significant regression results, strongly suggest that education plays a role in developing Inhibitory Control EF abilities. Somewhat surprisingly, early language exposure did *not* predict IC scores, suggesting that having a native language alone does not ensure success on this task. This is surprisingly contrary to results from previous Executive Function studies

comparing native signing deaf children and adults to those who acquired a sign language later in life (Contreras et al., 2013). It is most likely that an interaction exists between language and education for executive function abilities: the participants in previous studies all had educational experiences, but the participants with early language exposure were also most likely to have capitalized on their early educational experiences. Our design, however, cannot distinguish between membership in a language community combined with education and education alone.

This is also contrary to previous results with unschooled adults from rural areas (Ostrosky-Solis et al., 2004) that showed that there were no EF differences between unschooled adults and those with educational experiences. We must point out, however that it may be likely that their task was not sensitive enough to the type of Inhibitory-control that was tested here. The task described in Ostrosky-Solis et al., (2004) parallels more with our phases 1 and 2, where there is a single switch of rules (e.g., right hand to left hand), and where the second rule is then maintained. Ostrosky-Solis (2004) do not describe any phase where the two rules alternate, or conflict. This Conflict-Inhibitory-Control phase was the crucial phase in which we found differences between our groups, with Education resulting as the significant relation to IC abilities.

In sum, a *community language* (even an emerging one) combined with *moderate* levels of education apparently enabled NSL Signers to pass at a higher rate than the other two groups. Notably, NSL Signers' lack of a conventionalized language and the fact that their primary language was not even used in their classrooms did not prevent the majority of them from achieving criterion.

5.3. Study 4: Working Memory

5.3.1 Introduction

Previous work (e.g., Gordon & Olson, 1998, Carlson et al., 2002, a.o.) has suggested ties between EF abilities and ToM development. They suggest that ToM abilities must tap into other "computational resources" in order to make correct predictions about others' beliefs or desires. One of these computational resources is one's ability to encode information and later transform that information dependent on a task, known as Working Memory (WM) abilities.

In this study, participants engaged in a visuospatial span task of short-term memory, known widely as the Corsi block-tapping task (CBT) (Kessels et al., 2000). While the Corsi block task is typically considered a span task, the reverse Corsi has been argued to be a better test of working memory rather than rote span memory (Eigsti, 2001) and thus more suited to the Working Memory needs of ToM (Gordon & Olson, 1998). This is because the participant must encode the original span, then "transform" the encoded memory in order to produce the same span in reverse.

This CBT-like spatial memory span task was chosen over other working memory tasks because its spatial properties are well suited for nonverbal testing of populations such as homesigners and NSL signers, whose verbal skills (in either a sign or spoken language) may be compromised.

This study aims to answer the following question: ***Is the ability to encode information and later transform, or update, it for use dependent on one's language or educational experiences?***

5.3.2 Participants

All participants were the same as for Study 1: Perspective Taking and Study 3: Inhibitory Control.

5.3.3 Materials and Procedure

Participants were tested using a Corsi-like block-tapping task that was created to match the format of other Corsi-like spatial memory span tasks. A thin, sturdy board, approximately ¼ inch in thickness was painted bright blue and then had nine 2”x2”x2” blocks affixed to it in a specified random pattern in which the spaces between the blocks varied in order to avoid any sort of visual pattern (Figure 17). The 2x2x2 blocks were painted white and had a number written on one side so that the experimenter could see them, but the participant could not (Figures 19 and 20).

The block-tapping pattern was created by first randomizing numbers one through nine (1-9) fourteen times, and then selecting the first two numbers from the first randomized string for trial 1a, the first two numbers from the second randomized string for trial Forward 1b, the first three numbers from the third randomized string for trial 2a, and so on, through trial Forward 7b. Reverse trials were then created by (a) switching the order of trials within each block set, and then (b) reversing the order of taps within each trial. For example, Froward trial 1a consisted of tapping square number 6 then 7,

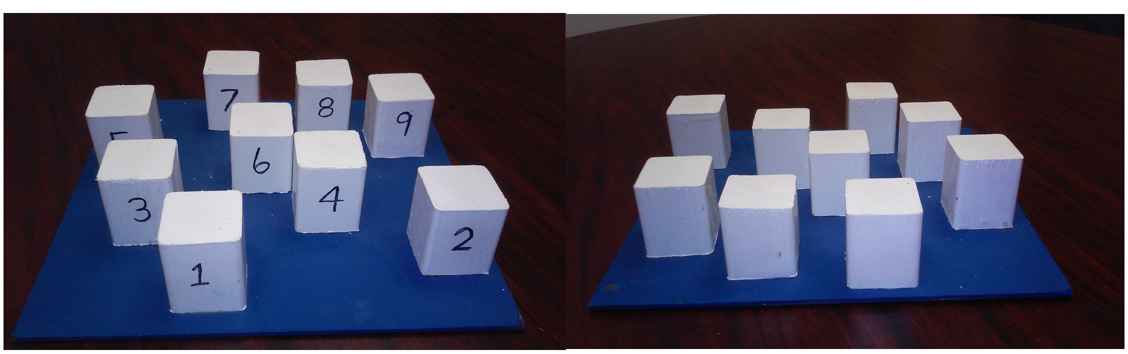


Figure 19: Views of the Corsi Block Task, from the experimenter's and participant's views, respectively.

Figure 20: Participant engaged in the Corsi Block Task.

and Forward trial 1b consisted of tapping square number 1 then 2. Reverse trial 1a consisted of square 2 then 1 and Reverse trial 1b consisted of square 7 then 6 (See Appendix B).

Participants were tested in a quiet area with minimal distractions. The experimenter sat across from the participant with a table between them whenever possible (see footnote 10) and provided them with spoken (for Spanish speaking participants), signed (for Cohort 1 signers), or gestural (for Homesigners) instructions. As part of the instructions, the experimenter tapped two blocks in sequence and encouraged the participant to tap the same two blocks in the same sequence. Practice and reiteration of the instructions was permitted for any participant who struggled with this. The test proceeded when the participant tapped the correct two blocks in the correct sequence twice (both trials for the span of 2). The experimenter gauged the participant's understanding at this point and provided feedback, reiteration, and more two-block

sequences if necessary.

Once the task started, the experimenter proceeded through the next 14 trials of increasingly longer spans. Spans ranged from 2 blocks tapped to 9 blocks tapped. No block was tapped twice in any sequence, and each span had two trials (i.e., two spans of two, two spans of three, two spans of four, etc.). The tapping rate was about 1 second between each tap, with no longer pauses.

Following the "Forward" span described above, the experimenter then explained (using the appropriate means of communication for the participant) that now the spans would be reversed – the experimenter would tap blocks and the participant was expected to tap the same blocks in reverse order. Again, the experimenter used the 2-span block to provide feedback, imitation, and instruction as needed to help the participant understand. The same strategies were employed as were described for the "forward" span.

All participants were tested for all spans; which deviates from the typical block tapping span protocol. This was done for two reasons – first, the spans were not coded "live" as they usually are in the CBT – all block tapping tasks for this study were videotaped for later coding. Second, the experimenter was sensitive to the fact that participants may be aware of their failures on many tasks and did not want to give them the impression that they were "failing" by scoring them live and ending the task prematurely. Instead, the experimenter nodded for all spans (after the initial round of feedback/ correction/ practice) without indicating whether the participant had actually succeeded.

Each participant received two scores for each of the forward and reverse span tasks, following the procedure outlined in Kessels et al. (2000) for the original CBT:

First they received a Span score, which indicates the longest correct span of blocks tapped within that task (forward or reverse), and second they received a Total score which is the product of the Span score and the number of correctly repeated sequences (Kessels et al., 2000). In the typical Corsi protocol, the test ends once the participant is unable to correctly repeat both sequences in any block. For example, a participant (we'll call him Participant A) could produce both sequences correctly in each of the blocks for spans 2 and 3, then one sequence correct in each of 4 and 5, and once he reaches the block for the span of 6, he incorrectly reproduces both the tapping sequences. At this point the experimenter in a typical protocol would have stopped the test. In our study, the experimenter continued the test through all blocks, but the scoring of the test followed the typical protocol in that once a participant incorrectly produces both sequences in a block, we have then found his or her "Span," as if the test had stopped at that point. This was done separately for "forward" and "reverse" tasks, given arguments that they do not necessarily test the same type of working memory (Eigsti, 2001).

