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The Impact of Individual Differences in Social Skills and Executive Control on Visual-Spatial Perspective-Taking in Signers and Nonsigners

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The Impact of Individual Differences in Social Skills and Executive Control on Visual-Spatial Perspective-Taking in Signers and Nonsigners

A dissertation submitted in partial satisfaction of the requirements for the degree Doctor of Philosophy

in

Language and Communicative Disorders

by

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The dissertation of Kristen Renee Secora is approved, and it is acceptable in quality and form for publication on microfilm and electronically:

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ABSTRACT OF THE DISSERTATION

The Impact of Individual Differences in Social Skills and Executive Control on Visual-Spatial Perspective-Taking in Signers and Nonsigners

by

Kristen Renee Secora

Doctor of Philosophy in Language and Communicative Disorders

University of California, San Diego, 2016
San Diego State University, 2016

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Inferring another's perspective is critical for successful communication and social interaction. Speakers must infer another's visual perspective in order to reference objects appropriately (e.g., objects on your right may be on my left). When spatial relations are expressed via the visuospatial modality as with sign languages

(e.g., American Sign Language, ASL), signers and addressees each have different, conflicting visual perspectives of the signer's articulators. For example, in face-to-face interactions, a sign produced on the left side is perceived by the addressee on the right side. Therefore, in order to avoid miscommunication, one interlocutor must adopt the other's visual perspective. Little is known about the cognitive mechanisms underlying the perspective-alignment process that is critical for correctly conveying and comprehending spatial descriptions in a signed language. This dissertation examines the relative contributions from inhibitory control, social skills, and mental rotation abilities on the ability to adopt another's visual-spatial perspective during communication or when performing nonlinguistic perspective-taking tasks.

Chapter 1 provides an overview of the literature describing a) the relationships between inhibitory control, social skills, and visual-spatial perspective-taking (VSPT) abilities and b) how experience with a sign language may affect these relationships. Chapter 2 presents a study examining the relative cognitive burdens for producers and comprehenders of manual gestures from non-egocentric perspectives. Comprehending, but not producing, gestures from non-egocentric perspectives was related to inhibitory control abilities. Chapter 3 examines whether deaf ASL-signing adults approached a nonlinguistic VSPT task socially (like hearing English-speaking adults) or whether they utilized nonsocial, perceptual strategies similar to deaf children. Results suggest that deaf signing adults used a nonsocial approach to the VSPT task, possibly due to effects of language modality and/or sociocultural experiences. Chapter 4 examines whether nonlinguistic perspective-taking or mental rotation abilities are related to signers' comprehension of perspective-dependent

structures within ASL (e.g., locative classifier constructions). Correlational analyses indicated that linguistic perspective-taking was related to participants' overall ASL abilities, nonlinguistic VSPT abilities, and (to a lesser extent) mental rotation abilities. The overall findings are discussed in terms of ramifications for educational and clinical practices as well as for understanding the relationship between spatial cognition and language.

CHAPTER 1: INTRODUCTION

"Put yourself in my shoes." This common colloquial statement reflects the pervasiveness of the idea of perspective-taking, but what exactly does it mean to see from someone else's perspective? Perspective-taking involves being able to realize that you have certain thoughts, feelings, visual experiences, and knowledge that someone else may not share or may experience differently from your own, and additionally, to infer what another's perceptual or mental state may be.

This ability to infer another's perspective is critical for successful social and communication exchanges. At a basic level, knowing how a scene appears differently to others is necessary for correctly referencing the spatial relationships in the scene relative to their viewpoint (e.g., in a face-to-face exchange, what is on my left is on your right). Without appropriate perspective-taking, interlocutors do not achieve a mutual understanding which results in miscommunication. To take it one step further, what others can or cannot see is often a critical clue about their knowledge of a situation and may be essential for correctly interpreting their statements or behavior. For example, imagine a scenario in which one woman boards a subway behind another woman. Everyone in the subway car immediately jumps up to give the first woman a seat but no one even glances at the second woman. The second woman may think the others are rude or socially inappropriate; however, if the first woman turns slightly and reveals that she is pregnant, then suddenly the others' actions take on new meaning and are no longer offensive. The example above highlights the importance of being able to infer others' visual and cognitive perspectives for successful interpretation of social interactions. Without access to some visual information that others have or because of an inability to use that information to infer another's perspective, the actions of others can be misinterpreted as offensive.

While visual-spatial perspective-taking (VSPT) is involved in interpreting another's viewpoint-dependent description when conveyed via spoken language (e.g., "Pass the cup on your left, not my left"), it may play a much more integral role for correctly interpreting descriptions communicated via signed languages, which are produced and perceived in the visuospatial modality. Sign languages such as American Sign Language (ASL) are produced by the hands, face, and body and utilize space to convey meaning. For example, space can be used topographically; in this case, the spatial locations of the hands map iconically onto the spatial locations of real or imagined referents. To show 'a book on a shelf,' a signer could produce the classifier[1] handshape associated with a book and place it physically on the classifier associated with a shelf. Where spoken languages often use prepositions to convey spatial relationships (e.g., *on),* sign languages rely predominantly on classifier constructions produced iconically in space to depict spatial locations.

Because of the topographic use of space to mark spatial relationships, sign languages may involve VSPT in a way that differs markedly from spoken languages. As a result of signs being produced in space, the addressee experiences a different visual perspective of the signer's hands than does the signer – what is produced by the

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[1] In signed languages, classifier constructions are predicates in which certain

signer on her[2] left is viewed by the addressee on his right. When the description relates to objects present in the environment, signers use what has been termed *Shared Space* (Emmorey & Tversky, 2002). The spatial arrangement of the signs maps directly on the spatial arrangement of the objects in the environment – no perspective-taking is necessary. However, when signers converse about objects or scenes that are not present in their current environment, the spatial arrangement of the signer's productions creates a perspective conflict for the interlocuters. If the signer describes a bed to the left of a chair from her perspective, the addressee views the signer's hands depicting the bed on the right of the chair from his perspective. The conflicting perspectives will lead to a miscommunication unless one interlocutor disregards his or her own perspective and adopts the other's perspective. While the convention across many unrelated sign languages is for the addressee to adopt the signer's perspective (Pyers, Perniss, & Emmorey, 2008), little is currently known about the processes that underlie visual perspective-taking within a signed language.

Therefore, the goal of this dissertation is to investigate the cognitive processes that support VSPT for adult deaf signers during linguistic and nonlinguistic perspective-dependent tasks. This first chapter provides an overview of the current literature surrounding VSPT and what is known about spatial transformations during sign language production and comprehension. Chapter 2 presents a study examining the role of inhibitory control for resolving conflicting visual perspectives. This chapter

[2] For clarity, signers will be referred to with female pronouns and addressees with male pronouns throughout.

focuses on the resolution of the perspective-conflict for gestures produced by nonsigning individuals to describe spatial relations (these individuals have no experience following the sign language perspective convention). Chapter 3 delves further into the relationship between sign language experience and VPST abilities by examining the effects of individual social abilities on VSPT performance for hearing nonsigners and deaf signers. Chapter 4 examines the relative contributions of mental rotation and VPST ability during comprehension of perspective-dependent ASL structures. Finally, Chapter 5 provides a discussion of how this knowledge of VSPT within sign language contributes to understanding the relationship between social cognition and language as well as how it can be applied to educational and clinical practice.

1.1. Visual-Spatial Perspective-Taking

Broadly speaking, visual-spatial perspective-taking (VSPT) involves being able to infer another's visual or spatial experiences; however, not all types of visual-spatial perspective-taking (VSPT) tasks require the same kinds of cognitive processes. Evidence from children (e.g., Flavell, Everett, Croft, & Flavell, 1981; Masangkay et al., 1974) and adults (e.g., Surtees, Butterfill, & Apperly, 2012) suggests there are two distinct types of VPST processing: Level 1 and Level 2. Level 1 VSPT involves being able to infer what another person can or cannot see (e.g., if an object is occluded from view by another object), and this ability develops fairly early in childhood (between 18-24 months; Moll & Tomasello, 2006). Solving Level 1 VPST tasks (e.g., whether an avatar can see a disk) seems to involve a line of sight calculation, which is not dependent upon the angular disparity between the perspective-taker's viewpoint and that of the avatar (e.g. Kessler & Rutherford, 2010; Michelon & Zacks, 2006; Surtees, Apperly, & Samson, 2013). Level 2 VSPT, on the other hand, involves being able to infer how a scene may appear differently from another vantage point (e.g., an object on my left is on your right) and develops later in childhood, around 4.5-5 years old (Flavell et al, 1981; Masangkay et al., 1974). Level 2 VSPT tasks seem to involve an imagined self-rotation through space by the perspective-taker in order to align his or her view with that of another (e.g., an avatar) in which response times vary with how disparate the two perspectives are (e.g., Kessler & Rutherford, 2010; Kessler & Thomson, 2010; Michelon & Zacks, 2006).

Evidence from atypical populations has suggested a possible dissociation between visual perspective-taking and other spatial abilities (e.g., mental rotation). For example, tasks that require adopting another's visual perspective or cognitive perspective (e.g., Theory of Mind, ToM) can be impaired while leaving other spatial abilities (such as mental rotation) intact. Hamilton, Brindley, and Frith (2009) showed that hearing children with Autism Spectrum Disorder (ASD) were significantly impaired on a Level 2 VSPT task but not on a task requiring mental rotation, suggesting different mechanisms for the VSPT and mental rotation tasks. Similarly, Shield, Pyers, Martin, & Tager-Flusberg (2016) found that deaf signing children with ASD also were impaired on Level 2 VSPT and ToM tasks but were no worse than their typical signing peers on a mental rotation task. Further, Langdon and Coltheart

(1999, 2001) provided evidence that adults who were high in schizotypy[3] traits were impaired in both visual and cognitive (i.e., ToM) perspective-taking tasks compared to individuals with fewer schizotypy personality traits. Thus, similar mentalizing processes (ToM or "mindreading"; for review see Baron-Cohen, 1996; Frith & Frith, 2003) seem to be involved in imagining another's perspective, which may be required for both cognitive and visual perspective-taking tasks.

1.1.1. VSPT and Social Abilities

Personality traits associated with ASD in subclinical populations also appear to relate to VSPT ability, particularly traits related to social and communication abilities. Shelton and colleagues investigated whether social and communication abilities relate to an individual's ability to adopt another's visual perspective (Clements-Stephens, Vasiljevic, Murray, & Shelton, 2013; Shelton, Clements-Stephens, Lam, Pak, & Murray, 2012). They found that social/communication abilities modulated VSPT performance but only when a social context had been established. In the absence of overt cues suggesting a social context, however, individuals seem to rely on different, nonsocial strategies for the VSPT task (e.g., using mental rotation or an executive, rule-based strategy). Brunyé et al. (2012) also showed that performance on a Level 2 (but not Level 1) VSPT task was related to social abilities. These results align with other evidence that Level 2 VSPT tasks involve mentalizing perhaps by means of an

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[3] For an explanation of the types of behaviors that are reflective of schizotypy and the scale used for classification in Langdon and Coltheart's study see Raine (1991).

embodied, imagined self-rotation through space to determine how a visual scene appears to someone else. Altogether, the evidence suggests that social abilities relate to VSPT performance, specifically on Level 2 type tasks. However, there are other ways in which perspective-taking can play a role in linguistic exchanges.

1.1.2. Perspective-Taking Within Language

During a conversation, interlocutors each have their own visual perspective of the environment, which can lead to some objects being in visual common ground and others being within one interlocutor's privileged ground. Objects in common ground are visible (and known) to both parties and while objects in privileged ground are known only to one interlocutor (e.g., Clark, 1996; Stalnaker, 1978). Objects can be established in common ground by linguistic exchanges as well as by being visible to both parties (e.g., Brown-Schmidt, Gunlogson, & Tanenhaus, 2008). Brown-Schmidt and colleagues have shown that adults are sensitive to whether an object is in common ground or privileged ground during early stages of sentence processing and thus only consider objects in their own privileged ground as potential answers for a question (e.g., Brown-Schmidt, 2009; Brown-Schmidt et al., 2008). However, Keysar and colleagues showed that adult addressees still make errors when limiting potential referents to only objects known to their interlocutor (e.g., Keysar, Barr, Balin, & Brauner, 2000; Keysar, Lin, & Barr, 2003). Although there remains debate as to the reason for errors in applying perspective information (e.g., Brown-Schmidt, 2009; Keysar et al., 2000), two main facts are apparent: 1) adults occasionally make errors due to failure to apply another's visual perspective when comprehending language, and 2) visual perspective information seems to be one of many factors that affects online comprehension of perspective-dependent language.

Like with language comprehension, each person's visual perspective also appears to be one of many factors that guide language production. Schober (1993) and Mainwaring, Tversky, Ohgishi, and Schiano (2003) provided evidence that for simple description tasks, English and Japanese speakers tend to produce descriptions from their addressee's perspective, resulting in an increased cognitive load for the speaker while alleviating some of the load for the addressee. Thus, across different cultural and linguistic groups, speakers tend to take on the extra burden of adopting their addressee's perspective for relatively simple spatial descriptions. However, with increases in the cognitive burden for speakers, they are less likely to adopt the addressee's perspective. For example, in a task where a speaker had to learn an array of objects and convey those locations to an addressee, the speaker was more likely to adopt the addressee's perspective when the perspective-taking was fairly easy (e.g., when the speaker's and the addressee's perspectives were not very different; Galati & Avraamides, 2013). However, when the addressee's perspective involved adopting a perspective that was much farther from the addressee's perspective (e.g., differing by 135°), speakers were much less likely to adopt the addressee's perspective. These findings are in keeping with Clark and Wilkes-Gibbs' (1986) proposal of *least collaborative effort*, in which interlocutors work together to minimize the cognitive load of the exchange rather than minimizing any one individual's cognitive burden. Therefore, the visual perspective of others seems to comprise one factor that both speakers and addressees make use of during online comprehension and production of spoken language. However, little is known about how differing visual perspectives affect language processing when the language itself is visuospatial.

1.1.3. VSPT and Sign Languages

One critical ramification of the topographic expression of spatial relations in ASL is that each interlocutor experiences their own visual perspective of the signer's hands, which conflicts with other interlocutors' visual perspectives. When the signer describes a scene that is not present in the current environment, the conflicting visual perspectives will lead to different mental representations if one interlocutor does not adopt the other's perspective. Because of the visual-spatial modality of signed languages, there is an inherent perspective conflict for non-jointly viewed descriptions that is not found with spoken languages. Experience with reconciling this perspective misalignment may lead to differences in spatial cognition or cognitive control for deaf signers that are not found for hearing speakers without sign language experience.

Resolving perspective-misalignment is not intuitive. When nonsigners express spatial descriptions with gestures, both interlocutors overwhelmingly maintain their own egocentric perspective of the scene resulting in frequent miscommunications (Pyers, Perniss, & Emmorey, 2015). Therefore, conventionalization within the language is necessary for successful communication exchanges and must be learned as a part of the language system. As noted above, spoken language users frequently opt for non-egocentric descriptions from their addressee's perspective (e.g., Schober, 1993; Mainwaring et al., 2003), unless the cognitive demands are exceptionally large (e.g., Galati & Avraamides, 2013). The pressures driving many unrelated sign languages towards egocentric (rather than non-egocentric) productions may be related to greater cognitive burdens for non-egocentric productions in sign languages than for non-egocentric productions in spoken languages due to the visual-spatial modality.

Because adopting a non-egocentric perspective in nonlinguistic, visuospatial tasks seems to involve inhibiting one's own visual perspective (e.g., Qureshi et al., 2010; Samson, Apperly, Kathirgamanathan, & Humphreys, 2005), adopting a non-egocentric perspective in sign language may also involve cognitive control. Results from Pyers et al. (2015) demonstrated that gesturers were significantly less accurate in their productions when adopting a non-egocentric perspective, but gesture comprehenders did not experience any additional cost for adopting a non-egocentric versus an egocentric perspective. Pyers et al. (2015) hypothesized that this asymmetry may reflect greater cognitive cost for producing rather than comprehending from a non-egocentric perspective. However, the nature and extent of the conflict that must be resolved in order to correctly adopt a non-egocentric perspective of gestures or signs remains unknown.