For Participant A above, this means he achieved a *Span* of 5 (longest correctly produced sequence), and correctly produced 6 sequences (2+2+1+1)[16], which is then used to calculate his Total score of 30 (Span of 5 x 6 correct sequences). Participant B, however, may also have a Span of 5 but may have struggled all along, having produced only 1 correct sequence per block (1+1+1+1 = 4 correct sequences). Her Total score would then be 20 (Span of 5 x 4 correct sequences). The Total score is therefore a better measure of the robustness of the participant's ability at the task.

[16] Note that because there is no "span" of 1, achieving a span of five means the participant has only participated in blocks of 2, 3, 4 and 5 spans.

5.3.4 Results

Spearman's correlations testing the relationship between *educational experiences* or *years without a language* and both forward and reverse *span* and *score* were conducted, for a total of 8 analyses. Years of education and years without a language were input for each participant as they were for the studies of Perspective Taking and Inhibitory Control.

Forward memory span scores did not show any significant relationship with either years without a language (Span: $r_S[18] = 0.197$, $p = 0.40$, Total score: $r_S[18] = 0.353$, $p = 0.13$), or educational experience (Span: $r_S[18] = -0.050$, $p = 0.83$, Total score: $r_S[18] = 0.015$, $p = 0.95$).

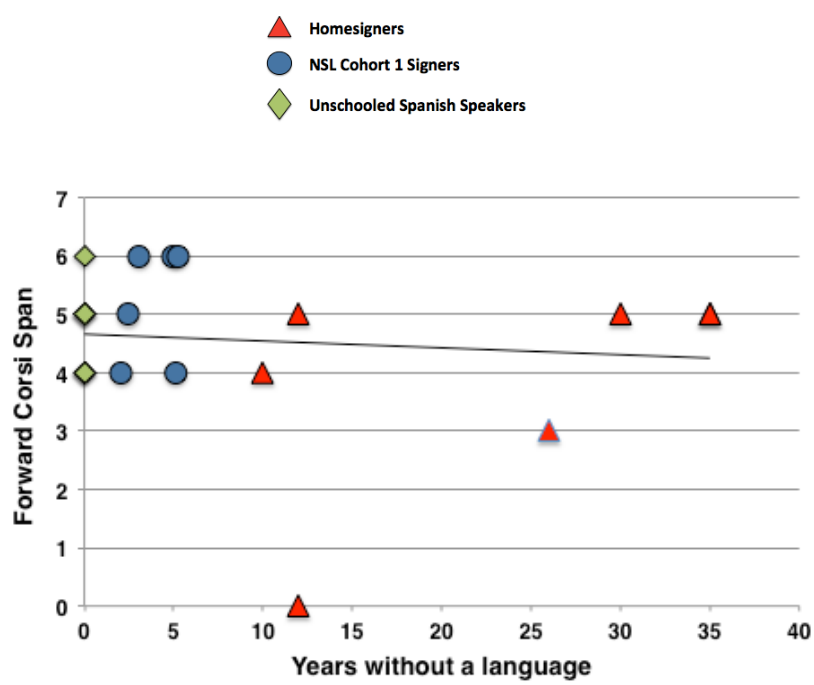


Figure 21: Years of life without exposure to a language did not predict forward memory spans.

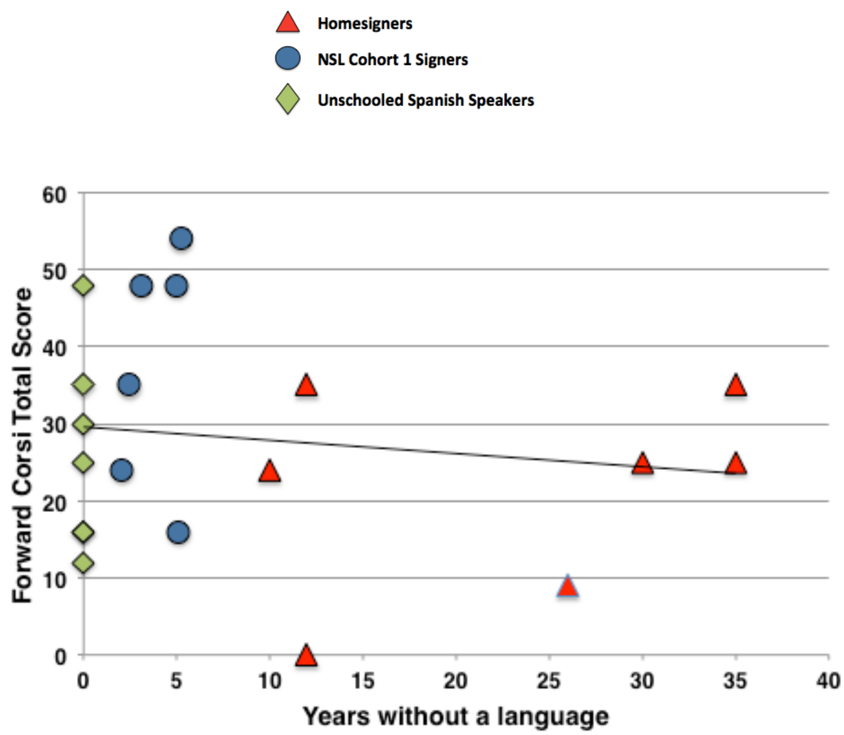


Figure 22: Years of life without language exposure did not predict forward memory span total scores.

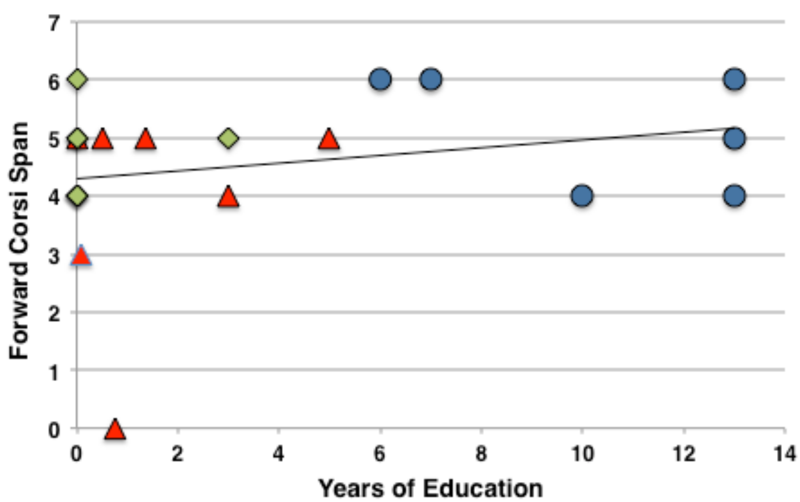


Figure 23: Years of educational experience did not predict forward memory Spans.

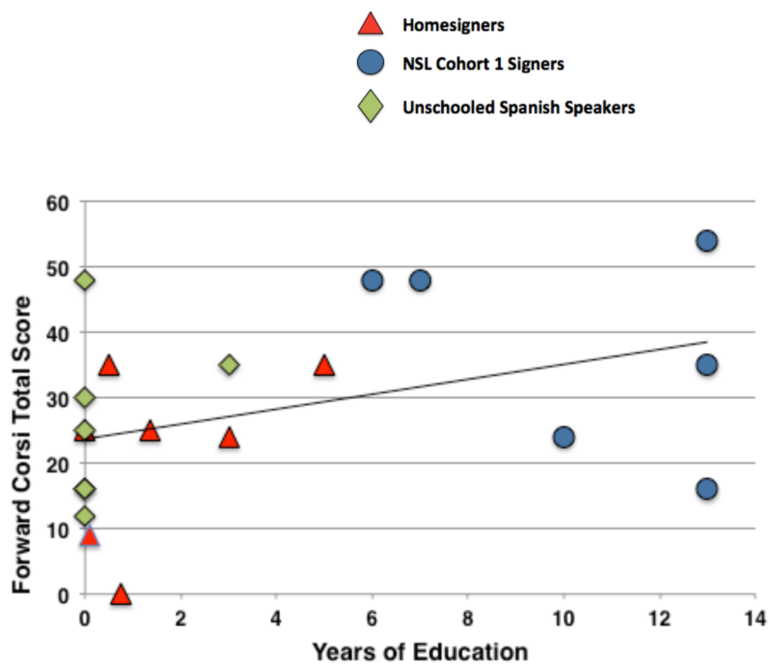


Figure 24: Years of educational experience did not predict forward memory span Total scores.

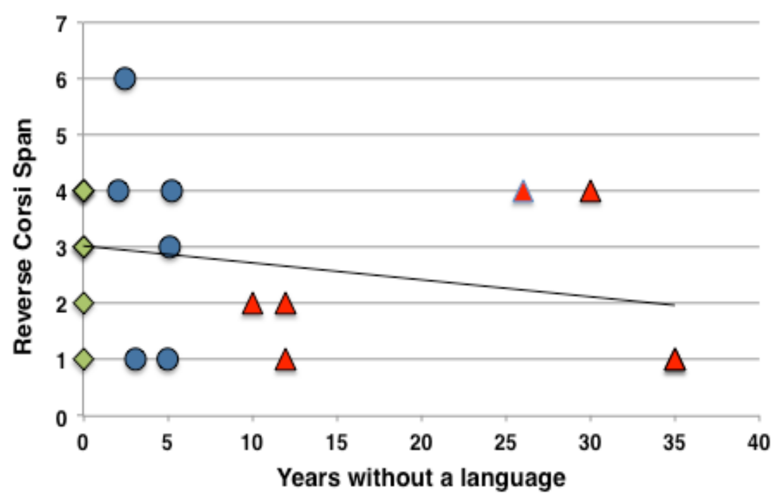


Figure 25: Years without a language did not predict Reverse memory Spans.

Likewise, reverse memory span scores for years without a language (Span: $r_S[18] = -0.272$, $p = 0.25$, Total score: $r_S[18] = -0.42$, $p = 0.066$) or Years of Education (Span: $r_S[18] = 0.171$, $p = 0.47$, Total score: $r_S[18] = 0.176$, $p = 0.45$) yielded no significant results, although the relationship between years without a language and reverse score approached significance.

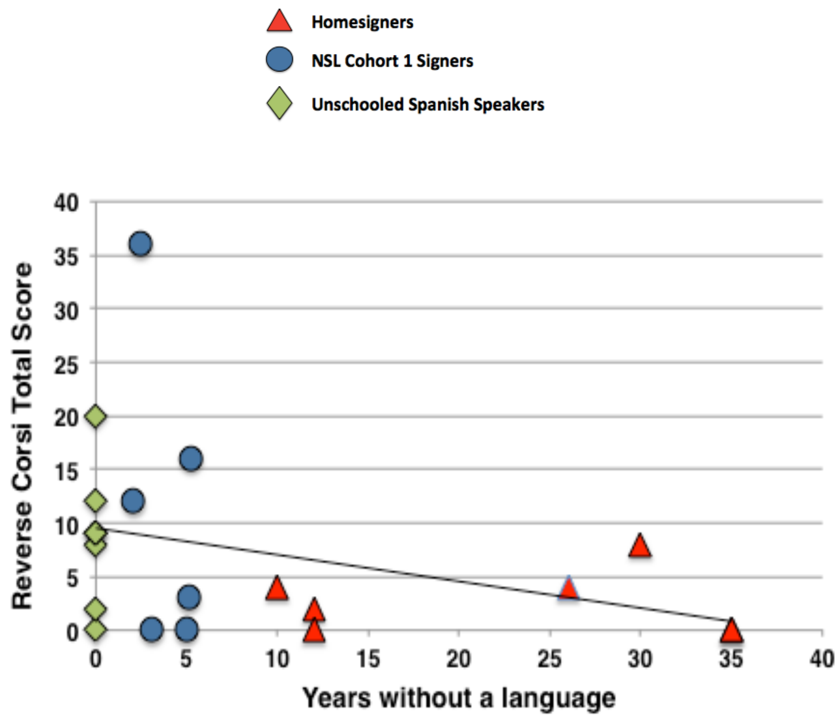


Figure 26: Years without exposure to a language did not predict Reverse memory span Total scores.

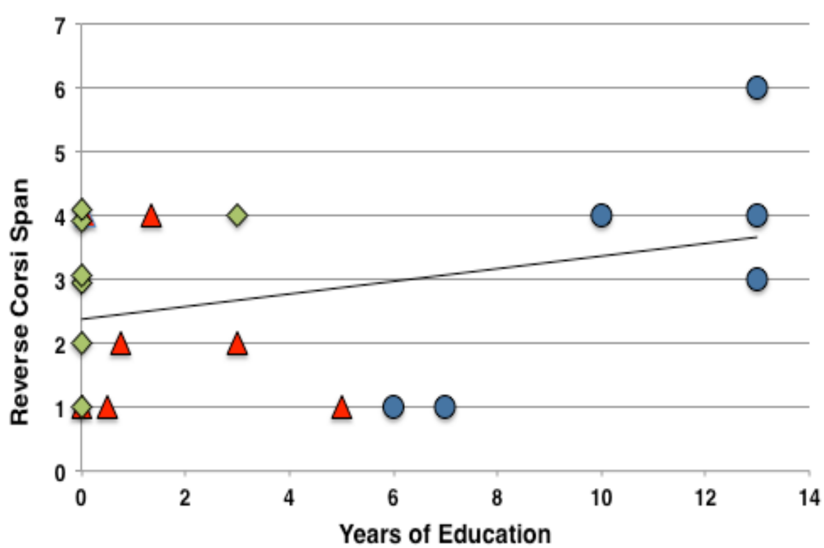


Figure 27: Years of educational experiences did not predict Reverse memory Spans.

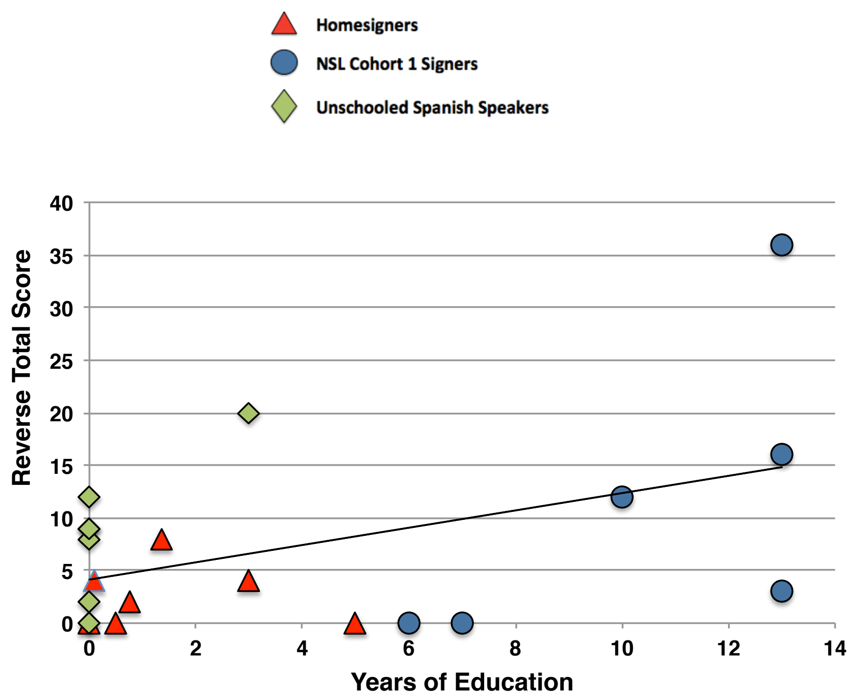


Figure 28: Years of educational experience did not predict Reverse memory span Total Scores.

5.3.5 Discussion

All participants achieved similar spans for the forward and reverse memory span tasks, but only years without a linguistic community came close to significantly relating to Reverse Total scores. As reverse span tasks have been argued to be a better measure of working memory (Eigsti 2001), we interpret this finding to mean that language may provide a better scaffold than educational experiences for the development of this executive function skill.