1.1.4. VSPT and Social Abilities

Although better social abilities seem to play a facilitating role in VPST performance for hearing nonsigners (e.g., Brunyé et al., 2012; Clements-Stephens et al., 2013; Shelton et al., 2012), signers have extensive experience with language in the visual modality, which may lead them towards a higher reliance on visual/perceptual VSPT strategies. Howley and Howe (2004) found that deaf children performed significantly worse than hearing children on a cognitive (ToM) perspective-taking task but were no different on a VSPT task, suggesting different strategies for the visual and cognitive perspective-taking tasks. Howley and Howe hypothesized that the deaf children in their study approached both cognitive and VSPT tasks nonsocially, using visual perceptual strategies for the VSPT task that they extrapolated to the cognitive perspective-taking task, whereas hearing children approached both tasks with social strategies. It is unknown whether adult deaf signers approach VSPT tasks with nonsocial/perceptual strategies as has been suggested for deaf children or with social strategies similar to hearing, nonsigning adults.

1.1.5. Sign Language and Spatial Cognition

In addition to differences in VSPT strategies, deaf signers may show an enhancement for VSPT abilities due to their extensive experience with the perspective transformation necessary to adopt the signer's perspective within ASL. While deaf signers do not show a generalized enhancement in spatial abilities due to sign language experience (e.g., Marschark et al., 2015), there is evidence that experience with specific spatial abilities that are integral to sign language use may result in enhancements for those spatial abilities in nonlinguistic contexts, such as image generation (Emmorey, Kosslyn, & Bellugi, 1993), mental rotation (Emmorey, Klima, & Hickok, 1998), and segmenting meaningful structures from continuous movement (Klima et al., 1999). Experience with spatial and perspective transformations within sign language may lead to an advantage in nonlinguistic VSPT tasks for deaf signers, as has been seen with other aspects of spatial cognition.

Additionally, as Quinto-Pozos et al. (2013) suggested, perspective-dependent structures in ASL may depend on nonlinguistic VPST abilities. In a case study, Quinto-Pozos et al. demonstrated that a native signing teenager with a developmental visuospatial deficit struggled only with specific ASL structures that seemed to depend on perspective-taking abilities, such as locative classifier constructions. However, her overall ASL abilities were intact, resulting in highly proficient use of ASL structures that were not perspective-dependent. Similarly, Shield and Meier (2012) examined the fingerspelled[4] productions of native signing deaf children with diagnoses of ASD. They found that, unlike typically developing native signing children, the children with ASD produced fingerspelled letters facing inward (rather than outward), indicating that they did not transform their visual perspective of the fingerspelled letters. Therefore, evidence from atypically-developing signers suggests that being able to perform visual perspective-taking may be a precursor to mastering certain types of sign language structures; however, the relationship between linguistic and nonlinguistic perspective-taking abilities has not yet been documented in typical adult signers.

1.2. Contributions of the Current Dissertation

To date, very little is known about the cognitive mechanisms underlying the perspective-alignment within ASL that is critical to correctly conveying and

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[4] In the ASL fingerspelled alphabet, a specific handshape corresponds to each English orthographic letter, which allows signers to manually spell English words.

comprehending spatial descriptions. However, one important piece of the puzzle is already known: the conventionalized, cross-linguistic pattern is for signers to produce egocentric descriptions while addressees give up their perspective to interpret from the signer's perspective (Pyers et al., 2008). While Pyers et al. (2015) suggested that the convention may have been established because of the differing inhibitory control burdens placed on the signer vs. addressee, this remains to be empirically tested. Study 1 of this dissertation directly tests the hypothesis that producing manual descriptions from a non-egocentric perspective may involve inhibitory control more strongly than comprehending from a non-egocentric perspective. However, inhibitory control burdens may only be part of the picture.

Deaf signing adults may also utilize social abilities or visual/perceptual abilities to help reconcile this perspective-conflict. If they approach the perspective-taking task as an imagined self-projection through space, they may be more likely to rely on their social abilities for performing this transformation, as has been suggested for hearing nonsigners (e.g., Shelton et al., 2012, Gronholm et al., 2012; Kessler & Thomson, 2010), particularly since ASL is a highly social, face-to-face language. If, however, deaf signers rely on a mental rotation strategy as Emmorey et al. (1998) suggested, then they may rely on nonsocial or perceptual approaches when performing VSPT tasks. Study 2 investigates whether adult deaf signers utilize a social strategy for VSPT tasks like adult hearing nonsigners (suggesting the importance of social life experiences in the use of social abilities during VSPT tasks) or whether they adopt a nonsocial/perceptual strategy as has been posited for deaf children (suggesting that experience with being a deaf signer may be a stronger driving factor than social experience resulting in use of a nonsocial, perceptual visual strategy).

Additionally, perspective-taking within a linguistic domain and a nonlinguistic domain may be related for deaf signing adults, as has been suggested for atypically-developing signing children (e.g., children with ASD or developmental visuospatial deficits). This interaction between linguistic and nonlinguistic perspective-taking abilities may result in signers experiencing enhancements in nonlinguistic VSPT abilities as a result of their lifetime of experience with perspective-taking within language (addressed in Study 2). A second, non-mutually exclusive possibility is that linguistic perspective-taking abilities may depend on sufficient nonlinguistic VPST abilities as Quinto-Pozos et al. (2013) suggested. Study 3 addresses whether this proposed link between linguistic and nonlinguistic perspective-taking ability applies for neurotypical adult signers. An individual's relative strengths in nonlinguistic VSPT may relate to his or her ability to perform the visual-perspective transformation necessary for comprehension of perspective-dependent structures within ASL.

Examining VSPT processes in a language that makes use of the visuospatial modality allows for an interesting discussion of the interface between language and spatial cognition. Additionally, this examination will help clarify what role cognitive control mechanisms play in driving the cross-linguistic perspective convention observed for sign languages. Most importantly, this dissertation fills a gap in the literature as to the nature of the cognitive processes that are involved in using perspective-dependent structures in ASL for adult deaf signers. Understanding these cognitive processes for neurotypical signing adults is important for interpreting typical and atypical acquisition of these structures and for understanding how language modality and sociocultural differences may influence visual-perspective taking abilities.

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Chapter 2: Perspective-Taking in Gestured Spatial Descriptions and the Role of Inhibitory Control (Experiment 1)

2.1. Abstract

Speakers tend to describe viewpoint-dependent *left/right* relations from their addressee's perspective, while signers tend to produce egocentric spatial descriptions. We hypothesized that this language difference results from an asymmetry in the cost of perspective-taking in the visual-spatial modality. To sign from the addressee's perspective, signers must manually represent an opposite spatial arrangement to what they perceive, likely requiring inhibitory control. To test this hypothesis, sign-naïve participants (N=31) produced and interpreted gestured descriptions from either an egocentric or non-egocentric perspective. They also completed three inhibitory control tasks. There was no difference between the cognitive cost for producing vs. comprehending non-egocentric perspectives. Inhibitory control measures correlated with participants' ability to comprehend (r range = .390 – .493; ps< .05), but not produce, gestured descriptions from a non-egocentric perspective. Overall, the results suggest that the convention for signers to produce egocentric descriptions may be related to factors other than inhibitory control.

2.2. Introduction

Visual-spatial perspective-taking ability is critical for a variety of cognitive, linguistic, and social tasks. For example, a speaker needs to know what and how another person sees a scene in order to correctly refer to spatial locations within it.

Children's development of this ability to interpret scenes from another's visual perspective was initially described by Piaget and Inhelder (1956) with respect to their Three Mountains task. In more recent years, referential communication tasks have demonstrated that even as adults, perspective-taking ability is not free from errors; for example, in the visual world paradigm, adults still look towards and occasionally reach for objects that are not in their interlocutor's visual perspective and thus are not viable referents (e.g., Brown-Schmidt et al., 2008; Keysar, Barr, & Horton, 1998; Keysar, Lin, & Barr, 2003). Most previous studies have used spoken language with visual referents to investigate the role of visual-spatial perspective-taking within communicative exchanges; however, this role is less clear when the language itself is visual-spatial.

Sign languages make use of the hands, face, and body as articulators to represent the relative spatial position of objects iconically in space: a handshape representing a cup is placed on top of a handshape representing a table to describe the location of a cup on a table. Viewpoint-dependent spatial descriptions, such as *left* or *right,* exhibit an inherent viewpoint conflict associated with the iconic representation of such spatial relations – the signer and the addressee each have a different, conflicting visual perspective of the signer's articulators. For example, in face-to-face interactions, a sign articulated on the left side is perceived by the addressee on her right side. Across different sign languages, the convention is for signers to express viewpoint-dependent relations of non-present referents[5] from their own perspective, and for addressees to interpret the spatial description from their interlocutor's point of view (Pyers et al., 2008; Pyers et al., 2015). Here, we examined whether the cross-linguistic similarity observed across sign languages is driven by the relative inhibitory control costs of adopting the interlocutor's perspective when communicating or comprehending viewpoint-dependent spatial relations in the visual-manual modality.

The mental process underlying the perspective-taking involved in the iconic depiction of spatial relations in the visual-spatial modality is complex. If signers choose to express a spatial relation from the perspective of their interlocutor, they must first form a mental image of the desired spatial description (e.g., a ball to the left of a cup) and then transform the mental image to convey the opposite perspective to match that of their interlocutor (see Fig. 2.1A). This mental transformation could be through a mental rotation process, an embodied perspective transformation, or a rule-mapping transposition strategy to "reverse what I see." Thus, signers must ignore the spatial positions of the objects as originally represented in the mental image in order to iconically map the reversed spatial locations of objects onto their hands (i.e., producing the cup on their left side and the ball on their right). Consequently, for signers adopting the perspective of their interlocutor, the mental representation and the

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[5] When signers describe a referent that is present in their environment, they often use *shared space* where both signer and addressee simply map the descriptions onto the jointly-viewed physical space. There is no need for perspective-taking. In descriptions of non-present referents, however, there is no jointly viewed environment to allow for use of shared space and thus both interlocutors must consider whose perspective of the scene to represent. See Emmorey (2002) and Emmorey and Tversky (2002) for further discussion of shared space.

linguistic expression of the spatial relation are mismatched. Similarly, for addressees to adopt the signer's perspective, they must first ignore the spatial positions conveyed with the signer's articulators, and then perform a perspective transformation so that their mental image aligns with the visual perspective of the signer (also perhaps via a mental rotation, embodiment, or a rule-mapping process to "reverse what I see"; see Fig. 2.1B). This perspective-transformation creates a mismatch between the perceived location of the signed description and the correct mental image of the spatial relation.

The need for perspective alignment in iconic signed descriptions of viewpoint-dependent spatial relations is clear, and consequently, perhaps it is intuitive to resolve for those communicating in the manual modality. However, this does not appear to be the case. In a shielded communication task, sign-naïve participants spontaneously gestured viewpoint-dependent spatial relations from their egocentric perspective, just like Deaf users of American Sign Language (ASL) (Pyers, Perniss, & Emmorey, 2015). But, unlike signers, they also interpreted gestural descriptions of viewpoint-dependent spatial relations egocentrically, leading to a perspective misalignment and a miscommunication on 76% of the trials. A comparison group of fluent Deaf signing participants signed egocentric descriptions 100% of the time and their addressees interpreted these descriptions non-egocentrically in the vast majority of trials (91% of the time), resulting in successful communication exchanges. Thus, while signers and nonsigners did not differ in how often they *produced* from an egocentric perspective, they differed significantly in how often they *comprehended* from an egocentric perspective and therefore in how often the message was successfully interpreted. Fig. 2.2 illustrates the perspective alignments that result both in successful communication

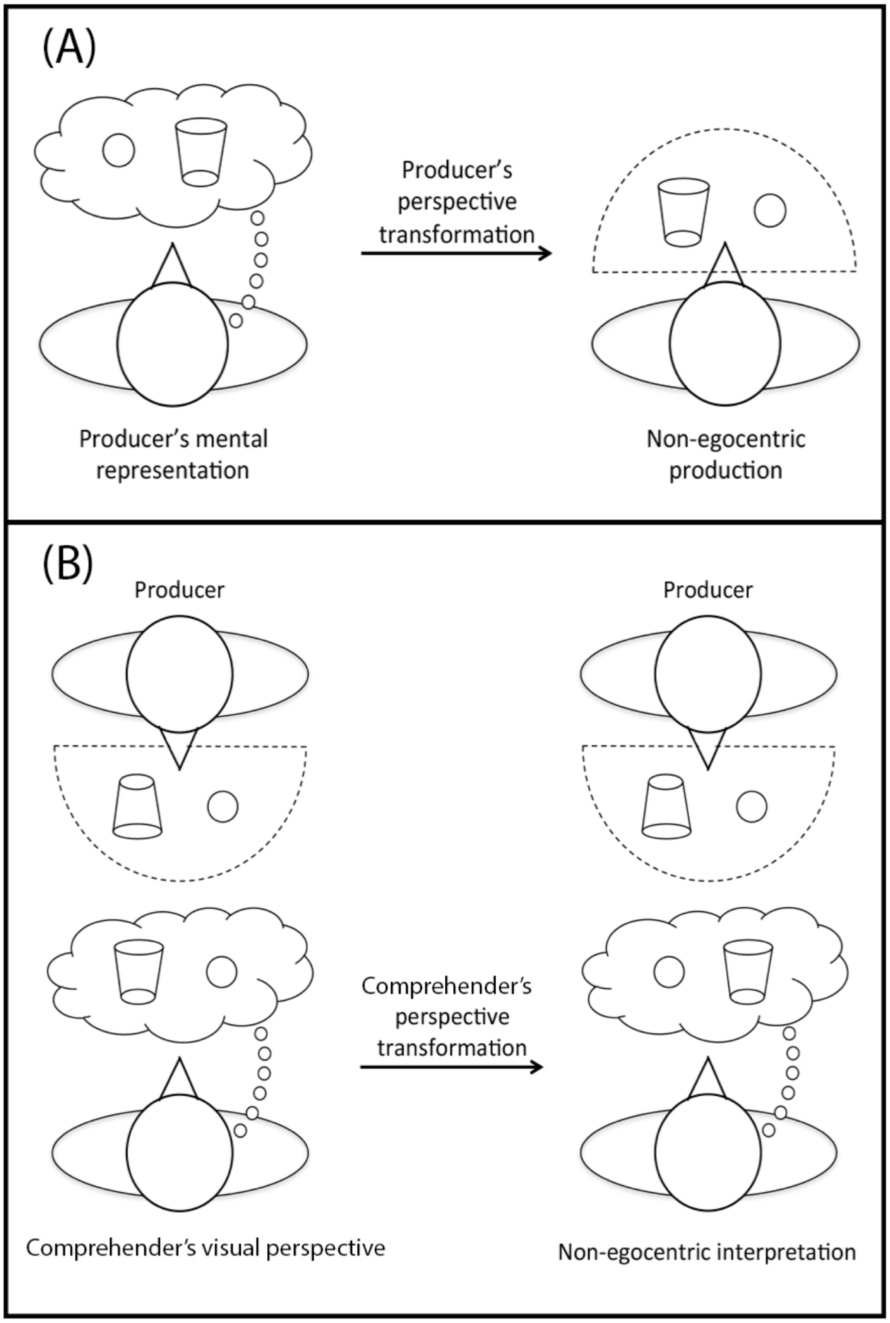

Figure 2.1. Perspective alignment processes for producers and comprehenders. (A) Producers must transform their mental representation in order to produce the manual description from a non-egocentric perspective. (B) Comprehenders must transform the perceived spatial arrangement of the description in order to interpret from a non-egocentric perspective. Note that if comprehenders do not transform their perspective (as in the left side of (B)), they will incorrectly interpret the producer's description. Mental representations are depicted in thought bubbles and physical productions are depicted in dotted line semicircles.