Kessels et al. (2000) attempted to establish a standard of Corsi scoring by testing 140 typically developing American adults. They found the mean forward Total score in this population to be between 40 and 50. The *overall* mean forward score across the groups in the current study was 28 (Figure 29); Homesigners had a mean score of 21.8, Cohort 1 37.5, and Unschooled Spanish Speakers 26. These results introduce a second possible factor over linguistic community – recall that the reason for introducing the

Unschooled Spanish Speakers was to factor out language or education in any results from the NSL signers. Considering that the NSL signers have the highest mean forward score, it could be that their education, or even namely the fact that their education not only introduces them to a first, but also a second (written) language (Spanish) that may give them an extra boost.

This isn't unheard of, in fact Kovacs (2009) argues for the benefit for bilingualism in False Belief tasks. Could the bilingualism factor in to one of the supporting (e.g., perspective taking or EF skills) rather than directly into the False Belief task? This will be addressed further in section 7.

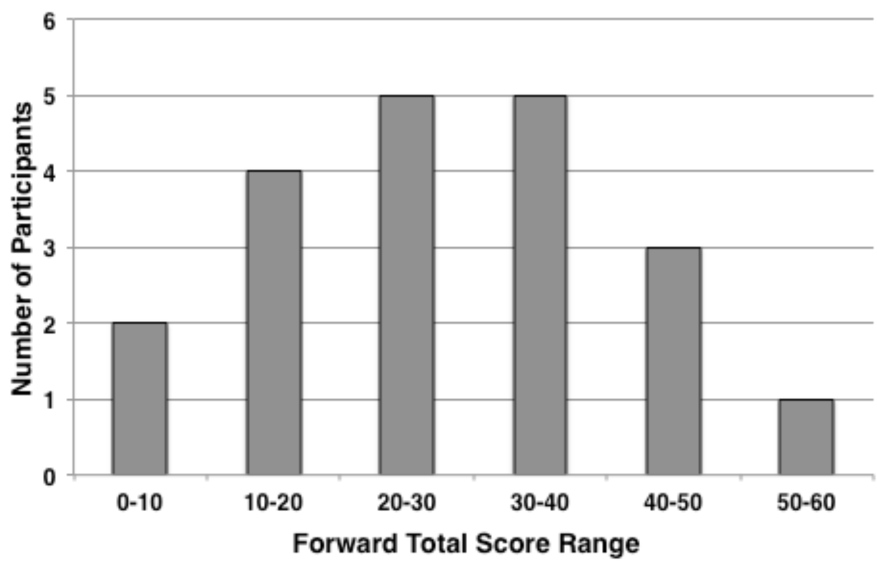


Figure 29: Number of participants (from all groups) in each forward Total Score range.

To be assured that participants understood the task, incorrect responses were also coded for items in which participants nevertheless included the correct blocks tapped (and only the correct blocks), regardless of sequence order. For forward memory spans, Homesigners tapped the correct blocks, but in the wrong order, 16% of the time, Cohort 1 9% of the time, and Unschooled Spanish Speakers 22% of the time. For reverse memory

spans, all groups were more apt to tap the correct blocks in the wrong order, perhaps because of the impulse to imitate exactly (as in a forward memory span task) rather than respond with the reverse sequence. Homesigners included the correct blocks for reverse memory span 34% of the time, Cohort 1 signers 29%, and Unschooled Spanish Speakers 27%[17]. These results tell us two things: first, that the participants were still attempting to remember and produce the correct taps, and second, that they did understand the task.

Overall, working memory (measured by the reverse visuo-spatial span task) is significantly related to language exposure, and not to educational experience.

6. Predictors of False Belief Performance

Given a previously suggested relationship between EF abilities and FB performance (e.g., Gordon & Olson, 1998; Carlson et al., 2002, 2004; a.o.), Spearman's correlation coefficients were calculated to see if either working memory *or* inhibitory control were significantly related to overall success on the FB task.

6.1 Participant data

Data from all participants who engaged in both the executive function (Working Memory and Inhibitory Control) tasks *and* the experiential False Belief tasks were included: 4 homesigning adults, 6 NSL signers (Cohort 1), and 5 unschooled Spanish speaking Nicaraguan adults. Overall False belief scores (of 0, 1, or 2) were used as the measure of each participant's performance.

6.2 Results

Spearman's correlation coefficients showed a significant relationship between

[17] These percentages "incorrect" include those trials that went beyond what was deemed the participant's "span." It is possible, therefore, that the last "correct" span that a participant produced was in the block of 5, but in the block of 6, he tapped the correct blocks, but in the wrong order.

Overall False Belief scores and Inhibitory Control ($r_S[13] = .55$, $p = 0.032$), Corsi reverse span ($r_S[13] = .74$, $p = 0.001$) and Corsi reverse score ($r_S[13] = .80$, $p < 0.001$). No relationship was found between Overall False Belief scores and Corsi forward span ($r_S[13] = .22$, $p = 0.421$) or Corsi forward score ($r_S[13] = .33$, $p = 0.222$).

6.3 Discussion

Our results confirmed the hypotheses that success on the False Belief task must somehow tap in to Executive Function abilities to suppress and transform (update) relevant information for understanding others' beliefs, actions, and intentions. This is particularly striking because success on the FB task and on Working Memory (as measured by the reverse Spatial Span Total Score) was predicted by participants' exposure to a linguistic community, while success on the conflict-IC was predicted by education and not age of language exposure.

7. General Discussion

7.1. Overall summary

This series of studies sought to investigate the relative contributions of social (life) experience and language experience (or participation in a linguistic community) to the development of Theory of Mind abilities. Because our population of interest, homesigners, have neither received any accessible language exposure nor any education, we needed to disentangle the effects of education on Theory of Mind development by introducing two other participant groups. We included NSL Cohort 1 signers who, like the homesigners, are deaf and have not received a language model. However, NSL signers differ from homesigners in that they participate in a linguistic community, mainly accessed via educational experiences. We also included Unschooled hearing Spanish

speakers, who had early exposure to rich language models but who, like the homesigners, had little to no schooling.

The results show that some abilities are available to *all groups,* some are dependent on *educational experience*, and some are dependent on exposure to and participation in a *linguistic community.*

7.1.1. Abilities available to all groups.

These results, taken together, suggest that certain aspects of Theory of Mind and Executive Function are available regardless of language exposure, education, or social experiences. Specifically, all participants across all groups were able to succeed at Perspective Taking Level 1 at 100% accuracy. Likewise, while there was variation in actual scores, no differences were found in accuracy between groups for Perspective Taking Level 2 tasks. While we can confidently rule out language or education as being a key factor to Perspective Taking Level 2 abilities, we cannot say for certain whether it is life experience or just pure visuo-spatial maturation that drives this development, and further investigation is necessary to explore variations between groups in the types of incorrect answers provided.

Similarly, we can say that the homesigners did not differ from the NSL signers nor from the Unschooled Spanish speakers on the Corsi forward tasks; namely those which tap in to pure spatial span memory (without the transformational element required for it to be "working" memory). The same goes for the Inhibitory Control task's 2nd phase, where the rule has changed from the first phase, but only one rule remains in effect. Again, we cannot say for certain whether maturational or experiential effects are at play here.

Regardless, a benefit of these studies is that we now have evidence to show that these specific abilities do *not* suffer in individuals who are deaf and who do not have access to the spoken language around them.

7.1.2. Differences due to education

The conflict-Inhibitory Control results are particularly striking in that they relate only to educational experiences and not to experience within a linguistic community. Thus, we can suggest that education, more than language, underpins Inhibitory Control, contra previous studies. Ostrosky-Solís and colleagues (2004) found no differences between participants with and without education on a task (the “opposites” task) that was similar to our control Phase 2. We have not located any studies that examine language or education effects on a Phase 3-type task, which requires participants to manage both same- and opposite-responses. The orally-educated deaf children in Shusterman et al.’s (2012) study showed delays in executive function relative to their hearing counterparts., Given our results, we speculate that later improvements in these deaf children’s EF would stem from additional educational experience rather than from further linguistic development. Interestingly, Contreras et al. (2013) found that Deaf individuals from Deaf parents outperformed deaf individuals from hearing parents, even into adulthood, seemingly arguing for a language-based foundation in EF abilities. It is possible that because their EF task was quite different than our IC task, it actually tapped into skills more akin to our Working Memory task, which we found was marginally significantly related to language exposure and not education. For all deaf American populations, there is a potential for a language X education interaction: deaf children in the United States usually benefit from relatively early exposure to the school system, be it an oral/aural

program or a sign-language based program. It is possible that the early-signing participants in Contreras (2013) were able to capitalize on the education provided because they already had a fully accessible early language model.

Although no differences were found between groups for Perspective Taking Level 2, there were some unexpected and interesting responses and challenges when working with the Unschooled Spanish speakers[18]. The difficulty seemed to stem from using 2-dimensional images to portray a 3-dimensional object. When asked about the experimenter's perspective of the duck *as the duck faced the participant (Figure 30)*, a few times the participant selected his own perspective (Figure 30). As this was a training/ practice phase, the experimenter responded with "I see the duck's tail. Can you show me which picture shows what I see?" Yet again, the image in Figure 30 was selected. The experimenter then responded with "Can you show me the tail in that

Figure 30: The participant's perspective of the duck in one block of practice Perspective Taking trials.

picture?" at which point the participant responded with "It's behind the duck."

This interaction seems to show that the lack of schooling experience that the Spanish speaking participants had didn't necessarily affect their ability to take another's perspective as much as it means they didn't have many opportunities to translate that knowledge into a new (2–dimensional) form (see Cole, 2005 for a discussion of the

[18] Note that the testing of 3/6 of the unschooled Spanish speakers occurred at the farm where they lived and worked; very few 2-dimensional images were present in the form of printed media or photographs.

developmental effects of education). One can imagine a situation in which all 2-dimensional images conjure up 3-dimensional expectations. In the end, of course if the duck is facing the participant, the tail is *still there*, and yes, it is actually facing the experimenter.

Finally, we must consider that for the NSL signers, and for most deaf individuals attending a school that uses sign as the primary mode of communication, their experience is a *bilingual* experience. Previous studies (e.g., Kovács, 2009) have suggested that there is a bilingual benefit for ToM development. While the current series of studies isn't specifically attuned to testing for bilingual effects, we can note that while we have controlled for general educational experiences, the bilingual (the local sign language and the majority written langauge – e.g., American Sign Langauge and written English, or Nicaraguan Sign Language and written Spanish) experience of deaf students may help them overcome any delays caused by their lack of native exposure to a linguistic community. This highlights the benefit of studies like O'Reilly et al. (2014) who compare those with early sign exposure to late sign exposure (both who then later become sign / written language bilinguals) both in childhood and later on, in adulthood, with sensitive ToM assessments, such as with the use of sarcasm.

7.1.3. Differences due to participation in a linguistic community

The main thrust of this study was to investigate the unique position of False Beliefs on the developmental cline of ToM-related abilities and to disentangle possible social vs. linguistic effects on the development of the understanding of False Beliefs. Given the results of our study, we can confidently say that it is not likely that social experiences (visual life experiences) are enough to scaffold False Belief understanding.

Language provided by participation in a linguistic community, however, does seem to be more crucially necessary for FB performance.

One way we can test the probable position of False Belief on the developmental cline (Figure 1), is to ask about the higher-order ToM abilities such as the use of sarcasm and narrative abilities. While the use of sarcasm hasn't been investigated directly in homesigners, preliminary work by Coppola et al. (2013) and Miranda et al. (2014) shows that homesigners do suffer in their narrative productions. If their ToM development is somehow affected by their lack of exposure to a language model and linguistic community, then it follows that their narratives will be affected as well. This may also be supported by research by Marschark et al. (2000), who show that deaf teens of hearing parents perform equivalently to hearing peers on use of mental state language in narrative, in spite of previous work showing that deaf children are delayed akin to individuals with autism.

7.2 How do we know the participants understood the tasks?

A fundamental question in any work investigating cognition in homesigners is ***Did the participant understand the task?*** While it is difficult to provide an unambiguously positive response to this question, the available evidence suggests that yes, participants, particularly the homesigners, understood what was being asked of them.

7.2.1 Communication choices

To maximize understanding, the experimenter chose to use whichever communication means most readily available to the participant (Gesture, some NSL signs, spoken Spanish). While this may create differences in protocol or procedure, this was one strategy used to make sure that participants were clear for the task instructions.

All participants engaged in other tasks with the experimenter before and after the False Belief task, including the tasks described as part of this study. During this time, the experimenter was able to learn the best means of communicating with each participant. Additionally, the homesigners' success at some tasks (e.g., Spatial memory span, Perspective Taking, Conflict-Inhibitory Control) indicates that they are able to understand the experimenter and follow instructions as they were presented. This was, however, not the only means of achieving comprehension, for the design of the False Belief task itself guides the participant to the crucial question regardless of the communication method during the task.

7.2.2 False Belief task: Comprehension checks are built-in to the task design

The experiential False Belief task modeled after Pyers (2005) has several built-in assurances to guide the participant to the crucial FB question (but not the right answer). This occurs mainly in Phase 1, or the sticker phase (Table 4). Participants experienced "easy" or "obvious choice" trials in which they could easily predict the choices of the confederate. They also experienced "hard" or "individual preference" trials during which they had to guess the confederate's choice. They also earned incentives for making correct choices. All participants who failed to predict either False Belief trial either made a prediction about the confederate's choice that was different from their own prior choice, or they experienced making an incorrect prediction, and therefore did not earn the incentive (allowing the experimenter to re-emphasize the goal of the prediction phase).

Another, somewhat obvious feature built into the design is that the participant could have learned from his mistake in the first FB prediction. If the participant was responding to the question "What *should* the confederate choose?" (what the participant

knows is in the box, or the plate the participant knows has the real cookies), then the expected pattern of results should include: a) some participants who would have passed Unexpected Contents only and / or b) fewer participants who failed *both* FB phases. As trials were counterbalanced (some received the Appearance/Reality question before Unexpected Contents, and others the reverse), we can confirm that a) no participants learned from a failed Appearance Reality question and later passed an Unexpected Contents question, and b) we have many participants who were not able to succeed on either question. Regardless, the question still stands: Perhaps the participants who failed to make a correct prediction were responding to what the confederate "should" choose rather than to what the confederate "will" choose.

7.2.4 Understanding "Will" vs. "Should"

The question as to whether participants are responding to what "will" the confederate choose vs. what "should" the confederate choose is a difficult one. It is still possible, after all the built-in strategies to encourage the participant to answer the intended FB question, that they still are adamant about predicting the "should" question through both FB phases. Perhaps they chalk the error up to the confederate? Perhaps they think that the confederate is the one who should be learning, that this is somehow a teaching moment? The deaf participants are probably used to engaging in gestural, object-based learning from interactions with their families. This task could have been interpreted to be that type of event. If that were the case, however, it does not explain the behavior of the hearing Spanish speakers who also failed to make correct predictions despite the use of Spanish in their instructions: "Qué crees que él va a eligir?" (*What do you think he will choose?),* which makes the contrast between "will" and "should"

explicit. The upshot is that there is no definitive way to be sure which question the participants were answering; however, all attempts were made to ensure comprehension within the constraints of working with a language-limited population.

7.3. Factoring in the experience of deaf individuals

While we cannot completely account for the Unschooled Spanish Speakers' failures to predict the confederate's choices, it is possible that the homesigners and Cohort 1 participants might be reacting either to the confederate's white male status, his American status, or his "hearing" status – that is, they may not want to attribute "not knowing" to the confederate for any one of these reasons.

It is a common anecdote in the American Deaf experience, or in the experience of the hearing people around D/deaf people, for the D/deaf person to attribute more situational or incidental knowledge to a hearing person than may be warranted. This, in a way, isn't very surprising, given differences in sensory experiences. For example, take a situation in which a hearing person says to a deaf person "John is here" when John isn't visible yet, but the hearing person, who is familiar with John's gait, hears that pattern coming from the hallway. With repeated instances like this, it is not unreasonable for the deaf person to later ask a hearing person "Who is at the door?" when the doorbell has been rung but no one has yet opened the door.

Given these types of experiences, it is possible that the deaf participants (homesigners and NSL signers) in this study may have attributed more knowledge to the hearing confederate than, say, the Unschooled Spanish Speakers may have, given the common experience (across the three participant groups) of being from the same country/

culture faced with a white American male confederate.