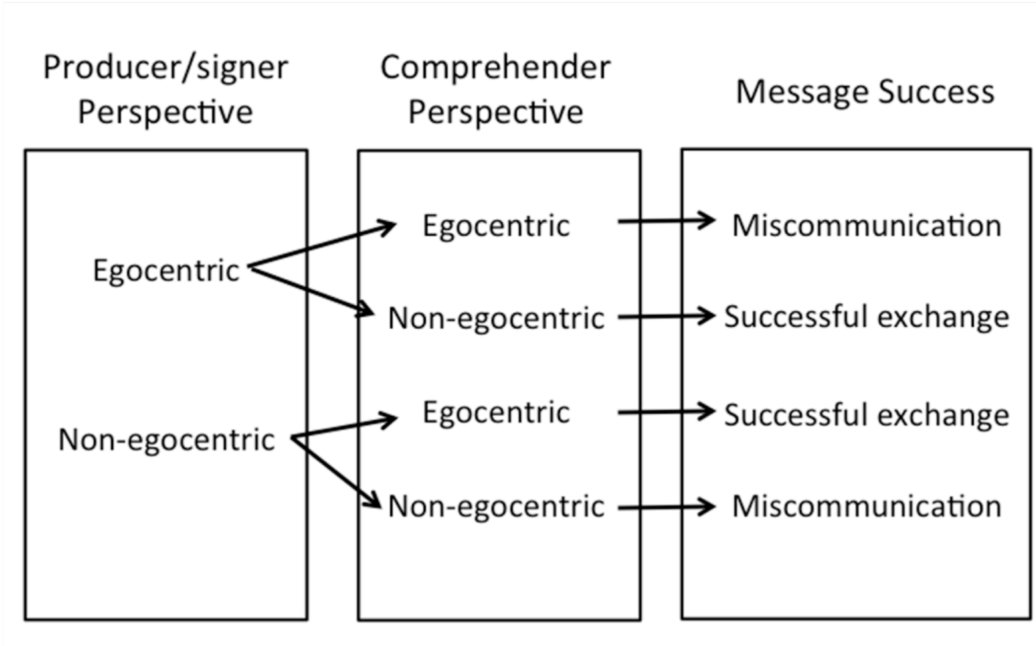

Figure 2.2. Perspective alignment and message success for producers and comprehenders.

exchanges and miscommunications. Clearly, perspective alignment within a manual communication exchange does not arise spontaneously and must be conventionalized in order for the communication exchange to be successful, as is the case for mature sign languages.

The pattern of viewpoint alignment observed for ASL (i.e., describing egocentrically and interpreting non-egocentrically) has been observed across a variety of unrelated sign languages (Pyers, Perniss, & Emmorey, 2008), suggesting that there may be cognitive pressures that favor a perspective alignment based on egocentric production/non-egocentric comprehension over an alignment based on non-egocentric production/egocentric comprehension. Because of the viewpoint convention that has been established in mature sign languages, cognitive costs must be examined in sign-naïve participants who cannot draw from linguistic conventions to guide their performance. Based on their results with nonsigners, Pyers et al. (2015) hypothesized that the cognitive pressure stems from a greater cost to *produce* from a non-egocentric perspective than to *comprehend* from a non-egocentric perspective. They suggested that producing a non-egocentric description might place greater demands on the executive function system because of the need to inhibit the egocentric perspective in order to adopt the non-egocentric perspective.

In nonlinguistic/communication perspective-taking tasks, some evidence has suggested there is a relationship between inhibitory control (IC) – the ability to ignore irrelevant conflicting information in order to attend to the relevant information – and visual perspective-taking. For example, participants asked to adopt the perspective of an avatar exhibited a greater processing cost (as measured by increased reaction times and error rates) when they had to concurrently perform an IC task, although they nevertheless demonstrated some sensitivity to the avatar's perspective (Qureshi et al., 2010). Additionally, Surtees, Samson, and Apperly (2016) suggest that directly selecting and reporting how another sees a scene may involve cognitive control but that another's perspective (i.e., whether that person sees something) may be calculated automatically. Such a finding is in keeping with previously proposed models of two systems for visual perspective-taking: one that is automatic, and one that is effortful and thus may require cognitive control (Apperly & Butterfill, 2009; Samson, Apperly, Braithwaite, Andrews, & Bodley Scott, 2010; Surtees, Butterfill, & Apperly, 2012).

The relationship between IC and perspective-taking extends beyond the non-linguistic monitoring of perspective to the online application of non-egocentric perspectives during language processing. In a referential communication task in which speakers asked questions to obtain information about referents, Brown-Schmidt et al. (2008) found that addressees focused their attention to referents in private ground and ignored referents in common ground. Thus, addressees were sensitive to speakers' visual perspective, attending to referents that were unknown to the speaker and thus more likely to be asked about. In another study using the same referential communication task apparatus, participants' performance on a verbal Stroop task correlated with their ability to ignore competitors that were already visible to the speaker (Brown-Schmidt, 2009). This relationship suggests that individuals who were better able to inhibit conflicting verbal information also were better able to apply knowledge of another perspective during an online communication task. Although monitoring perspective during communication tasks seems to recruit inhibitory control, the precise nature of the conflict control involved in selecting the correct visual perspective and ignoring the competing perspective remains unknown.

The Dimensional Overlap Model (Kornblum, 1994; Kornblum, Stevens, Whipple, & Requin, 1999) provides a possible account for how IC may be involved in perspective conflicts. This model describes two kinds of conflict that can arise between stimuli and responses. First, a Stimulus-Stimulus (S-S) conflict arises when two dimensions of the stimulus are in conflict. For example, in the Spatial Simon task (e.g., Blumenfeld & Marian, 2011, 2014), conflict appears in the spatial dimension when arrows point either to the left or to the right and are placed either on the left or right side of the screen. Here arrow direction (e.g., pointing to the left) and side of the screen (e.g., presented on the right side of the screen) can conflict to result in a S-S conflict. Second, a Stimulus-Response (S-R) conflict occurs when an aspect of the stimulus is in conflict with an aspect of the response. The Spatial Simon task also involves S-R conflict. Individuals press either a left or right response key to indicate the direction that the arrow points. When the arrow is presented on the left side of the screen but points to the right, the appropriate response is to press the right response key which creates a conflict between one aspect of the stimulus (side of the screen) and an aspect of the response (side of the response key).

The differential demands of perspective alignment in the manual modality may similarly draw on different types of IC conflict. When signs/gestures are produced from an egocentric perspective, the interlocutor may experience S-S conflict between the spatial location of the productions and the spatial location of the correct interpretation of the stimulus. To return to the initial example of describing a ball to the left of a cup (Fig. 2.1B), comprehenders could interpret the production from a non-egocentric perspective. In order to do so, they must ignore the visually-perceived location of the signs/gestures and imagine a spatial location that is non-egocentric and thus opposite of the perceived location of the hands. This process may additionally be shaped by the cognitive resources required to map the manual productions to pictured objects. While the Spatial Stroop task includes identical stimuli with spatial aspects in conflict (e.g., arrows), non-egocentric comprehension of gestured spatial descriptions includes not only conflicting spatial aspects but also an additional mapping process between the hand gestures and the pictured and/or imagined objects to which they refer. Thus, the S-S conflict may be weaker in the gesture comprehension task than when identical stimuli are used (as in the Spatial Stroop task).

Conversely, producers could describe the spatial arrangement non-egocentrically. In that case, producers would need to imagine their desired description (e.g., ball to the left of cup) and produce the opposite spatial arrangement of the signs/gestures (e.g., cup to the left of ball; Fig. 2.1A). Such a non-egocentric production could involve a S-R conflict because one aspect of the stimulus (spatial position of the object in the representation) conflicts with one aspect of the response (side of sign/gesture production). The difference between the S-S and S-R conflict might explain the pattern of results seen previously in non-egocentric gesture production and comprehension tasks.

Pyers et al. (2015) found modest evidence that there was a cognitive cost for hearing non-signers when producing or comprehending gestured descriptions of spatial locations from a non-egocentric perspective (their Experiment 2). Producers were significantly less accurate in their productions when adopting a non-egocentric perspective, but comprehenders performed similarly with both egocentric and non-egocentric perspectives (although there was a numeric trend for higher accuracy for comprehenders during egocentric perception). Additionally, producers were slower to initiate productions from a non-egocentric perspective on the first trial (measured off-line from videotape), but they adapted to the task such that there was no overall timing difference between the perspective conditions. Comprehenders were non-significantly faster in egocentric perspectives as compared with non-egocentric perspectives overall and on the first trial.

The observed asymmetry between comprehenders and producers may be due to the differing nature of the conflict for gesture production and gesture perception.

Comprehenders must resolve conflicting aspects of the stimuli (S-S conflict), mapping from the gestures to the pictured objects, whereas producers must resolve conflicting stimulus and response aspects (S-R conflict). However, the lack of a cost observed by Pyers et al. (2015) for comprehending from non-egocentric perspectives should be interpreted with caution. Offline recording of RT from video frames is an imprecise measure of RT and may have failed to detect subtle costs associated with comprehending from non-egocentric perspectives. Additionally, the between-subjects design may have introduced extra variation that masked a cost for comprehenders to adopt non-egocentric perspectives. Finally, they did not specifically test whether the cognitive cost is explicitly related to the ability to *inhibit* one's own perspective in order to express a non-egocentric one.

Pyers et al. (2015) made two suggestions about the nature of the cost associated with perspective alignment in the manual modality. First, they considered the argument outlined above, that IC demands might be different for producers and comprehenders. Second, they suggested that motor embodiment mechanisms may be an alternate approach to performing the perspective-transformation, namely for comprehenders. However, both producers and comprehenders may imagine their interlocutor's perspective by imagining the process of physically moving themselves through space to align with their interlocutor's perspective. This embodied self-rotation seems to involve an imagined visual and proprioceptive experience of moving oneself through space to align with the other's spatial position (Kessler & Rutherford, 2010; Kessler & Thomson, 2010). Such an embodied perspective-transformation strategy has been suggested to rely minimally on executive control functions and thus would be expected to show no correlations with any Stroop- or Simon-type IC tasks (Gardner et al., 2013).

By using a within-subjects design, we explicitly tested whether IC was related to the ability to produce or comprehend manual gestures from a non-egocentric perspective. We isolated the comprehension and production components of the gesture communication task by having each participant complete the task in both communication roles, allowing us to control for random effects due to individual differences. In addition to creating more experimental control, we collected more precise, computer-timed RTs for both communication tasks to increase our ability to detect any subtle costs associated with non-egocentric perspective-taking.

In sum, the research questions driving this study were:

(1) Within the same individual, is the cost greater for producing gestures from non-egocentric perspectives than for comprehending gestures from non-egocentric perspectives?
(2) Do inhibitory control abilities support production and/or comprehension of manual gestures from non-egocentric perspectives?
(3) Does the conflict control involved in producing or comprehending non-egocentric perspectives involve Stimulus-Stimulus and/or Stimulus-Response conflict?

Based on Pyers et al. (2015), we predicted that producers would show a cost for adopting non-egocentric perspectives during the gesture production task. Further, we predicted that in our within-subjects design, comprehenders' responses would show a significant cost for interpreting non-egocentric perspectives. We also expected to observe an asymmetrical cost for producers as compared with comprehenders that would be indicated by a significant interaction between perspective (egocentric, non-egocentric) and task (production, comprehension). Such a result would support the hypothesis that sign languages have converged on egocentric production/non-egocentric perception because of a greater cost for producing non-egocentrically. Additionally, we predicted that individual IC abilities would correlate with performance on the gesture communication tasks. Following the Dimensional Overlap Model (Kornblum, 1994; Kornblum, Stevens, Whipple, & Requin, 1999), we hypothesized that the ability to produce non-egocentrically would recruit similar cognitive mechanisms as resolving S-R conflict, particularly within the spatial domain. Conversely, the ability to comprehend non-egocentrically should involve similar cognitive mechanisms to those used in the resolution of spatial S-S conflict. Finally, if the cognitive control demands are not specific to inhibition in the spatial domain, then individuals' IC abilities on a nonspatial IC task should also correlate with the cost of adopting non-egocentric perspectives in the gesture communication tasks.

2.3. Methods

2.3.1. Participants

Thirty-one hearing nonsigners (24F; M_{age} = 23.1 years, *SD* = 3.9; range: 18.1 - 33.5 years) participated in the experiments in San Diego, CA. All participants were monolingual native English-speaking adults, with no sign language experience.

Participants' self-report of race consisted of Caucasian (*n* = 26), more than one race (*n* = 3), and unknown (*n* = 2). Four participants reported Latino/Hispanic ethnicity.

2.3.2. Materials

Participants completed two communication tasks (Gesture Comprehension and Gesture Production) and three Inhibitory Control (IC) tasks (Spatial Stroop, Spatial Simon, and Nonspatial Simon) individually in a quiet testing room. The presentation order of tasks was counterbalanced across participants with one exception: the Nonspatial Simon task was always presented last. The Spatial Simon and Spatial Stroop were of most theoretical interest to our research questions, and thus we wanted to avoid carryover effects from the Nonspatial Simon task. In all tasks, participants received both verbal and written instructions.

2.3.2.1. Communication tasks.

In a fully within-subjects, 2x2 factorial design, we manipulated perspective (egocentric vs. non-egocentric) and array (front/back vs. left/right) for both comprehension and production tasks. Participants were first taught four hand gestures that corresponded with four visually distinct objects: a cup, a chopstick, a piece of paper, and a ball (see Fig. 2.3).

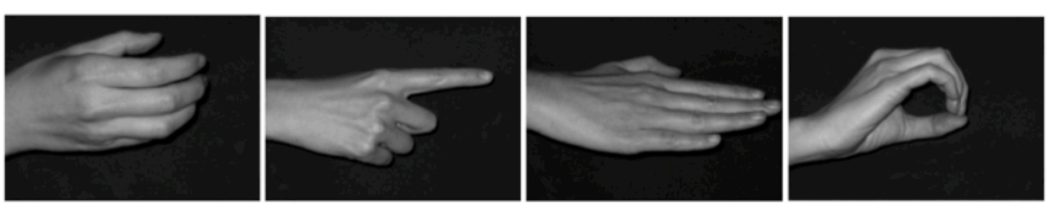

Figure 2.3. The four gestures taught to hearing, sign-naïve participants for use during the Gesture Comprehension and Gesture Production tasks, in order from left to right: cup gesture, chopstick gesture, paper gesture, and ball gesture (based on Pyers et al., 2015).

2.3.2.1.1. Gesture Comprehension.

In the Gesture Comprehension task, participants viewed videos of a task- and sign-naïve model producing gestures simultaneously with both hands to represent two of the four objects, one with each hand (Fig. 2.4A). The participants' task was to choose the picture that matched the model's gestural description.

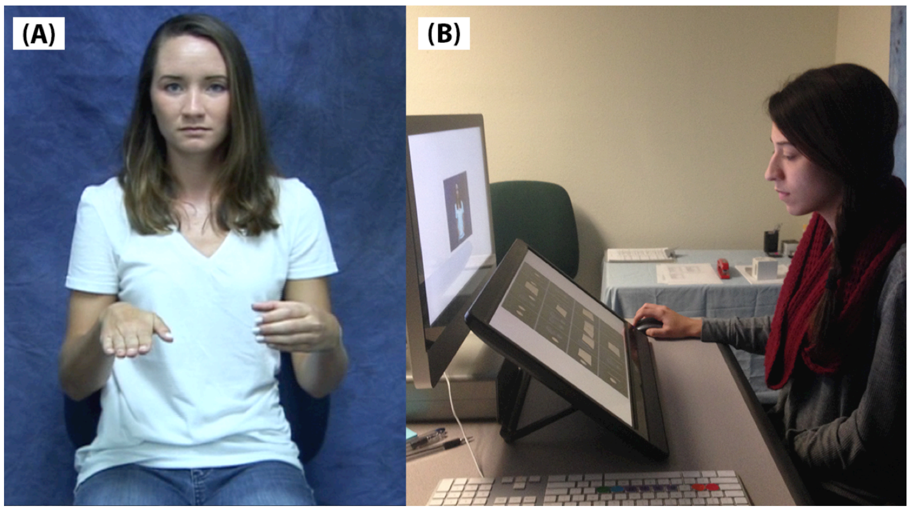

Figure 2.4. Sample stimulus for the Gesture Comprehension task. (A) Sample still frame from a stimulus video. (B) Gesture videos were presented on an iMac screen and the response grid was displayed on an external monitor in front of the iMac.