7.4 Do homesigners really have no understanding of others' thoughts and beliefs?

So, what does this mean? Does it mean that the individuals in this study who failed the False Belief tasks do not have any understanding of others' thoughts, beliefs and desires? Consider the experience of these participants, who are living in a hearing world – one filled with individuals who have greater access to information through their ability to hear. It remains possible that there isn't enough observable evidence (from the deaf person's perspective) to infer what a hearing person could and could not know, without possessing language to scaffold that understanding. Thus, for these individuals, developing a Theory of Mind may actually mean developing the understanding that others are *not* omniscient. This differs from the traditional child-centered explanation for why preschoolers fail the FB task, where the assumption is that the child assumes that the puppet or confederate only knows what he or she (the participant) knows.

There is spontaneous evidence to show that the homesigners do have a sense of others' thoughts and beliefs; stories where they talk about others not seeing or not being aware of something happening. This is reflective, however, of understanding seeing and knowing, but not actually mentally representing the *belief* of someone else, only their *ignorance*. It is argued that the belief representation is much more complex because it involves a representation that is counter to reality; that is what was tested with the Experiential False Belief task.

It is also likely that the homesigners *could* pass a Theory of Mind task if it were designed for infants (e.g., one like those described in Onishi & Baillargeon (2005)). Apperly & Butterfill (2009) make a strong case for a two-system Theory of Mind

process, one that, like number cognition, has a basic, almost innate set of abilities to track attitudes and behaviors, and another that is much more cognitive and flexible, given certain other cognitive abilities, such as the Executive Functions. Their suggestion is appealing for a case like this: we have evidence here that language plays a part in the development of these additional cognitive abilities, but these cognitive abilities still have a strong relationship with False Belief success, even if that False Belief is an exact replica of one's own experiences.

In sum, it is likely that the homesigners *are* very attuned to the environment around them; but this *includes* the "evidence" that hearing people are able to understand, perceive, and "know" more than they do. The same goes for the Unschooled Spanish speakers – perhaps they were also attributing some sort of knowledge to the white male confederate? Once we factor in the results from the Perspective Taking Level 2 task, where we saw that participants sometimes struggled with responding either with their own perspective versus any other (correct or incorrect) perspective. This was reflective of the differences between understanding that others have a different perspective than their own and the ability to actually imagine, or *mentalize* that other perspective or experience – this could be an example of overloading the cognitive system as suggested by Apperly & Butterfill (2009). Perhaps then, that is what exists in the gap between language and education– a sort of skepticism about others' abilities and the means to mentalize and later discuss it.

7.5 Limitations and improvements

We acknowledge some limitations. First, Homesigners, NSL Signers, and Unschooled Spanish-speaking adults are extremely rare and difficult to recruit and test,

yielding small sample sizes. Also, we did not administer any standard IQ tasks. Over many years of interaction with the research group, the homesigners have not exhibited signs of congenital cognitive deficits, nor have their parents reported evidence of such deficits. Further, their performance on perceptual matching and mental rotation tasks is in the same range as that of their hearing family members (Spaepen et al, 2011).

Future work will: 1) utilize implicit measures of FB performance, such as eyegaze or looking time measures 2) attempt to include a deaf, Nicaraguan confederate to level the playing field and remove some of the possible assumptions on the part of the participants and 3) include American deaf participants and hearing Nicaraguan preschoolers as additional comparison groups.

8. **Conclusion**

Four studies were conducted investigating the effects of language and education on perspective taking, false belief understanding and executive function performance in three Nicaraguan groups: Homesigners, who do not participate in a linguistic community and have little schooling; Nicaraguan Sign Language Signers, who were among the initial creators of this emerging language, and Unschooled Spanish Speakers, members of a linguistic community, with sparse education.

The results suggest four conclusions: 1) a linguistic community is necessary, but not sufficient, to support success on False Belief tasks; 2) education, more than language, relates to Inhibitory Control; 3) a linguistic community is likely necessary for transformational ("working") memory, and 4) executive function abilities (Inhibitory Control and Working Memory) are related to false belief performance.

These results support theories in which language may play a crucial role in the

development of theory of mind. According to simulation theorists, having an experience of a false belief shortly before predicting the response of another individual holding the same false belief in the very same situation would eliminate the need for language, and indicate that life experience and introspection supports the understanding of others' beliefs and actions. The results show that life experiences, even those experienced immediately prior to prediction, did not help adults without a linguistic community. Thus, Simulation (and related) theories (e.g., Gordon, 1986; Goldman, 1992, Nickerson, 1999) cannot explain the behavior of homesigners in these experiential tasks; homesigners who presumably reflect on their own experiences, yet remain unable to leverage that reflection into successful prediction of others' behavior.

Appendix A. Summary of Homesigners' contact with Nicaraguan Sign Language, other deaf individuals, and education

Homesigner	Regular contact with NSL outside of an educational context	Regular communication partners who know NSL	Education	Contact with other deaf or signing individuals
NAHS01	No	No	~1 month at a boarding school in Managua ~age 21 that focused on simultaneous signing and speech	Occasional contact with one Deaf friend who uses NSL who moved to the US ~2010.
NAHS02	No	No	Between 17 and 20 years of age, spent a total of 23 weeks at a small boarding school in the northern part of Nicaragua with ~2-3 teachers who signed NSL. His brother also attended the school for some of that time.	Very sporadic visits with a male former classmate, who also left the school more than 12 years ago. Annual visits with a 20 year-old female former classmate who was ~6 years old when she arrived at the boarding school. He is aware of another deaf woman who married a man from a city about 2 hours away, but he does not know her name.
NAHS03	No	No	Mother reports limited attendance at a vocational program with other deaf individuals during childhood; NSL was not used.	Yes but very superficial—he occasionally has played soccer at the Deaf association in Managua.
NAHS05	No	No	None	Has been approached by signing Jehovah's Witnesses, but reports that she has not attended any of their events.

Appendix B: Corsi-like Spatial Memory Span Task

Participant: ______________________ **Participant Group:** ______________________

Date: ______________________ **Test Location:** ______________________

	Corsi Block Test									Corsi Block Test								Xtra	Xtra	Xtra	Notes
Forward	1a	6	7																		
Forward	1b	1	2																		
Forward	2a	6	2	7																	
Forward	2b	5	2	9																	
Forward	3a	5	7	2	1																
Forward	3b	3	6	8	5																
Forward	4a	8	6	4	3	9															
Forward	4b	1	7	4	2	3															
Forward	5a	1	6	3	7	2	4														
Forward	5b	6	5	9	3	1	2														
Forward	6a	5	7	4	9	8	3	2													
Forward	6b	1	3	9	4	2	6	5													
Forward	7a	3	8	4	1	7	9	2	6												
Forward	7b	1	6	5	7	2	8	3	9												
Reverse	1a	2	1																		
Reverse	1b	7	6																		
Reverse	2a	9	2	5																	
Reverse	2b	7	2	6																	
Reverse	3a	5	8	6	3																
Reverse	3b	1	2	7	5																
Reverse	4a	3	2	4	7	1															
Reverse	4b	9	3	4	6	8															
Reverse	5a	2	1	3	9	5	6														
Reverse	5b	4	2	7	3	6	1														
Reverse	6a	5	6	2	4	9	3	1													
Reverse	6b	2	3	8	9	4	7	5													
Reverse	7a	9	3	8	2	7	5	6	1												
Reverse	7b	6	2	9	7	1	4	8	3												

References

Anderson, P. (2002). Assessment and development of executive function during childhood. *Child Neuropsychology, 8*(2).

Apperly, I. A., & Butterfill, S. A. (2009). Do humans have two systems to track beliefs and belief-like states? *Psychological Review*, *116*(4), 953.

Astington, J. W. (1990). Narrative and the child's theory of mind. In B. K. Britton & A. D. Pellegrini (Eds.), *Narrative Thought and Narrative Language*. (pp. 151-171). Hillsdale, NJ, England: Lawrence Erlbaum Associates, Inc.

Astington, J. W., & Jenkins, J. M. (1999). A longitudinal study of the relation between language and theory-of-mind development. *Developmental Psychology, 35*(5), 1311-1320.

Baron-Cohen, S., Leslie, A. M., & Frith, U. (1985). Does the autistic child have a "theory of mind"? *Cognition, 21*(1), 37-46.

Behne, T., Carpenter, M., Call, J., & Tomasello, M. (2005). Unwilling versus unable: Infants' understanding of intentional action. *Developmental Psychology, 41*(2), 328.