The videos were presented on a 21.5-inch iMac screen. A response grid of 16 pictures in a fixed order depicting different pairs of the four objects was presented on a separate tablet screen monitor (21.5-inch) positioned on the table below the iMac in front of the participant at a 140 degree angle from the table (Fig. 2.4B). Using a mouse, the participants clicked on the picture in the response array that corresponded to each gesture production. Two types of object pairs were included in the array: *perspective-dependent* items depicted two different objects (e.g., a ball and a chopstick), while *perspective-independent* stimulus items depicted two identical items (e.g., two chopsticks). The response grid displayed all possible spatial arrangements of the four target objects.

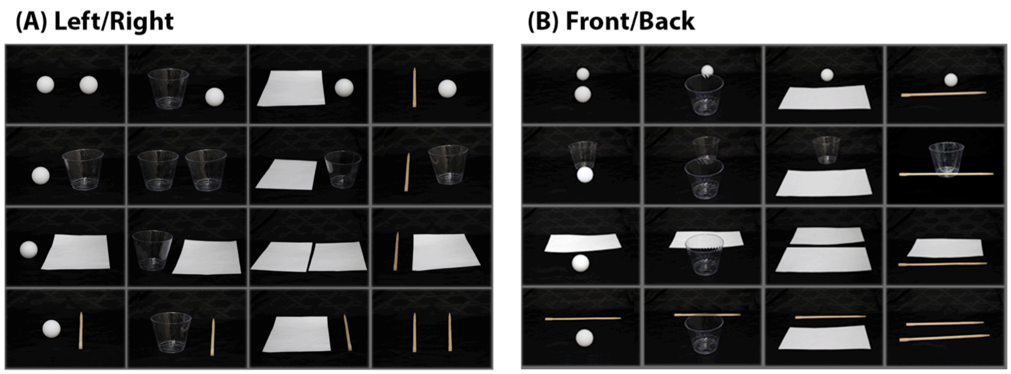

Figure 2.5. Response grids corresponding to the left/right array (A) and front/back array (B) for Gesture Production and Gesture Comprehension tasks. Participants and confederates selected the corresponding picture after viewing the gesture production.

In the egocentric condition, participants were asked to interpret the model's gestures from their egocentric perspective, and in the non-egocentric condition, they were asked to interpret the gestures from the model's perspective. In the left/right condition, the objects were aligned on the x-axis (Fig. 2.5A), and in the front/back condition they were aligned on the z-axis (Fig. 2.5B). The order of presentation of the four blocks (egocentric-front/back, non-egocentric-front/back, egocentric-left/right, non-egocentric-left/right) was counterbalanced across participants with the constraint that participants saw the egocentric and non-egocentric conditions of each array condition (front/back or left/right) consecutively, and that perspective conditions were presented in the same order for both arrays. We blocked conditions to reduce the cognitive load of switching between response arrays, which would have increased participants' search times.

All blocks began with a still frame example of the gestures for a sample picture with the corresponding correct response picture. Then participants completed 16 practice trials – one trial for each of the 16 response pictures to ensure that no one picture was seen more than any other. During the practice, participants received corrective feedback.

After practice, participants completed the experimental block of 16 trials (one trial for each of the 16 response pictures) without feedback for a total of 64 experimental trials across conditions. Within each condition, stimulus items were presented in a pseudorandomized order, ensuring that one object was not presented more than two times in subsequent trials. No sequential trials consisted of reversed spatial arrangements of the same two objects (e.g., a cup in front of the ball immediately followed by a cup behind the ball), and at least two perspective-dependent trials occurred between perspective-independent trials.

Reaction time (RT) and accuracy (proportion of correct responses) were collected for each response. RTs were measured from the video onset (average video duration = 2095 ms, *SD* = 269 ms) until the participant clicked the mouse to select the response picture. The participant clicked on a centrally placed fixation cross to start the video.

We computed a measure of "Cost RT" by subtracting the reaction times of "perspective-independent" trials, which did not require adopting another perspective, from "perspective-dependent" trials, which required considering perspective. In essence, the perspective-independent trials allowed us to remove the time required to view a video, make a decision, and click on a picture in order to isolate the response cost of adopting another's perspective.

2.3.2.1.2. Gesture Production.

In the Gesture Production task, participants were shown pictures depicting pairs of the four objects on a 15-inch Apple Power Book G4 laptop. They were asked to produce the corresponding hand gestures to describe the picture to a confederate who selected a picture from the same response grid as was used in the Gesture Comprehension task. Confederates were research assistants or staff who were instructed to select a picture by pointing to the grid. Participants could not see confederate's selections. Counterbalancing and order of item presentation followed the same guidelines as laid out for the Gesture Comprehension task.

In the egocentric condition, participants were told to produce the gestures exactly as they saw the objects in the picture. In the non-egocentric condition, participants were instructed to produce the gestures from their partner's perspective so that their partner could choose the picture that matched how they saw the producer's hands. In both conditions, participants were provided with a sample picture stimulus item and the corresponding object gestures.

Participants pressed down and held the spacebar for the stimulus picture to appear on the screen. They held down the spacebar for as long as they wanted to plan their gesture production, and then released it to produce both hand gestures simultaneously. The stimulus disappeared from the screen with the release of the spacebar key. Gesture productions were video recorded for offline coding. The dependent measures were accuracy (proportion of correct productions) and gesture planning time, or the duration that the spacebar was held down. We also computed a "Cost RT" in the same way outlined above for the Gesture Comprehension condition.

2.3.2.1.3. Gesture Production coding.

Although participants may have produced multiple gesture productions for a single trial (e.g., correcting an erroneous gesture production), we coded only participants' first gesture productions. We further coded the spatial arrangement of the gestures by coding the position of each gestural representation (right or left side, or close to or far from the body). Additionally, we coded "Production Quality" using a binary coding system. Productions received a score of "1" if the production included both hands immediately producing simultaneous gesture productions, and a score of "0" if there was hesitation, asynchrony in productions, or if participants changed their hand gestures during the first production.

We observed high interrater reliability between two independent coders who coded all of the data (93% agreement; Cohen's kappa = .955, $p < .0001$). Any disagreements were discussed until a consensus was reached. RT analyses included only productions that received a score of "1" for Production Quality, eliminating any noise from motor production errors.

2.3.2.2. Inhibitory Control tasks.

2.3.2.2.1. Spatial Stroop.

In the Spatial Stroop task (Blumenfeld & Marian, 2011; 2014), participants viewed a series of individual black arrows pointing either to the left or right on a 15-inch Apple Power Book G4 laptop screen. Participants were instructed to press a response key (the 'z' key) when they saw an arrow pointing leftward and a different response key (the '/' key) when they saw an arrow pointing rightward. Additionally, the arrows were presented in one of three spatial locations on the screen: left, middle, or right. Participants were instructed to ignore the arrow's location on the screen. Congruent trials occurred when the direction of the arrow matched the side of the screen on which the arrow was presented (e.g., arrow pointing leftward presented on the left side of the screen; see Fig. 2.6). Incongruent trials occurred when the direction of the arrow mismatched the side of the screen on which the arrow was presented (e.g., arrow pointing leftward presented on the right side of the screen). Baseline trials displayed the arrow in the center of the screen.

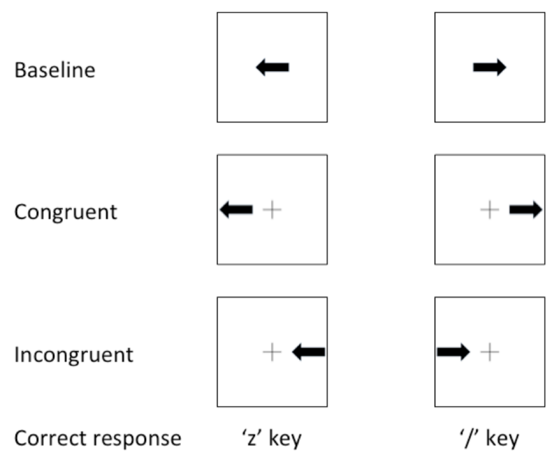

Figure 2.6. Spatial Stroop stimuli and responses. Participants were instructed to press the key corresponding to the direction of the arrow (left or right).

Participants viewed a fixation cross for 500 ms followed by an arrow for up to 2000 ms that disappeared once a response had been made. Between trials, participants viewed a blank screen for 500 ms. Participants were shown 20 practice trials (4 baseline, 12 congruent, and 4 incongruent trials). During the experimental trials, participants viewed 126 congruent trials, 42 incongruent trials, and 42 baseline trials in a fixed pseudorandomized order. Both directions of arrows were equally represented in each of the conditions (congruent, incongruent, and baseline).

Each person's Spatial Stroop effect was calculated by subtracting the average RT for congruent trials from the average RT from incongruent trials for that task. A small Spatial Stroop effect indicates reduced cost for incongruent trials. The Spatial Stroop effect provides a metric for how well each person ignored the irrelevant features of the stimulus (e.g., spatial location of the arrow) in order to attend to the target feature in the stimulus or response (e.g., direction that the arrow points).

2.3.2.2.2. Spatial Simon.

In this task (from Blumenfeld and Marian, 2014), participants viewed a series of individual black arrows pointing either up or down on a 15-inch Apple Power Book G4 laptop. Participants were instructed to press a response key (the 'z' key) when they saw an upward pointing arrow and a different response key (the '/' key) when they saw a downward pointing arrow. The arrows were presented in one of three spatial locations on the screen: left, middle, or right. Congruent trials occurred when the location of the arrow matched the location of the correct response key (e.g., an upward pointing arrow requiring a left key press presented on the left side of the screen). Incongruent trials occurred when the location of the arrow mismatched the location of the correct response key (e.g., an upward pointing arrow requiring a left key press presented on the right side of the screen; see Fig. 2.7). Baseline trials consisted of arrows presented in the center of the screen. Incongruent trials in the Spatial Simon task exhibit S-R conflict where one stimulus dimension (i.e., arrow location) and one response dimension (i.e., response location) conflicted. Participants viewed the same number of congruent, incongruent, and baseline trials as in the Spatial Stroop task in a fixed pseudorandomized order with equal numbers of each direction of arrow. Trials were presented using the same fixation and timing procedures as the Spatial Stroop task. Each participant's Spatial Simon Effect was computed in the same way as the Spatial Stroop Effect.

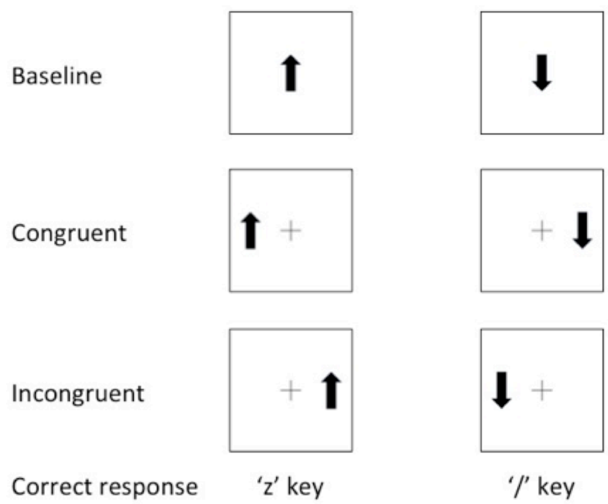

Figure 2.7. Spatial Simon stimuli and responses. Participants were instructed to press the left button ('z' key) when the arrow pointed upward and the right button ('/' key) when the arrow pointed downward.

2.3.2.2.3. Nonspatial Simon.

In the Nonspatial Simon task, participants viewed either squares or circles on a laptop screen. These shapes were presented in one of three colors: black, blue, or orange. Participants were instructed to use only the index finger of their dominant hand to press one of two response keys in accordance with the rule: "Press the blue key when you see a square and the orange key when you see a circle" while ignoring the color of the shape. The response keys were created by affixing a colored sticker to either the ‘y’ key (blue sticker) or the ‘h’ key (orange sticker). These keys were selected in order to minimize the spatial component of the response buttons. Although this arrangement does not eliminate the spatial component entirely, it differs from the left/right arrangement of keys for the other IC tasks, and the forward/backward spatial arrangement is irrelevant to the demands of the task.

In the congruent trials, the shape color matched the response key color (i.e., a circle presented in orange ink; see Fig. 2.8). In the incongruent trials, the color of the shape mismatched the color of the correct response key (i.e., a circle presented in blue ink). Baseline trials were black and neither matched nor mismatched the response key colors. Participants viewed the same number of congruent, incongruent, and baseline trials as in the Spatial Stroop and the Spatial Simon tasks in a fixed pseudorandomized order with equal numbers of each shape. Trials were presented using the same procedure as the Spatial Stroop and Spatial Simon tasks. Each participant’s Nonspatial Simon Effect was computed in the same way as the Spatial Stroop Effect.

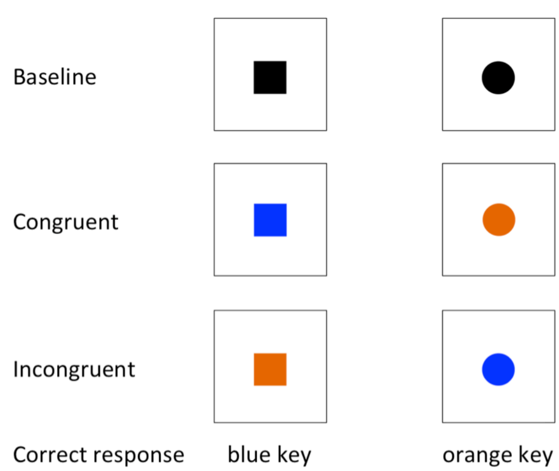

Figure 2.8. Nonspatial Simon stimuli and responses. Participants were instructed to press the blue button (‘y’ key) when they saw a square and the orange button (‘h’ key) when they saw a circle.

2.4. Results

We excluded practice trials from all analyses, and only included correct trials for the reaction time (RT) analyses. For the Gesture Comprehension and Gesture Production tasks, RTs greater than 3 *SD* from each person's mean were eliminated from the analysis (0.94% and 1.4% of the data, respectively). Nonspatial Simon scores were unavailable for one participant due to time constraints during testing.

2.4.1. Gesture Communication Tasks Results

2.4.1.1. Reaction Time

The pattern of results was similar whether we used raw RTs or Cost RTs. Thus, we report the results with Cost RTs as the dependent measure because they reflect a more specific measure of the cognitive cost associated with the perspective demands of the task. The results are shown in Fig. 2.9.

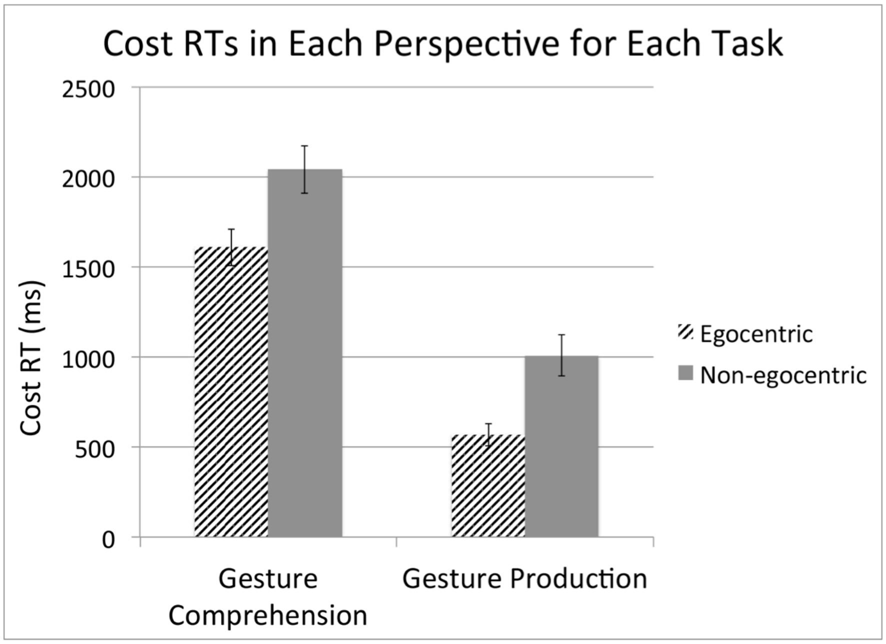

Figure 2.9. Cost RTs were greater for non-egocentric than for egocentric perspectives, and Cost RTs were greater in the Gesture Comprehension task than in the Gesture Production task.