Bialystock, E., & Senman, L. (2004). Executive-function in appearance-reality tasks: The role of inhibition of attention and symbolic representation. *Child Development, 75*, 562-579.

Brentari, D., Coppola, M., Mazzoni, L., & Goldin-Meadow, S. (2012). When does a system become phonological? Handshape production in gesturers, signers, and homesigners. *Natural Language & Linguistic Theory, 30*(1), 1-31.

Carlson, S., Mandell, D., & Williams, L. (2004). Executive function and theory of mind: Stability and prediction from ages 2-3. *Developmental Psychology, 40*(6), 1105-1122.

Carlson, S. M., Moses, L. J., & Brenton, C. (2002). How specific is the relation between executive function and theory of mind? Contributions of inhibitory control and working memory. *Infant and Child Development, 11*(2), 73-92.

Carrigan, E. M., & Coppola, M. (2012). Mothers do not drive structure in adult homesign systems: Evidence from comprehension. *Proceedings of the 34th Annual Conference of the Cognitive Science Society,* pp. 1398-1403.

Carrigan, E. M., & Coppola, M. (2012). Mothers do not drive structure in adult homesign ystems: Evidence from comprehension. *Proceedings of the 34th Annual Cognitive Science Society,* Austin, TX.

Charman, T., & Shmeuli-Goetz, Y. (1998). The relationship between theory of mind, language and narrative discourse: An experimental study. *Cahiers De Psychologie Cognitive/Current Psychology of Cognition, 17(2), 245-271*

Chasiotis, A., Kiessling, F., Hofer, J., & Campos, D. (2006). Theory of mind and inhibitory control in three cultures: Conflict inhibition predicts false belief understanding in Germany, Costa Rica and Cameroon. *International Journal of Behavioral Development, 30*(3), 249-260.

Cicchetti, D., Rogosch, F. A., Maughan, A., Toth, S. L., & Bruce, J. (2003). False belief understanding in maltreated children. *Development and Psychopathology, 15*(4), 1067-1091.

Contreras, J., Israel, E., & Hauser, P. C. (2013, July). Deaf students' performance on the color trails test: Effect of early sign language acquisition. Poster presented at the *Theoretical Issues in Sign Language Research Conference,* London, U.K.

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) pp. 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, UK: Cambridge University Press.

De Jaegher, H., & Di Paolo, E. (2007). Participatory sense-making. *Phenomenology and the Cognitive Sciences, 6*(4), 485-507.

De Jaegher, H., Di Paolo, E., & Gallagher, S. (2010). Can social interaction constitute social cognition?. *Trends in Cognitive Sciences, 14*(10), 441-447.

de Villiers, J., & Pyers, J. (2002). Complements to cognition: A longitudinal study of the relationship between complex syntax and false-belief understanding. *Cognitive Development, 17*(1), 1037-1060.

de Villiers, J. G., & de Villiers, P. A. (2000). Linguistic determinism and the understanding of false beliefs. In Riggs, K. J. (Ed.), *Children's Reasoning and the Mind.* (pp. 191-228). Hove, England: Psychology Press/Taylor & Francis.

de Villiers, P., & de Villiers, J. (2012). Deception dissociates from false belief reasoning in deaf children: Implications for the implicit versus explicit theory of mind distinction. *British Journal of Developmental Psychology, 30*(1), 180-209.

Flavell, J. H., Everett, B. A., Croft, K., & Flavell, E. R. (1981). Young children's knowledge about visual perception: Further evidence for the level 1–Level 2 distinction**.** *Developmental Psychology, 17*(1), 99-103.

Gallese, V. (2007). Before and below 'Theory of Mind': Embodied simulation and the neural correlates of social cognition. *Philosophical Transactions of the Royal Society: Biological Sciences, 362*(1480), 659-669.

Gallese, V., & Goldman, A. (1998). Mirror neurons and the simulation theory of mind-reading. *Trends in Cognitive Sciences, 2*(12), 493-501.

Gergely, G., Nádasdy, Z., Csibra, G., & Biro, S. (1995). Taking the intentional stance at 12 months of age. *Cognition, 56*(2), 165-193.

Gibson, E. (1998). Linguistic complexity: Locality of syntactic dependencies. *Cognition, 68*(1), 1-76.

Gola, A. (2012). Mental verb input for promoting children's theory of mind: A training study. *Cognitive Development,, 27*(1), 64-76.

Goldin-Meadow, S. (2003). *The resilience of language: What gesture creation in deaf children can tell us about how all children learn language*. New York: Psychology Press.

Goldman, A. I. (1992). In defense of the simulation theory. *Mind & Language, 7*(1-2), 104-119.

Gopnik, A., & Astington, J. W. (1988). Children's understanding of representational change and its relation to the understanding of false belief and the appearance-reality distinction. *Child Development, 59*(1), 26-37.

Gordon, A. C., & Olson, D. R. (1998). The relation between acquisition of a theory of mind and the capacity to hold in mind. *Journal of Experimental Child Psychology, 68*(1), 70-83.

Gordon, R. M. (1986). Folk psychology as simulation. *Mind & Language, 1*(2), 158-171.

Gottman, J., Gonso, J., & Rasmussen, B. (1975). Social interaction, social competence, and friendship in children. *Child Development*, 46(3), 709-718.

Grice, P. (1989). *Studies in the way of words.* Cambridge, MA: Harvard University Press.

Groce, N. E. (1985). *Everyone here spoke sign language: Hereditary deafness on Martha's Vineyard.* Cambridge, MA: Harvard University Press.

Hale, C., & Tager-Flusberg, H. (2003). The influence of language on theory of mind: A training study. *Developmental Science, 6*(3), 346-359.

Howard, A., Mayeux, L., & Naigles, L. (2008). Conversational correlates of children's acquisition of mental verbs and a theory of mind. *First Language, 28*(4), 375-402.

Iacoboni, M. (2009). Imitation, empathy, and mirror neurons. *Annual Review of Psychology, 60*, 653-670.

Kessels, R. P., van Zandvoort, M. J., Postma, A., Kappelle, L. J., & de Haan, E. H. (2000). The Corsi block-tapping task: Standardization and normative data. *Applied Neuropsychology, 7*(4), 252-258.

Kohler, E., Keysers, C., Umilta, M. A., Fogassi, L., Gallese, V., & Rizzolatti, G. (2002). Hearing sounds, understanding actions: Action representation in mirror neurons. *Science, 297*(5582), 846-848.

Kovács, Á. M. (2009). Early bilingualism enhances mechanisms of false-belief reasoning. *Developmental Science, 12*(1), 48-54.

Leung, E. H., & Rheingold, H. L. (1981). Development of pointing as a social gesture. *Developmental Psychology, 17*(2), 215-220.

Liu, D., Wellman, H. M., Tardif, T., & Sabbagh, M. A. (2008). Theory of mind development in Chinese children: A meta-analysis of false-belief understanding across cultures and languages. *Developmental Psychology, 44*(2), 523-531.

Low, J. (2010). Preschoolers' implicit and explicit False-Belief understanding: Relations with complex syntactical mastery. *Child Development, 81*(2), 597-615.

Lundy, J. E. (2002). Age and language skills of deaf children in relation to theory of mind development. *Journal of Deaf Studies and Deaf Education, 7*(1), 41-56.

Marschark, M., Green, V., Hindmarsh, G., & Walker, S. (2000). Understanding theory of mind in children who are deaf. *Journal of Experimental Child Psychology and Psychiatry, 41*(08), 1067-1073.

Masangkay, Z. S., McClusky, K. A., McIntryre, C. W., Sims-Knight, J., Vaughn, B. E., & Flavell, J. H. (1974). The early development of inferences about the visual percepts of others. *Child Development*, 357-366.

Mauldin, L. (2011). Cochlear implants and the mediated classroom-clinic: Communication technologies and co-operations across multiple industries. *Disability Studies Quarterly.* 31(4).

Mauldin, L. (2012). Parents of deaf children with cochlear implants: A study of technology and community. *Sociology of Health & Illness: A Journal of Medical Sociology, 34*(5), 529-543.

Meltzoff, A. N., & Decety, J. (2003). What imitation tells us about social cognition: A rapprochement between developmental psychology and cognitive neuroscience. . *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences, 358*(1431), 491-500.

Meltzoff, A. N., & Moore, M. K. (1983). Newborn infants imitate adult facial gestures. *Child Development,* 54(3), 702-709.