In order to determine whether there was a larger cost for adopting non-egocentric perspectives as compared with egocentric perspectives, a 2 (task: Gesture Production, Gesture Comprehension) x 2 (perspective: egocentric, non-egocentric) x 2 (array: left/right, front/back) repeated measures ANOVA was conducted using Cost RTs as the dependent measure. We observed a main effect of perspective with significantly higher Cost RTs in the non-egocentric condition as compared with the egocentric condition, $F(1,30) = 50.6$, $p < .001$, $\eta_p^2 = .628$. There was no interaction between task and perspective indicating that (contrary to our prediction) adopting a non-egocentric perspective was not more costly during the production task than during the comprehension task, $F(1,30) = .013$, $p = .909$. Notably, adopting an egocentric perspective for both tasks also incurred a cost, i.e., the Cost RT for egocentric perspectives was not zero. This egocentric cost suggests that retrieving two object-gestures that must be mapped to each hand (required for the perspective-dependent trials) is more effortful than retrieving a single object-gesture that is identical for both hands (required for the perspective-independent trials). Additionally, there was a main effect of task with larger Cost RTs in the Gesture Comprehension task than the Gesture Production task $F(1,30) = 90.5$, $p < .001$, $\eta_p^2 = .751$. This effect is likely due to task-specific differences: before making a response in the Gesture Comprehension task, participants had to watch the gesture video and search the response grid for the desired picture, resulting in longer RTs as compared with the Gesture Production task which only required viewing a photograph and planning the gestures.

Additionally, there was a significant interaction between array (left/right vs. front/back) and task (Gesture Comprehension vs. Gesture Production), $F(1,30) = 16.8$, $p < .001$, $\eta_p^2 = .359$. Post hoc t-tests revealed that the difference between left/right and front/back arrays was significant for comprehenders, $t(30) = 3.46$, $p = 001$. For comprehenders, RTs for front/back arrays (mean = 1693 ms: *SD* = 112) were faster than for left/right arrays (mean = 1956 ms; *SD* = 112). For producers, there was a nonsignificant trend in the opposite direction, $t(30) = 1.48$, $p = .075$, such that RTs for front/back arrays (mean = 833 ms: *SD* = 101) were longer than for left/right arrays (mean = 727 ms; *SD* = 76). There was no interaction between array and perspective, $F(1,30) = .346$, $p = .561$, and the three-way interaction was nonsignificant, $F(1,30) = 1.36$, $p = .253$.

Because there was no statistically significant difference in Cost RT between the two arrays (left/right or front/back object arrangement), $F(1,30) = 2.34$, $p = .137$, we collapsed data for these conditions for the correlation analyses, increasing our power to detect a relationship between the perspective cost in the communication tasks and the inhibitory control measures.

2.4.1.2. Accuracy

A 2 (task: Gesture Production, Gesture Comprehension) x 2 (perspective: egocentric, non-egocentric) x 2 (array: left/right, front/back) repeated measures ANOVA was conducted on perspective-dependent experimental items using arcsine transformations of the accuracy data as the dependent measure. Results were similar with the untransformed percentage data. Errors in perspective (e.g., producing an egocentric description instead of a non-egocentric description) and object (e.g., selecting the wrong gesture for one of the pictured objects) were labeled as errors for the accuracy analysis, but errors in motor production were not (e.g., hesitant or asynchronous productions). Participants were significantly more accurate in the Gesture Comprehension task (mean = 97.5%; SD = 0.6%) than in the Gesture Production task (mean = 92.4%; SD = 1.3%), $F(1,30) = 13.4$, $p = .001$, $\eta_p^2 = .309$. Additionally, the interaction between task and perspective was significant, $F(1,30) = 5.21$, $p = .030$, $\eta_p^2 = .148$. Post hoc t-tests revealed a nonsignificant trend for producers to be more accurate in egocentric (mean = 97.3%; *SD* = 1.3%) compared to non-egocentric perspectives (mean = 90.9%; *SD* = 2.0%), $t(30) = 1.39$, $p = .088$, with no difference in accuracy between egocentric (mean = 97.1%) and non-egocentric (mean = 97.9%) perspectives for the comprehension task, $t(30) = .104$, $p = .541$. There were no main effects of array (left/right or front/back), $F(1,30) = 1.63$, $p = .212$, or perspective (egocentric or non-egocentric), $F(1,30) = 1.14$, p = .295. Similarly, the interactions between array and perspective, $F(1,30) = .125$, $p = .726$, array and task, $F(1,30) = 2.58$, $p = .119$, and the three-way interaction, $F(1,30) = .537$, $p = .469$ were all nonsignificant.

Taken together, we saw a greater cost for non-egocentric trials across the board, but no relatively greater cost for producers compared to comprehenders in RTs. We did, however, find higher accuracy for comprehenders compared to producers.

2.4.2. Relations to Inhibitory Control

To investigate whether inhibitory control ability was related to the ability to produce or comprehend manual gestures egocentrically or non-egocentrically, we calculated Pearson's correlation coefficients using the Cost RT for egocentric and non-egocentric conditions in the Gesture Comprehension and Gesture Production tasks (see Table 2.1).

For the Gesture Comprehension task, the cost for comprehending gestures non-egocentrically was significantly related to an individual's Spatial Stroop, Spatial Simon, and Nonspatial Simon effects. Critically, none of the IC effect measures correlated with Cost RT in the Gesture Production task. Together, these findings suggest that conflict control is related to the ability to *comprehend* gestures from non-egocentric perspectives but may not mediate the perspective-transformation necessary to *produce* gestures from non-egocentric perspectives.

Table 2.1. Correlation Table for the Gesture Comprehension and Gesture Production Cost RTs for the IC Effect Measures.

	1	2	3	4	5	6	7
1. Egocentric Gesture Comprehension							
2. Non-egocentric Gesture Comprehension	.65*						
3. Egocentric Gesture Production	.37*	.33					
4. Non-egocentric Gesture Production	.35	.27	.78*				
5. Spatial Stroop effect	.25	.39*	-.07	.05			
6. Spatial Simon effect	.20	.49*	-.07	.001	.80*		
7. Nonspatial Simon effect	.41*	.49*	.08	.08	.29	.16	

*p < .05

Somewhat surprisingly, the Nonspatial Simon effect significantly correlated with the Cost RT for comprehending from an *egocentric* perspective. We hypothesized that this correlation might be due to interference from experiencing a non-egocentric perspective block first, and therefore, we analyzed responses from each block separately. If participants were influenced by knowledge of the non-egocentric perspectives only after having experienced a non-egocentric perspective, then there should be no correlation between the egocentric Gesture Comprehension Cost RT and the Nonspatial Simon effect in the first block. However, there was in fact a strong correlation between egocentric Gesture Comprehension Cost RT and the Nonspatial Simon effect in the first block (r = .909, p < .001), but not in any of the subsequent blocks (second block: r = .115, p = .671; third block: r = .308, p = .284;

fourth block: $r = .378$, $p = .149$). Therefore, the relationship between comprehending from an egocentric perspective and the Nonspatial Simon effect is not due to carryover effects from first experiencing non-egocentric conditions. Rather, this relationship may be due to the nature of the mapping process required for both the Gesture Comprehension task and the Nonspatial Simon task, which we will address in the Discussion section.

In order to understand what is driving the significant correlations between the IC effect measures and the Cost RT for comprehending from a non-egocentric perspective, the IC effect measures were divided into their two component parts: the cost of inhibiting incongruent responses ("Interference": Incongruent RT – Baseline RT) and response facilitation for congruent responses ("Facilitation": Baseline RT – Congruent RT). Cost RT for comprehending non-egocentric productions correlated significantly with the Interference measures on the IC tasks, but not with the Facilitation measures (see Table 2.2). This result suggests that ignoring irrelevant conflicting information is the specific cognitive ability that is related to comprehending manual gestures from a non-egocentric perspective. Facilitation from the overlapping features of the stimulus and the response does not seem to play a role.

Table 2.2. Correlation Table for Non-egocentric Comprehension Cost RTs and IC Facilitation and Interference Measures.

	1	2	3	4	5	6	7
1. Non-egocentric Gesture Comprehension							
2. Spatial Stroop interference	.42*						
3. Spatial Stroop facilitation	.03	-.03					
4. Spatial Simon interference	.39*	.55*	-.13				
5. Spatial Simon facilitation	.29	.62*	.32	-.03			
6. Nonspatial Simon interference	.65*	.34	.004	.15	.27		
7. Nonspatial Simon facilitation	-.31	-.15	.07	-.12	-.19	-.61*	

*p < .05

Finally, using linear regression, we investigated which of the IC variables explained the most unique variance in non-egocentric Gesture Comprehension Cost RTs (see Table 2.3). All three IC tasks exhibit S-R conflict, while the Spatial Stroop task additionally exhibits S-S conflict. The Spatial Simon and the Nonspatial Simon effects explained a significant amount of the variance (42%). The Spatial Stroop effect did not significantly account for any additional variance. Thus, when coupled with the significant correlation between all IC effect measures and non-egocentric Gesture Comprehension, the results indicate that S-R conflict, rather than S-S conflict, seems to be driving the relationship between IC abilities and comprehending gestures from non-egocentric perspectives.

Table 2.3. Regression Model Accounting for the Variance in the Non-egocentric Gesture Comprehension Data.

	Unstandardized Coefficients		Standardized Coefficients		
Predictors	β	*SE*	β	*t*	*p*
Constant	1312	248		5.30	<.001*
Spatial Simon effect	8.54	3.38	.634	2.52	.018*
Nonspatial Simon effect	15.42	5.06	.470	3.05	.005*
Spatial Stroop effect	-3.82	3.72	-.266	-1.03	.314

*p < .05

2.5. Discussion

Participants were given a series of tasks to examine the cost of perspective-taking during gestural communication and the relationship between that cost and inhibitory control (IC) abilities. Similar to previous findings, the cost for producing and comprehending gestures from non-egocentric perspectives was significantly higher than for egocentric perspectives. However, this cost was not greater for producers than for comprehenders, contrary to Pyers et al.'s (2015) findings. Nonetheless, we found some evidence suggesting a trend for producers to make more errors in non-egocentric versus egocentric perspectives, whereas comprehenders' accuracy was similar for both perspective conditions. Thus, it is possible that the error rate for adopting another's perspective was slightly greater for producers. However, the overall results indicated that the cognitive cost of adopting another's perspective was not reliably greater for producers than comprehenders.

Somewhat surprisingly, the results from the correlational analyses indicated that comprehending from an *egocentric* perspective was related to participants' performance on the Nonspatial Simon task, but only during the first block of trials. In order to perform the Gesture Comprehension task, comprehenders had to interpret the mapping between the different objects and their corresponding gestures. Similarly, in the Nonspatial Simon task, participants had to establish a mapping between the different shapes on the screen and the appropriate response key. The Spatial Simon and Spatial Stroop tasks did not require the same kind of mapping between different objects and responses – participants saw the same stimulus arrow on the screen for each trial. While the Nonspatial Simon task involved cognitive control, like the other IC tasks, it also required this additional mapping process. In the first block, participants were still getting used to the mapping between the manual responses (picture-selection or color key-presses) and the stimuli (gestures or shapes) in both the Gesture Comprehension task and the Nonspatial Simon task. Therefore, the ability to comprehend gestures from egocentric perspectives was correlated with performance on the Nonspatial Simon task because of the similar mapping processes required by both tasks. After the first block, however, this mapping process became overlearned, and participants no longer needed to recruit cognitive resources to perform the mapping process. Once the mapping had been learned, tasks that continued to recruit IC abilities maintained the significant correlation with the IC tasks, such was the case with the Gesture Comprehension task in the non-egocentric perspective conditions.

Additionally, results from the correlational analyses demonstrated that Cost RTs for comprehenders and not producers were significantly related to their performance on IC tasks. Individuals who were better able to inhibit conflicting visual information were better able to comprehend gestures from a non-egocentric perspective. However, IC abilities did not appear to mediate the cost for producing manual gestures from a non-egocentric perspective. These results suggest that producers may rely on cognitive abilities other than IC in order to perform the perspective transformation required for producing gestures from another's perspective.

For comprehenders, performance on both spatial and nonspatial Simon-type tasks (and not the Stroop-type task) significantly explained a unique amount of the variance in the non-egocentric perspective Cost RTs from the Gesture Comprehension task. Comprehending gestures non-egocentrically seem to recruit IC abilities, specifically with respect to resolution of both spatial and nonspatial S-R conflict. Such a finding appears to be in conflict with the prediction from the Dimensional Overlap Model (Kornblum, 1994; Kornblum, Stevens, Whipple, & Requin, 1999). This model predicts that comprehension of stimuli from conflicting visuospatial perspectives is likely to rely on S-S conflict resolution while production of manual gestures that conflicted with stimuli is likely to rely on S-R conflict. Results from the current study found that comprehending from non-egocentric perspectives seemed to recruit the inhibitory control abilities associated with S-R conflict and not S-S conflict. Our results suggest that S-S conflict may require identical stimulus items, as with the same arrows for each trial in the Spatial Stroop, in order to involve that kind of conflict resolution. The spatial location of the object and the spatial location of the gesture do not seem to be sufficiently similar to require this kind of conflict resolution.

In contrast, the spatial location of a perceived gesture and a conflicting response creates conflict that must be resolved using IC mechanisms in order for a response to be made (S-R conflict). When participants comprehended the gestures from a non-egocentric perspective, they needed to inhibit their egocentric view of the gesturer's hands in order to choose the picture that corresponded with the non-egocentric interpretation of the gesture. This pattern of results could reflect use of an executive strategy that participants employed to perform the perspective-taking task.

Others have previously suggested that the strategy that an individual adopts may affect whether inhibitory control abilities are recruited during a visuospatial perspective-taking task. Gardner et al. (2013) asked participants to complete an embodied perspective-taking task where they reported whether a figure on a screen held a ball in its left or right hand by pressing the corresponding left or right response key. Depending on whether the figure faced the participant or had its back to the participant, the spatial position of the participant's response was either congruent or incongruent with the spatial position of the target black ball. Participants additionally completed a transposition task without a human figure in which they reported whether a black ball was on the left or the right side. On some trials, they simultaneously viewed a visual cue that required them to press the response key corresponding to the opposite side. Participants were asked to report the strategy they used during the tasks. The results showed a significant relationship between performance on the embodied and transposition tasks, but only for those participants who reported performing the embodied perspective-tasking task by using a disembodied transposition strategy.

In another study, Gronholm et al. (2012) had participants perform the same embodied perspective-taking task described previously (i.e., deciding in which hand a figure held a black ball) and complete the Empathy Quotient questionnaire, which is designed to measure different empathic traits of typical adults' personalities (Baron-Cohen & Wheelwright, 2004). Performance on the perspective-taking task correlated with their scores on the Empathy Quotient, but only for individuals who reported using an embodied perspective-transformation strategy and not a disembodied transposition strategy. This selective relationship indicates that those who report more empathic personality traits are more likely to adopt an embodied strategy involving imagining the perspective of the other figure. Similarly, an individual's social skills seem to be related to their performance on an embodied perspective-taking task but only when the context encouraged the use of a social, embodied strategy and not a disembodied, nonsocial strategy (Shelton et al., 2012). Thus, embodied and disembodied routes to perspective-taking seem to be dissociable processes that are mediated by task strategy and task context.

Results from the present study support the idea that the strategy an individual adopts during visual perspective-taking may influence how IC abilities are involved in visual perspective-taking tasks. The nature of the Gesture Comprehension task may have led many participants to spontaneously adopt a disembodied transposition strategy, which would involve IC abilities. If participants completed the task with a physical interlocutor (rather than a model on a computer screen), more people may have adopted an embodied route to perspective-taking. Whether adopting an embodied perspective-transposition strategy relates to *non-egocentrically* expressing manual descriptions of viewpoint dependent spatial relations is a question for future research.