Meristo, M., Falkman, K. W., Hjelmquist, E., Tedoldi, M., Surian, L., & Siegal, M. (2007). Language access and theory of mind reasoning: Evidence from deaf children in bilingual and oralist environments. *Developmental Psychology, 43*(5), 1156-1169.

Mertiso, M., Morgan, G., Geraci, A., Iozzi, L., Hjelmquist, E., & Surian, L. (2012). Belief attribution in deaf and hearing infants. *Developmental Science, 15*(5), 633-640.

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

Moeller, M. P., & Schick, B. (2006). Relations between maternal input and theory of mind understanding in deaf children. *Child Development, 77*(3), 751-766.

Moores, D. F. (2001). *Educating the deaf: Psychology, principles, and practices.* Boston: Houghton Mifflin.

Morgan, G., & Kegl, J. (2006). Nicaraguan Sign Language and theory of mind: The issue of critical periods and abilities. *Journal of Experimental Child Psychology and Psychiatry, 47*(8), 811-819.

Nadel, J., Guérini, C., Pezé, A., & Rivet, C. (1999). The evolving nature of imitation as a format for communication. In J. Nadel & G. Butterworth (Eds.), *Imitation in infancy* (pp. 209-234). New York, NY: Cambridge University Press.

Nickerson, R. S. (1999). How we know—and sometimes misjudge—what others know: Imputing one's own knowledge to others. *Psychological Bulletin, 125*(6), 737-759.

Noble, K. G., Norman, M. F., & Farah, M. J. (2005). Neurocognitive correlates of socioeconomic status in kindergarten children. *Developmental Science, 8*(1), 74-87.

O'Reilly, K., Peterson, C. C., & Wellman, H. M. (2014). Sarcasm and advanced theory of mind understanding in children and adults with prelingual deafness. *Developmental Psychology, 50*(7), 1862-1877.

Oberman, L. M., Hubbard, E. M., McCleery, J. P., Altschuler, E. L., Ramachandran, V. S., & Pineda, J. A. (2005). EEG evidence for mirror neuron dysfunction in autism spectrum disorders. *Cognitive Brain Research, 24*(2), 190-198.

Onishi, K. H., & Baillargeon, R. (2005). Do 15-month-old infants understand false beliefs? *Science, 5719,* 255-258.

Ostrosky-Solís, F., Ramírez, M., Lozano, A., Picasso, H., & Velez, A. (2004). Culture or education? Neuro- psychological test performance of a Maya indigenous population. *International Journal of Psychology, 39*(1), 36-46.

Peterson, C. C., & Siegal, M. (1999). Representing inner worlds: Theory of mind in autistic, deaf, and normal hearing children. *Psychological Science, 10*(2), 126-129.

Peterson, C. C., Wellman, H. M., & Slaughter, V. (2012). The mind behind the message: Advancing Theory of Mind scales for typically developing children, and those with deafness, autism, or Asperger syndrome. *Child Development, 83*(2), 469-485.

Piaget, J., & Inhelder, B. (1956). *The child's conception of space.* London: Routledge and Kegan Paul.

Polich, L. (2001). Education of the deaf in Nicaragua. *Journal of Deaf Studies and Deaf Education, 6*(4), 315-326.

Polich, L. (2005). *The emergence of the deaf community in Nicaragua*. Washington D.C.: Gallaudet University Press.

Pyers, J. E. (2005). *The relationship between language and false-belief understanding: Evidence from learners of an emerging sign language in Nicaragua.* Doctoral Dissertation, University of California - Berkeley.

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.

Rhys-Jones, S. L., & Ellis, H. D. (2000). Theory of mind deaf and hearing children's comprehension of picture stories and judgments of social situations. *Journal of Deaf Studies and Deaf Education, 5*(3), 248-265.

Richie, R., Yang, C., & Coppola, M. (2014). Modeling the emergence of lexicons in homesign systems. *Topics in Cognitive Science, 6*(1), 183-195.

Russell, P. A., Hosie, J. A., Gray, C. D., Scott, C., Hunter, N., Banks, J. S., et al. (1998). The development of theory of mind in deaf children. *Journal of Experimental Child Psychology and Psychiatry, 39*(6), 903-910.

Sabbagh, M. A., Xu, F., Carlson, S. M., Moses, L. J., & Lee, K. (2006). The development of executive functioning and theory of mind: A comparison of Chinese and US preschoolers. *Psychological Science, 17*(1), 74-81.

Sandler, W., & Lillo-Martin, D. (2006). *Sign language and linguistic universals*. Cambridge, UK: Cambridge University Press.

Selman, R. L. (1980). *The growth of interpersonal understanding.* New York: Academic Press.

Senghas, A. (2003). Intergenerational influence and ontogenetic development in the emergence of spatial grammar in Nicaraguan Sign Language. *Cognitive Development, 18*(4), 511-531.

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.

Senghas, R. J., Senghas, A., & Pyers, J. (2005). The emergence of NSL: Questions of development, acquisition, and evolution. In *Biology and knowledge revisited* (pp. 287-306). Mahwah, NJ: Erlbaum.

Shahaeian, A., Nielson, M., Peterson, C. C., Aboutalebi, M., & Slaughter, V. (2014). Knowledge and belief understanding among Iranian and Australian preschool children. *Journal of Cross-Cultural Psychology, 45*(10), 1643-1654.

Shatz, M., Wellman, H. M., & Silber, S. (1983). The acquisition of mental verbs: A systematic investigation of first references to mental state. *Cognition, 14*, 301-321.

Shatz, M., Diesendruck, G., Martinez-Beck, I., & Akar, D. (2003). The influence of language and socioeconomic status on children's understanding of false belief. *Developmental Psychology, 39*(4), 717-729.

Shield, A. M. (2010). The signing of deaf children with autism: Lexical phonology and perspective-taking in the visual-spatial modality. Doctoral Dissertation, University of Texas - Austin.

Shusterman, A., Berkowitz, T., & Lange, R. (2012). The acquisition of number concepts in oral-deaf preschoolers. *Paper Presented at the Boston University Conference on Language Development,* Boston, MA.

Slade, L., & Ruffman, T. (2005). How language does (and does not) relate to theory of mind: A longitudinal study of syntax, semantics, working memory and false belief. *British Journal of Developmental Psychology, 23*(1), 117-141.

Slaughter, V., & Perez-Zapata, D. (2014). Cultural variations in the development of mind reading. *Child Development Perspectives, 8*(4), 237-241.

Smith, R. L., & Rose, A. J. (2011). The "cost of caring" in youths' friendships: Considering associations among social perspective taking, so-rumination, and empathetic distress. *Developmental Psychology, 47*(6), 1792.

Spaepen, E., Coppola, M., Spelke, E. S., Carey, S. E., & Goldin-Meadow, S. (2011). Number without a language model. *Proceedings of the National Academy of Sciences, 108*(8), 3163-3168.

Stuss, D. T. & Knight, R. T. (Eds.). (2013), *Principles of frontal lobe function. Oxford, UK:* Oxford University Press.

Tomasello, M., & Carpenter, M. (2007). Shared intentionality. *Developmental Science, 10*(1), 121-125.

Vaccari, C., & Marschark, M. (1997). Communication between parents and deaf children: Implications for social-emotional development. *Journal of Experimental Child Psychology and Psychiatry, 38*, 793-801.

Vanderwert, R. E., Westerlund, A., Montoya, L., McCormick, S. A., Miguel, H. O., & Nelson, C. A. (2014). Looking to the eyes influences the processing of emotion on face-sensitive event-related potentials in 7-month-old infants. *Developmental Neurobiology.*

Wellman, H. M., Cross, D., & Watson, J. (2001). Meta-analysis of theory of mind development: The truth about false belief. *Child Development, 72*(3), 655-684.

Wellman, H. M., & Liu, D. (2004). Scaling of theory-of-mind tasks. *Child Development, 75*(2), 523-541.

Wimmer, H., & Perner, J. (1983). Beliefs about beliefs: Representation and constraining function of wrong beliefs in young children's understanding of deception. *Cognition, 13*(1), 103-128.

Woolfe, T., Want, S. C., & Siegal, M. (2002). Signposts to development: Theory of mind in deaf children. *Child Development, 73*(3), 768-778.