Some visual perspective-taking strategies seem to recruit empathic, embodied cognitive networks, while others seem to recruit IC and other disembodied executive control networks. The current study provides evidence that typical nonsigning adults who know nothing of the perspective convention in sign language may adopt a disembodied strategy to engage visual perspective-taking during a communicative task. An open question is whether fluent signers' performance on the perspective-dependent descriptions is also mediated by a similar disembodied strategy. Alternatively, because signing addressees know that their interlocutor will be producing the viewpoint-dependent descriptions egocentrically, as is the convention in most sign languages, they may readily and consistently adopt an embodied strategy to comprehend the signed descriptions which may not require IC.

The iconic mapping of the position of the hands in space to the imagined spatial relation for viewpoint-dependent spatial descriptions requires visual perspective-taking abilities. Our finding that IC abilities can contribute to the resolution of perceptually-conflicting visual perspective information echoes previous findings showing that addressees' ability to consider their interlocuter's perspective positively correlated with their IC scores (Brown-Schmidt, 2009). Thus, our sign-naïve gesture comprehenders may draw on the same IC abilities as they would in a spoken communication task to apply non-egocentric perspective information.

Overall, producers' cognitive load does not seem to be the driving force behind the cross-linguistic convergence in perspective convention across sign languages. Signers may have many interlocutors at any given time, each possessing a unique visual perspective of the signer's hands. With many addressees, it is impossible for the signer to produce descriptions from all of their addressees' perspectives simultaneously. Thus, leaving the perspective-transformation to the addressee may be the convention for perspective alignment for manual descriptions because it accommodates every situation regardless of the number of addressees.[6]

The convention for signers to produce egocentric perspective-dependent descriptions may reflect what is collaboratively the least amount of effort for this type of communication exchange. Such an explanation would be in keeping with Clark and Wilkes-Gibbs' (1986) idea of "least collaborative effort" as an important driver in achieving mutual understanding (i.e., people try to minimize the work that they have to do together to achieve communication success). Even though addressees seem to draw on IC abilities in order to comprehend from non-egocentric perspectives (suggesting it is a somewhat effortful task), the alternative is likely to be even more effortful. Specifically, it would be particularly challenging for the producer to take into account the different visual perspectives of multiple addressees, and addressees may be in many different possible locations. It may be much easier to place the burden of the perspective accommodation onto the addressee(s). Once the utterance has been generated, addressees can make the single perspective transformation that is appropriate for them given their own visual perspective. Thus, while adopting non-egocentric perspectives is more effortful than egocentric perspectives for each interlocutor, the total cost of the interaction may be minimized when signers produce egocentrically and addressees adopt the signers' perspective during comprehension. The desire to minimize the collective effort is one possible contributing factor that has

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[6] We thank Daniel Casasanto for this suggestion.

led to the pattern seen across many different sign languages for perspective-dependent descriptions.

Evidence from the current study suggests that manual expression of spatial relationships from another's perspective does not involve IC abilities, but comprehending manually-produced spatial descriptions non-egocentrically does. This relationship, however, may be mediated by the cognitive strategy a comprehender spontaneously adopts. Therefore, the sign language convention of producing spatial descriptions egocentrically may be driven by practical concerns to reduce collaborative effort of the communicative exchange, rather than cognitive control pressures. Continued examination of the types of strategies used by signers versus nonsigners (e.g., embodied/disembodied, social/nonsocial) will further identify what processes are involved in visual-spatial perspective-taking within a language expressed in the visual-spatial modality and how cognitive constraints may differentially affect perspective-taking when the language modality changes.

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Chapter 3: The Relation Between Social Abilities and Visual-Spatial Perspective-Taking Skill Differs for Deaf Signers and Hearing Nonsigners (Experiment 2)

3.1. Abstract

The ability to adopt another's perspective, whether visually or cognitively, is essential for navigating social environments. Previous research has suggested that, for hearing nonsigning individuals, social abilities may influence performance on visual-spatial perspective-taking (VSPT) tasks (particularly within a social context). Social abilities may differentially influence VSPT abilities for deaf signers because of the visual-spatial modality of sign language. Interlocutors must take into account different visual perspectives held by each sign interlocutor, possibly resulting in visual/perceptual strategies for perspective-taking rather than social strategies. Evidence from children suggests that deaf children tend to rely on nonsocial perceptual strategies to perform VSPT tasks, but hearing children (like hearing adults) tend to rely on social strategies. It is unknown whether deaf adults approach VSPT tasks nonsocially or whether they approach VSPT tasks like hearing adults who draw on social abilities. Adult hearing nonsigners (n = 45) and deaf signers (who acquired ASL prior to age 6; n = 44) performed a nonlinguistic VSPT task in which they identified which perspectives of a display corresponded to a target image and also completed the Autism-Spectrum Quotient questionnaire. Results indicate that hearing individuals with better social abilities performed better on the VSPT task, suggesting they approach the VSPT task socially. Deaf signers, however, showed the opposite

relationship between social abilities and VSPT performance – individuals who were less social performed better on the VSPT task, suggesting use of a nonsocial approach. This distinct relation between social abilities and VSPT skill may be due to differences between deaf signers and hearing nonsigners in communication modality and/or sociocultural experiences.

3.2. Introduction

The ability to infer another's perspective is critical for successful social and communicative interactions. A speaker must know what another person can or cannot see and how objects appear to someone else in order to reference objects in scenes appropriately (e.g., an object on your right may be on my left). To take it one step further, inferring what and how someone sees a scene often is a critical clue to what knowledge he or she possesses relative to that scene. Visual-spatial perspective-taking (VSPT) ability is therefore important in being able to infer and reason about others' visual perceptions and mental states for appropriate social behavior.

Previous research has posited two different types of VSPT abilities: Level 1 judgments about whether or not something is visible to another person and Level 2 judgments about *how* something appears from another vantage point (e.g., Flavell, Everett, Croft, & Flavell, 1981; Masangkay et al., 1974). However, only Level 2 type judgments have been suggested to require processes involved in 'mentalizing' or interpreting another's actions with reference to his or her mental states including thoughts, attitudes, perceptions, and beliefs (also referred to as Theory of Mind and mindreading; for review see Baron-Cohen, 1996; Frith & Frith, 2003). While adults are able to successfully infer another's visual or cognitive perspective, they continue to make errors on Level 2 perspective judgments (e.g., Epley, Morewedge, & Keysar, 2004; Keysar, Barr, Balin, & Brauner, 2000). Such errors suggest that Level 2 tasks are effortful and require cognitive control, particularly when participants directly report on another's perspective (Qureshi, Apperly, & Samson, 2010; Surtees, Samson, & Apperly, 2016). Further, Level 2 VSPT judgments have been suggested to involve a motor embodiment strategy where the perspective taker imaginatively projects their own perspective to align with that of the perspective-taking target (Kessler & Rutherford, 2010; Michelon & Zacks, 2006; Surtees, Apperly, & Samson, 2013). Such an embodied perspective transformation has been suggested to involve social/empathizing abilities (Gronholm, Flynn, Edmonds, & Gardner, 2012). Therefore, there may be overlap between adopting another's visual perspective and adopting their cognitive or emotional perspective (i.e., "stepping into their shoes").

Shelton et al. (2012) examined this potential overlap by investigating whether individual scores on a social skills questionnaire, the Autism-Spectrum Quotient (AQ; Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001), correlated with participants' abilities on a three-dimensional Three Buildings VSPT task, similar to Piaget and Inhelder's (1967) Three Mountains Task. Participants were shown three distinct Lego buildings affixed to a wooden disk with seven differently-colored perspective-taking targets around the edge of the disk at 45° intervals. Three sets of perspective targets (faceless wooden artist figures, small cameras on stands, or small wooden triangles affixed to the top of a candlestick holder) were alternated to create three separate conditions of differing social contexts. Participants were shown a series of individual photographs representing the view at one of the perspective-taking targets and were asked to report which view the photograph represented (a Level 2 task). Shelton et al. (2012) found that both males and females showed a significant correlation between AQ and VSPT accuracy, but only for the condition where the perspective-taking target was humanlike (e.g., the artist figures). Thus they suggested that the context surrounding the perspective-taking task might dictate whether social skills play a role in visual perspective-taking: that is, people may only recruit social abilities during social VSPT contexts.

In a follow up study using a similar Three Buildings paradigm, Clements-Stephens et al. (2013) determined that adding something as simple as plastic eyes to the top of the wooden triangles or establishing agency through a story in which plain triangles (with no eyes) were aliens was enough to make the targets humanlike and the context social. They found significant correlations between the average AQ Social/Communication subscale score and accuracy on the Three Buildings task, but only in the social condition; there was no correlation in the nonsocial condition. Similarly, they found very strong carry-over effects such that, once people had seen the triangles-with-eyes social condition, they also interpreted the plain triangle condition (no eyes on top) with a social context. Therefore, only participants who saw the plain triangle condition first interpreted the array within a nonsocial context.

The AQ has been shown to reliably represent Autism Spectrum Disorder (ASD) traits in a subclinical general population. Males consistently score significantly higher (more ASD-like) than females, and students enrolled in science/mathematics university majors score significantly higher than those in humanities or social sciences (Baron-Cohen et al., 2001; Wakabayashi, Baron-Cohen, Wheelwright, & Tojo, 2006). The AQ has been translated into Dutch and Japanese and been validated internationally with good internal consistency and test-retest reliability (Dutch: Hoestra, Bartels, Cath, and Boomsma, 2008; Japanese: Wakabayashi et al., 2006). Both the Dutch and Japanese studies report effects similar to those found by Baron-Cohen et al. (2001): in the general population, males' AQ scores were significantly higher than females' and, for the student population, field of study significantly affected AQ (mathematics and natural/technical sciences greater than social sciences/humanities).

While gender differences in the AQ are frequently reported, the literature thus far is inconsistent with respect to whether males and females differentially recruit social abilities during VSPT tasks. Brunyé et al. (2012) found that overall AQ score was a significant predictor of Level 2 but not Level 1 performance; however, this relationship differed as a function of gender with a stronger relationship between VSPT and social abilities for males. However, Mohr, Rowe, and Blanke (2010) found that scores on Baron-Cohen and Wheelwright's (2004) Empathy Quotient (similar to the AQ but focused on empathic traits) correlated with VSPT task performance for females only and not for males. Kessler and Wang (2012) suggested that involvement of social strategies may reflect two different types of personalities (loosely following gender) that can be categorized as systemizers and embodiers based on Baron-Cohen's

(2002) extreme male brain theory of ASD. Systemizers tend to be male, generally excel at tasks that utilize a systematic approach (e.g., mathematics, logic), and generally score less strongly social on the AQ. Conversely, embodiers (who are more likely to be female) tend to be highly skilled socially, find it easy to imagine what another might think or feel, and tend to score more highly social on the AQ. Overall, they suggest that embodiers may rely on a strategy whereby they mentally transform their body schema onto that of the perspective target (i.e., imagined self-rotation). Systemizers on the other hand may be less skilled with imagined self-rotation (or more skilled with alternative, less social strategies) and therefore choose to employ nonsocial strategies such as object-rotation or cognitive rule-based strategies (e.g., “reverse what I see”).

Supporting this dissociation of strategies, Gardner, Brazier, Edmonds, and Gronholm (2013) suggest that the participants who adopted an embodied, self-rotation strategy also tended to utilize social abilities as reflected by a significant correlation between the EQ and VSPT task performance. However, the participants who adopted a disembodied, executive strategy to reverse what they saw (rather than an imagined self-rotation through space) did not show a relationship between EQ and VSPT scores, but did show a relationship with inhibition control abilities (Gronholm et al., 2012). Therefore, people who adopt a social, embodied strategy may recruit social abilities whereas those who adopt a nonsocial, disembodied strategy seem to utilize other cognitive strategies.

Altogether, it seems that there are two common types of strategies for solving VSPT tasks: social strategies that involve some kind of imagined or embodied self-rotation and nonsocial strategies that may be more related to object-rotation or rule-based strategies. An individual's relative strength in social/communicative abilities seems to play a role in which strategy he or she adopts. Additionally some evidence suggests that the relationship between VSPT and social skills may differ for males versus females. What remains unknown, however, is the relative contribution that a person's visuospatial skills may play in this strategy selection process. If an individual has extensive experience with visuospatial perspective transformations in another domain (i.e. linguistic perspective transformations), there may be ramifications for his or her abilities in a nonlinguistic, visuopatial domain.

Sign languages, such as American Sign Language (ASL), use the hands and body to express concepts iconically in space. For example, to express the concept 'the book on the shelf' a signer would place the hand shape representing the book physically on top of the hand shape representing the shelf. Because of the iconic expression of spatial relationships using signing space, left/right descriptions create an inherent perspective conflict between the visual perspective of the signer and the addressee/s if they are referring to nonpresent objects[7]. If the signer describes the cup to the left of the ball, an addressee who is facing the signer would perceive the manual

[7] For referents present in the environment, the visuospatial expression allows for use of 'shared space' where the interlocutors schematically map the signed description onto the signing space allowing each to maintain his or her own perspective (Emmorey, 2002; Emmorey & Tversky, 2002). Thus, it is only in descriptions of nonpresent referents where this inherent perspective conflict occurs.

description as the cup to the right of the ball. To avoid miscommunications, many unrelated sign languages have converged on the convention for signers to produce descriptions from their own perspective and addressees to adopt the signer's perspective for interpretation (Pyers, Perniss, & Emmorey, 2008; Pyers, Perniss, & Emmorey, 2015).

While signers canonically interact in face-to-face spatial arrangements, they also converse while sitting next to each other or at an angle (such as in a group interaction). The perspective-transformations are variable and depend on the location of the signer and addressee. It is presently unknown whether the spatial transformation necessary to comprehend from the signer's perspective involves mental rotation or perspective-taking processes. Hegarty and Waller (2004) found that mental rotation and perspective-taking abilities were related but dissociable abilities. Emmorey, Klima, and Hickok (1998) previously discussed the spatial transformation in sign comprehension in relation to mental rotation abilities; however, more recently Pyers et al. (2015) suggested that executive control or motor embodiment abilities might also support the ability to perform the spatial transformation needed to comprehend spatial descriptions from the signer's perspective. Similarly, Quinto-Pozos et al. (2013) argued that nonlinguistic perspective-taking ability supports acquisition of certain perspective-dependent structures in ASL. Whether via mental rotation or perspective-taking processes, sign comprehenders have extensive experience making adjustments in order to comprehend productions from another spatial perspective as a result of the modality of their language – up to 180° differences for canonical face-to-face exchanges. If the spatial transformation depends on perspective-taking processes as Quinto-Pozos et al. suggested (2013), this experience with VSPT in their language may enhance signers' nonlinguistic VSPT abilities.

Although much of the evidence argues against a generalized visuospatial advantage for deaf individuals (e.g., Bavelier, Dye, & Hauser, 2008; Marschark et al., 2015), there are aspects of spatial cognition that do seem enhanced as a result of sign language experience. For example, both deaf and hearing adult signers, who were native ASL users (i.e., learned sign from birth from deaf parents), outperformed hearing nonsigners on a task that required generating complex mental images quickly (Emmorey, Kosslyn, & Bellugi, 1993). The fact that hearing native signers (or Codas, Children Of Deaf Adults) performed similarly to deaf native signers suggests that this enhancement in image generation ability is due to knowing a signed language rather than an effect of deafness. Similarly, mental rotation abilities and the ability to detect mirror reversals seem to be enhanced for deaf signers compared with hearing nonsigners, which may be due to certain spatial requirements necessary for sign language interpretation such as reconciling differences between signers' and addressees' perspectives (Emmorey et al., 1993; Emmorey et al., 1998). Therefore, experience with spatial requirements integral to sign language production and comprehension may give rise to enhancements in related nonlinguistic spatial abilities.

Because of this extensive experience with language in the visual-spatial modality, deaf signers may utilize different strategies for nonlinguistic VSPT tasks. Evidence from developmental studies of cognitive perspective-taking (e.g., Theory of

Mind) and visual perspective-taking suggests that these two types of perspective-taking may be interrelated in both typically developing children (e.g., Gopnik, Slaughter, & Meltzoff, 1994) and atypically developing children (e.g., Hamilton, Brindley, & Frith, 2009; Pearson, Ropar, & Hamilton, 2013). Therefore, similar strategies may be utilized across different types of perspective-taking tasks. Howley and Howe (2004) examined VSPT and cognitive perspective-taking in deaf and hearing children (ages 5-11). They found that the deaf children did not differ from their age-matched hearing peers on either a Level 1 or Level 2 VSPT task but were significantly worse on the cognitive (Theory of Mind) perspective-taking task. Howley and Howe (2004) suggest that deaf and hearing children may utilize different pathways for cognitive and visual-spatial perspective-taking. The authors argue that "social interaction [via language] is less significant for phenomena that are overt and perceptible than for phenomena that are internal and abstract," the latter referring to cognitive perspective-taking (Howley & Howe, 2004, p 240). Therefore, deaf children may learn to approach visual perspective-taking tasks using perceptual, nonsocial strategies (i.e., more like 'systemizers') and then utilize those perspective-taking strategies for less overt, cognitive perspective-taking tasks. In contrast, hearing children may rely on social abilities (i.e., more like 'embodiers') for completion of both tasks. The pressure for deaf children to rely on perceptual, nonsocial strategies may be due to experience with a language in the visual-spatial modality or differences in social experiences with hearing peers (see Xie, Potměšil, and Peters, 2014, or Antia, Kreimeyer, Metz, & Spolsky, 2011, for review of deaf children's communication difficulties with hearing classmates).

Howley and Howe's (2014) results may have been influenced by the high degree of heterogeneity of their sample which included deaf children with a variety of linguistic and developmental backgrounds: children who had deaf parents (and were native signers) and also children who had hearing parents as well as children who used oral, manual, or a combination of oral and manual communication modalities. Age of acquisition of sign language was not explicitly reported for any of the children. Previous research has suggested that Theory of Mind abilities are not delayed in native signing children because of their early exposure to a full, natural language (e.g., Courtin & Melot, 1998; Schick, de Villiers, de Villiers, & Hoffmeister, 2007). The diversity in Howley and Howe's sample of deaf children may have obscured patterns perspective-taking ability (either visual or cognitive perspective-taking) that may be present in native signing populations but not for signing populations with later exposure or less fluency in a signed language.

Much of the initial work on perspective-taking with deaf individuals centered around the idea that many deaf children have reduced access to language which may impair social interactions, critically in resolving conflict in perspectives that occurs within a social, communicative context. Therefore, this reduced experience with confronting others' perspectives may result in delayed ability for deaf children to appreciate others' visual and cognitive perspectives (Cates & Shontz, 1990; Peterson & Peterson, 1990). Results from early work on visual perspective-taking with deaf children have been mixed: some studies show delays for deaf children (Dwyer, 1983; Hoemann, 1972), while others show no difference (Youniss & Robertson, 1978). All of these studies included deaf participants with widely varying linguistic backgrounds (i.e., some used sign language, some used spoken language, some used both sign and speech, many had hearing parents, etc.). Therefore, many of the participants likely experienced some delay in early linguistic input and difficulty with communication with their hearing parents (see Vaccari & Marschark, 1997, for review). Deaf native signing children however have unimpeded access to language and social interactions from birth and do not show the same communication barriers between parents and children as those with hearing parents. Howley and Howe's (2004) results could be explained by the different socio-communicative backgrounds of their participants: their deaf children's preference of nonsocial strategies could be due to experience with communication barriers in social interactions. Further examination is needed with native signing individuals in order to determine whether the effects are due to impoverished communicative environments (e.g., reduced access to language about conflicting perspectives) or to effects of sign language experience (e.g., experience with conflicting visual-spatial perspectives in spatial descriptions).

Additionally, little is known about the cognitive mechanisms that support perspective-taking abilities for deaf signing adults. Deaf signing adults may approach VSPT tasks in a nonsocial manner as suggested by Howley and Howe (2004) for deaf children (possibly involving mental rotation processes), or they may approach VSPT tasks similarly to hearing adults who appear to draw on social abilities to perform this

VSPT task. By specifically examining these abilities in deaf signing populations with native or early (prior to age six) exposure to sign language, we can eliminate or reduce effects due to impoverished social and linguistic familial interactions during development to isolate modality effects of sign language.

Therefore our research questions were:

1. Do social skills differentially affect VSPT performance for hearing nonsigners and deaf signers?
2. Does expertise with VSPT in a visuospatial language improve nonlinguistic VSPT?

With regard to the first question, several patterns of results are possible. First, individuals with better social skills could perform better on the perspective-taking task in both the deaf signing and hearing nonsigning groups. This pattern would suggest that both groups utilize social abilities during the task and that those social abilities are facilitative (i.e., people with better social abilities perform better on the VSPT task). We expect this relationship may only be present in the social context (triangles-with-eyes) as found by Shelton et al. (2012) and Clements-Stephens et al. (2013). However, it is possible that participants may approach both conditions socially (e.g., interpreting triangles without eyes as agents rather than as viewpoint markers); if so, then we would expect to find a correlation between AQ and VSPT performance in both the nonsocial and social conditions. Alternatively, we could find that better social skills correlate with better perspective-taking skills but only for the hearing nonsigners and not for the deaf signers. Such a finding would suggest that deaf signers do not recruit social abilities for performing the 3Bldgs VSPT task, but instead rely on other nonsocial strategies. This result would suggest that deaf signers may rely entirely on systemizing nonsocial strategies (such as the object-rotation or rule-based strategies).

A third possible outcome is that *decreased* social abilities are associated with better performance on the perspective-taking task for deaf signers. Such a result would suggest that those with stronger social skills may experience competition from their social skills on their preferred nonsocial/perceptual strategy, thereby reducing their overall performance. If social abilities interfere with the tendency to use a nonsocial/perceptual strategy for deaf signers, then individuals with less strong social abilities would experience less interference from a social VSPT approach, resulting in relatively higher performance on the VSPT task. Such a pattern would indicate that social abilities relate differently to VSPT performance for deaf signers and hearing nonsigners.

With regard to the second research question, if expertise with VSPT in ASL improves nonlinguistic VSPT performance, we would expect to see significantly better performance for the deaf signers as compared with the hearing nonsigners (e.g., higher accuracies or faster RTs). Such a boost in VSPT for the deaf signers relative to the hearing nonsigners would suggest that VSPT abilities are used during comprehension of perspective-dependent ASL structures and this extra experience with linguistic perspective transformations generalizes to a nonlinguistic VSPT context. If, however, nonlinguistic VSPT abilities are not affected by VSPT experience within linguistic contexts, we would expect to find no difference between performance by deaf signers and hearing nonsigners, suggesting the processes underlying perspective-taking might be different for linguistic and nonlinguistic domains. Such a finding would be consistent with the hypothesis that the spatial transformation involved in adopting the signer's perspective relies on cognitive abilities other than perspective-taking (possibly mental rotation abilities or executive strategies).

In sum, for the hearing nonsigners we expect to find that better social abilities are associated with better performance on the perspective-taking task, replicating Shelton et al. (2012) and Clements-Stephens et al. (2013), and this pattern could be mediated by gender (e.g., Mohr et al., 2010) or self-reported strategy for performing the task (e.g., Gronholm et al., 2012). Replicating previous results in the hearing nonsigners would be a strong indicator that the task is successfully tapping similar types of Level 2 VSPT processes as has been previously reported. For the deaf signers, there are three possible outcomes, reflecting different hypotheses about the factors that affect perspective-taking strategy. Deaf adults may pattern like hearing adults (i.e., better social skills associated with better perspective-taking abilities). On the other hand, there might be no relationship between social skills and perspective-taking abilities, suggesting that deaf adults (like deaf children) recruit nonsocial/perceptual strategies to solve VSPT tasks. A third possibility is that social abilities might actually interfere with using a preferred nonsocial strategy, leading to worse VSPT performance by deaf adults who are more social. Thus, the relationship between social abilities and visual perspective-taking for deaf participants will help to identify how differences in language modality and/or sociocultural experiences may lead to differences in VSPT strategy.

3.3. Method

3.3.1. Participants

Forty-five hearing nonsigners (32F; M_{age} = 23.6 years, *SD* = 5.0; range: 18.0-39.9 years) and 44 deaf signers (23F; M_{age} = 30.1 years, *SD* = 7.6; range: 20.4-48.5 years) were recruited from the community in San Diego, CA. The hearing nonsigners were monolingual, native English speakers who did not know ASL. The deaf participants were native signers (learned ASL from birth from deaf parents; *n* = 30) or early signers (learned ASL prior to age 6; *n* = 14).

Participants reported no history of Autism Spectrum Disorder (ASD). ASD screening information was unavailable from five hearing nonsigners and three deaf signers; however, informal evaluation during interactions provided no evidence to suspect a history of ASD. Three deaf signers and one hearing nonsigner were excluded from the initial sample of 47 deaf signers and 46 hearing nonsigners due to low accuracy on the VSPT Three Buildings task (30% or less on one or more experimental block). By using this conservative cutoff (well above the 12.5% accuracy that would be expected by chance with the eight possible response options), we could be certain that participants understood the task instructions.

The deaf signing and hearing nonsigning groups were balanced on nonverbal intelligence as measured by the matrices subtest of the *Kaufman Brief Intelligence*

Test, Second Edition (Kaufman & Kaufman, 2004), $t(87) = -.988$, $p = .163$ (score unavailable for one deaf participant). The groups contained marginally different proportions of males and females, $\chi^2(1) = 3.34$, $p = .067$. Both groups contained numerically more females than males. The mean age of the deaf signing group was significantly greater than the hearing nonsigning group, $t(87) = -4.53$, $p < .001$. The deaf group also had significantly more years of education than the hearing group, $t(87) = -1.92$, $p = .029$ (deaf $M_{education} = 16.6$ years, $SEM = 0.41$; hearing $M_{education} = 15.5$ years, $SEM = 0.34$).

3.3.2. Materials and Procedure

All participants completed two perspective-taking tasks (Three Buildings task and the Perspective-taking Spatial Orientation test), the Autism-Spectrum Quotient questionnaire, and a test of mental rotation ability. The tasks were completed individually in a quiet testing room.

3.3.2.1. Three Buildings task (3Bldgs)

In the three-dimensional perspective-taking 3Bldgs task (Clements-Stephens et al., 2013; Shelton et al., 2012), participants viewed two different building displays, one at a time. Each display had three unique buildings (six total across both displays) constructed with LEGO building blocks (Lego Group, Billund, Denmark; see Fig. 3.1A). Buildings were placed equidistant on a wooden disk (24-inches in diameter) that was covered with a faux grass mat. Each display was placed on a round table (36-inches in diameter) and photographed 30 inches from the center of the display at a 20° angle from the table, in 45° intervals around the disk. Seven perspective-taking targets were placed at 45° intervals around the display corresponding to 45°, 90°, 135°, 180°, 225°, 270°, and 315° with the participant seated at 0°. The targets were placed 3.5 inches from the edge of the display disk and 2.5 inches from the edge of the table. The perspective-taking targets were constructed from a wooden candlestick holder (6.75 inches in height), a wooden cube (1.5 inches in height), and a wooden triangular prism (dimensions: 0.81 inch height x 2.25 inch depth x 3.06 inch width). The cube and the triangular prism were painted with one of seven colors: blue, white, green, red, yellow, pink, and purple. For the social condition, plastic three-dimensional eyes (0.75 inches in diameter) were affixed to the top of the triangular prism (see Fig. 3.1B).

Figure 3.1. 3Bldgs task displays and perspective-targets. (A) The two displays with three unique buildings in each. (B) The perspective-taking targets for the nonsocial (plain triangles) and social (triangles-with-eyes) conditions.

Figure 3.2. Example of experimental set-up for the 3Bldgs task.

Participants viewed the photographs on a 15-inch Apple laptop placed on a separate small table in front of and two inches lower than the building display table so as to minimize visual obstruction of the building display (Fig. 3.2). Response keys were labeled with colored stickers corresponding to the color of the perspective-taking target at that spatial location. For example, the color of the perspective-taking target at 45° to the left of the participant matched the color of the label on the 'v' key. Subsequent target-response key color pairings continued clockwise around the display: 90° = 'f' key, 135° = 't' key, 180° = 'y' key, 225° = 'u' key, 270° = 'j' key, and 315° = 'n' key. Additionally, participants were shown photographs corresponding to their own view of the buildings corresponding to the response key 'b.' There was no perspective-taking triangle target for the self-view.

The participants' task was to decide: "Which triangle is at this view?" and to press the key on the keyboard labeled with the same color as the triangle they decided was at that view. All participants received written instructions. Deaf participants additionally received pre-recorded video instructions translated into ASL and signed by a native deaf signer. Participants viewed 40 trials per block, five at each of the eight perspectives, presented in a pseudorandomized fixed order. After completing the first block, the building display was changed and participants completed an additional block with the second building display. After completing blocks with both building displays for the nonsocial condition (plain triangles), the perspective-taking targets were changed to the social condition (triangles-with-eyes). Participants completed two more blocks in the social condition, following the same order of displays as in the nonsocial condition. Before starting the four practice trials preceding each block, participants were encouraged to walk around the building display to familiarize themselves with how the display appeared from all angles. Trials timed out after seven seconds if no response was made in order to encourage speeded decisions and attention to task. If participants were allowed unlimited time to make their decision, the long RTs likely would have masked any effects from the cognitive processes involved in performing the perspective-taking task, as has been shown for mental rotation tasks when given unlimited time (for discussion see Peters, 2005).

The initial 0° position of the buildings for each condition was counterbalanced across participants and no one saw the same 0° position for both social and nonsocial condition blocks. The colors of the perspective-taking targets were randomized between participants, but fixed for each participant. The order of the building displays was counterbalanced across participants. All participants completed the nonsocial condition first to avoid known carryover effects. Clements-Stephens et al. (2013) found that once participants had experienced the social condition, they continued to view the plain triangles socially. In order to be able to measure perspective-taking within a nonsocial context, all participants had to complete that condition first before the social condition had been introduced.

Following completion of the 3Bldgs task, all participants were given a written debriefing form asking: "What strategies did you use to perform this task? Did you change strategies during the task? Please describe." Responses were coded with respect to whether they reported an embodied, self-rotation strategy (e.g., putting themselves in the position of the triangle) or a disembodied strategy (e.g., creating a pairing between the triangle color and a landmark in the scene). By using an open-ended question format, participants were not influenced by pre-selected strategies and were allowed to describe the strategy they adopted in their own words.

3.3.2.2. Perspective-taking Spatial Orientation Test (PTSO)

In the PTSO (Hegarty & Waller, 2004), participants saw a fixed array of two-dimensional objects on paper and were instructed to imagine adopting a specific spatial perspective within that array relative to two objects (e.g., standing at the flower facing the tree; see Fig. 3.3A). Their task was to indicate the relative position of a third object (e.g., the cat) by drawing an arrow on a response circle (see Fig. 3.3B). Participants were given five minutes to complete the 12-item test. Participants were not permitted to rotate the booklet or their bodies during this task or to write on the picture array. Average angular disparity was calculated for this test measuring the difference between the participant's response and the correct response, averaged across all twelve items. Higher scores indicate responses that were farther from the correct response and thus worse performance on the task. If a participant's response did not extend from the center of the circle to the edge of the circle and thus was unable to be scored, that item was excluded from calculations of angular disparity (4 items across all participants; 0.34% of the data). Any items left blank due to time constraints were also excluded from calculations of angular disparity (19 items across all participants; 1.63% of the data).

We observed high interrater reliability between two independent coders who scored all of the data ($r = .983$, $p < .001$). All items that were scored by the coders with greater than ten degrees difference in response angle were discussed until a consensus was reached (2.3% of the data). For each item, the two coders' responses were averaged, and this average score was used in the calculation of the average angular disparity.

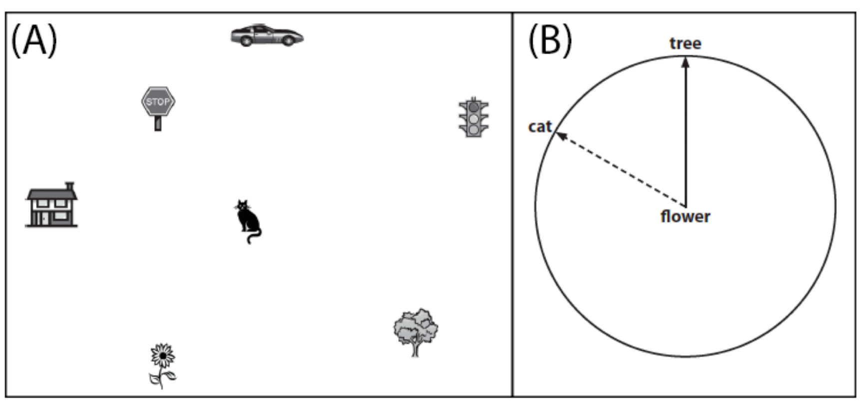

Figure 3.3. Example from the PTSO test for the item: "Imagine you are standing at the **flower** and facing the **tree**. Point to the **cat**." (A) Stimulus array used for the perspective transformation. (B) Response circle with a sample participant response (dotted line).

3.3.2.3. Revised Mental Rotation Test (MRT)

In the pencil-and-paper Revised Mental Rotation Test (Peters et al., 1995; Vandenburg & Kuse, 1978), participants were shown a target black and white line drawing of a three-dimensional block and four response pictures (Fig. 3.4). Two pictures of the four response pictures showed the target block rotated through three-dimensional space presenting slightly different faces of the same block. The other two pictures depicted blocks that could not be mentally rotated into alignment with the target block. Participants were instructed to draw an 'x' over the two pictures that matched the target picture. After completing an example and three practice trials with feedback, participants were given 12 trials and four minutes to complete the trials without feedback. After time ran out, participants were offered a brief break and then completed 12 additional trials in another four-minute time period. Items were only scored correct if both response pictures were correctly identified (for a maximum of 24 points).

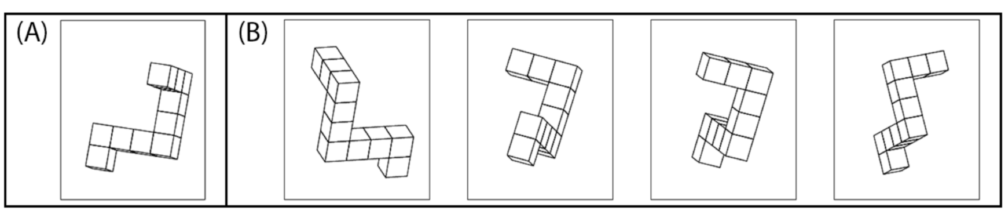

Figure 3.4. Sample item from the MRT. A) Sample block target figure. B) Response options, only two of which are correct (first and third pictures from the left).

3.3.2.4. Autism-Spectrum Quotient (AQ)

The AQ (Baron-Cohen et al., 2001) is an untimed 50-item questionnaire that measures traits associated with ASD in subclinical populations. For each item, participants rated whether they strongly agreed, slightly agreed, slightly disagreed, or strongly disagreed with the statement relative to themselves. High ASD-like traits reflected reduced social skills, reduced communication abilities, reduced imagination abilities, increased attention to detail, and reduced attention switching abilities. The questions are worded in such a way that for half the items, a response of 'agree' is associated with an ASD-like answer, and for the other half of the questions, a response of 'disagree' is associated with an ASD-like answer. The AQ was scored following Baron-Cohen et al.'s original scoring system: one point for each ASD-like trait answer (maximum score of 50).

For this study, the AQ was adapted for use with deaf participants with the help of two ASL signers (one deaf, one hearing) who had experience adapting clinical assessments and research paradigms for use with deaf individuals. For example, the AQ item number five: "I often notice small sounds when others do not" is not appropriate for use with deaf participants. Therefore, this item was adjusted to: "I often notice small vibrations when other Deaf people do not." Items were adjusted for hearing sensory terms, "speaking" terms (as opposed to communication), and simplified to reduce syntactically complex constructions. Additionally, social contexts were specified as being "among Deaf signing friends" so as to avoid measuring communication or social difficulties arising from language barriers (e.g., being the only signing person in a social gathering). The adapted AQ is given in Appendix A.

3.4. Results

Practice trials were excluded from all analyses. Reaction times were averaged for each angle of stimulus picture. On the 3Bldgs task, participants timed out on approximately 3.8% of trials (4.2% for hearing participants, 3.3% for deaf participants). Incorrect answers were excluded from all RT analyses. No differences were found between equal angles of rotation from 0° both clockwise and counterclockwise (e.g., 45° clockwise and 45° counterclockwise) similar to findings by Michelon and Zacks (2006). Therefore, angles with equal disparity were collapsed for subsequent analysis.

3.4.1. AQ Results

Means and standard deviations (*SD*s) for the overall AQ and each subscale are presented in Table 3.1. The means and *SD*s for the hearing group are comparable to those previously reported for samples of subclinical hearing nonsigning participants taken from the general population (e.g., Baron-Cohen, 2001; Wakabayashi, et al., 2006). A 2 (gender: male, female) x 2 (group: deaf, hearing) ANOVA examined group effects on AQ score. We found that males reported more ASD-like traits (higher AQ scores) than females, as has been previously reported (e.g., Austin, 2005; Baron-Cohen et al., 2001; Hoekstra et al., 2008), $F(1, 85) = 7.36$, $p = .008$, $\eta_p^2 = .080$. We also found that hearing nonsigners reported more ASD-like traits than deaf signers, $F(1, 85) = 26.6, p < .001, \eta_p^2 = .239$. Appendix B shows the distribution of deaf and hearing AQ scores. The deaf participants' AQ scores are concentrated in lower values compared with the hearing participants' AQ scores, indicating fewer ASD traits reported for the deaf participants. There was no significant interaction between gender and group $F(1, 85) = .069, p = .794$.

Table 3.1. Group AQ overall and subscale means (SDs).

			Subscale				
		Overall AQ score	Attention Switching	Attention to Detail	Communi-cation	Imagi-nation	Social Skills
Hearing	All (n=45)	16.7 (6.0)	4.3 (2.1)	6.0 (1.7)	2.0 (1.7)	2.5 (1.4)	1.9 (2.1)
	Female (n=32)	15.8 (6.0)	4.3 (2.3)	5.9 (1.6)	1.8 (1.9)	2.3 (1.4)	1.5 (1.9)
	Male (n=13)	19.0 (5.7)	4.5 (1.7)	6.3 (1.9)	2.4 (1.4)	3.2 (1.2)	2.7 (2.3)
Deaf	All (n=44)	11.8 (3.5)	2.4 (1.3)	5.0 (1.9)	1.1 (0.9)	2.4 (1.4)	0.9 (1.0)
	Female (n=32)	10.6 (3.1)	2.0 (1.3)	4.9 (2.0)	1.0 (0.8)	1.9 (1.2)	0.8 (1.0)
	Male (n=21)	13.2 (3.5)	2.9 (1.2)	5.2 (1.8)	1.2 (1.0)	2.9 (1.6)	1.0 (1.0)

To examine group differences on the AQ subscales, a 5 (subscale) x 2 (gender) x 2 (group) mixed-effects ANOVA was conducted. Mauchly's test was significant, indicating that the assumption of sphericity had been violated, χ^2 (9) = 32.4, $p < .001$. Therefore, degrees of freedom were corrected where appropriate using the Huynh-Feldt estimates of sphericity (ε=.911). Like with the overall AQ analysis, there were significant main effects of gender (males had higher AQ scores than females), $F(1, 85) = 7.36, p = .008, \eta_p^2 = .080$, and group (hearing greater than deaf), $F(1, 85) = 26.6, p <$

.001, η_p^2 =.239. We also found a significant main effect of subscale, $F(3.64, 309.67)$ = 108.86, p < .001, η_p^2 =.562. Post hoc two-tailed t-tests indicated that each subscale was significantly different from all other subscales except the Social Skills and Communication subscales, which were not different from each other.

The subscale x group interaction was also significant, $F(3.64, 309.67)$ = 3.28, p = .015, η_p^2 =.037. Post hoc 2-tailed t-tests indicated that four subscales were significantly higher for the hearing than deaf participants (attention switching: $t(87)$ = -4.94, p < .001; attention to detail: $t(87)$ = -2.27, p = .013; communication: $t(87)$ = -2.81, p = .003; social skills: $t(87)$ = -2.50, p = .007), but the imagination subscale was not statistically different for deaf and hearing participants, $t(87)$ = 0.32, p = .626. All other interactions were not significant, Fs < 1.

3.4.2. Spatial and Perspective-Taking Task Results

Due to the open-question format of the debriefing questionnaire, participants' self-report of strategy was unable to be used as a grouping variable because strategy descriptions could not unambiguously categorized. Means and standard deviations for the PTSO, MRT, and VSPT tasks for deaf and hearing males and females are presented in Table 3.2. Two-tailed t-tests reveal no differences for deaf and hearing participants on the PTSO, $t(87)$ = -0.674, p = .251, and the MRT, $t(87)$ = -0.559, p = .289. With respect to gender differences, both deaf and hearing males obtained better scores on the PTSO than females (i.e. significantly lower angular disparity). For the MRT task, hearing nonsigning males outperformed females, as has been found previously (e.g., Peters, 2005; Voyer, Voyer, & Bryden, 1995). Deaf signers however did not show an effect of gender: males and females performed equally well on the MRT, although numerically deaf males obtained a higher average number of MRT items correct than deaf females.

Table 3.2. Averages (SD) for Males vs. Females on Spatial and Perspective-Taking Measures.

		Female	Male	*t*
PTSO: Average Angular Disparity	Deaf	44 (25)	22 (15)	-3.32**
	Hearing	33 (19)	17 (9)	-3.40**
MRT: Number Items Correct	Deaf	12 (6)	15 (6)	-1.31
	Hearing	9 (4)	17 (6)	-3.81***
VSPT 3Bldgs RT (*SD*)	Deaf Nonsocial	3738 (691)	3611 (429)	-0.091
	Deaf Social	3527 (655)	3296 (578)	-0.773
	Deaf Total	**3627 (650)**	**3443 (478)**	**-0.563**
	Hearing Nonsocial	3822 (605)	3682 (552)	-0.099
	Hearing Social	3527 (592)	3296 (583)	-0.706
	Hearing Total	**3666 (563)**	**3482 (560)**	**-0.444**
VSPT 3Bldgs Percent Accuracy (*SD*)	Deaf Nonsocial	68 (13)	81 (13)	-2.89**
	Deaf Social	76 (12)	88 (9)	-3.51***
	Deaf Total	**72 (12)**	**84 (10)**	**-3.46*** **
	Hearing Nonsocial	72 (14)	83 (11)	-2.34*
	Hearing Social	79 (13)	89 (10)	-2.31*
	Hearing Total	**76 (13)**	**86 (9)**	**-2.61*** *

*p<.05, **p<.01, ***p<.001
Note: Perspective-taking Spatial Orientation test (PTSO), Mental Rotation Test (MRT), VSPT Three Buildings test (3Bldgs). VSPT *t*-values and significance levels are based on arcsine transformations of the percentage data.

In order to address the question of whether sign language experience improves performance on a nonlinguistic VSPT 3Bldgs task, separate 2 (group: deaf, hearing) x 2 (gender) x 2 (condition: nonsocial, social) ANOVAs were conducted for RT and accuracy. Condition was the within-subjects variable, and gender and group were between-subjects variables. For accuracy, results were similar whether using raw percentages or arcsine transformations of the percentages. Arcsine transformations are reported throughout because this transformation corrects for non-normality and heterogeneity of variance in percentage data, particularly when the scores are clustered towards one end of the scale (Ahrens, Cox, & Budhwar, 1990; Sokal & Rohlf, 1995).

Response times were faster for the social than the nonsocial condition, $F(1, 85) = 59.1$, $p < .001$, $\eta_p^2 = .410$, most likely due to practice effects (the social condition was always second). There was no significant effect of gender, $F(1, 85) = 2.06$, $p = .115$, or group, $F(1, 85) = .094$, $p = .760$. Additionally, none of the two-way or three-way interactions were significant (all ps > .20). For accuracy, participants performed better on the social than the nonsocial condition, $F(1, 85) = 49.0$, $p < .001$, $\eta_p^2 = .366$, and males performed better than females, $F(1, 85) = 20.0$, $p < .001$, $\eta_p^2 = .191$. There was no effect of group, $F(1, 85) = 1.39$, $p = .241$. None of the interactions for accuracy were significant (Fs < 1). Overall, deaf signers did not outperform hearing nonsigners on response times or accuracy on the VSPT task[8].

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[8] A subanalysis including only the native signing group revealed the same results as for the whole group. Thus, even when the analysis is limited to individuals who were exposed to sign language from birth, there does not seem to be any advantage compared with hearing nonsigners in either accuracy or reaction time for a nonlinguistic VSPT task.

3.4.3. Correlations Between VSPT and AQ

In order to examine the relationship between AQ score and performance on the VSPT task, we calculated Pearson's correlation coefficients for the deaf and hearing groups in each VSPT condition (social and nonsocial; see Table 3.3). For the hearing nonsigners, individuals with better communication skills (as measured by the Communication subscale) performed better on the VPST task, similar to the pattern Shelton et al. (2012) and Clements-Stephens et al. (2013) found for an averaged Social/Communication subscale score. In contrast, deaf signers showed the opposite relationship in overall AQ score: individuals with decreased social/communication skills performed better on the VPST task in both conditions. When broken down by subscale, however, only the Communication subscale was significantly related to performance on the VSPT task for both the hearing and deaf groups. Performance on the Imagination subscale additionally related to VSPT accuracy in the social condition only for deaf signers.

We report an averaged Social and Communication subscale score for several reasons. First, the Social and Communication subscales were not significantly different from each other in the ANOVA analysis for the AQ, and, as Austin (2005) reported, many of the questions of the original Social and Communication subscales load onto a single factor. Additionally, for the deaf participants, the Social subscale questions relate more strongly to social VSPT performance than do the Communication subscale questions, but for all other conditions the Communication subscale is more highly related to VSPT performance (Table 3.3). Therefore, both the

Communication and the Social Skills subscales appear to relate to VSPT performance and thus were collapsed into a single measure for the correlational analyses: Social/Communication Average. Since this Social/Communication average is the same measure reported by both Shelton et al. (2012) and Clements-Stephens et al. (2013) for their correlational analyses, reporting correlations with the average score allows for a more direct comparison between the current study and their previously reported results.

Table 3.3. Correlations Between VSPT Accuracy AQ By Group.

	Hearing		Deaf	
	Nonsocial	Social	Nonsocial	Social
Overall AQ Score	-.075	-.098	.379*	.418**
Subscale				
Attention Switching	-.114	-.008	.055	.176
Attention to Detail	.010	.017	.249	.218
Communication	-.293‡	-.303*	.435**	.104
Imagination	.197	.083	.185	.339*
Social Skills	.005	-.092	.106	.228
Social/Communication Average	-.143	-.205	.372*	.237

*p<.05, **p<.01
‡Marginally significant (p<.1)

Based on previous research that has shown males and females exhibit differing relationships between social or empathic traits and performance on perspective-taking tasks (e.g., Kessler & Wang, 2012; Mohr et al., 2010), we examined the correlations separately for males and females on an exploratory basis. Because we do not have equal numbers of males and females in each group (specifically, only thirteen hearing males), these results should be interpreted with caution. Scatterplots and correlation coefficients are presented in Fig. 3.5. The results showed that higher social scores (as measured by an average of the AQ Social/Communication subscales) were related to better accuracy on VSPT task for the hearing females in both conditions (nonsocial: *r* = -.405, *p* = .022; social: *r* = -.444, *p* = .011). However, there was no significant relationship between social scores and VSPT performance for male hearing

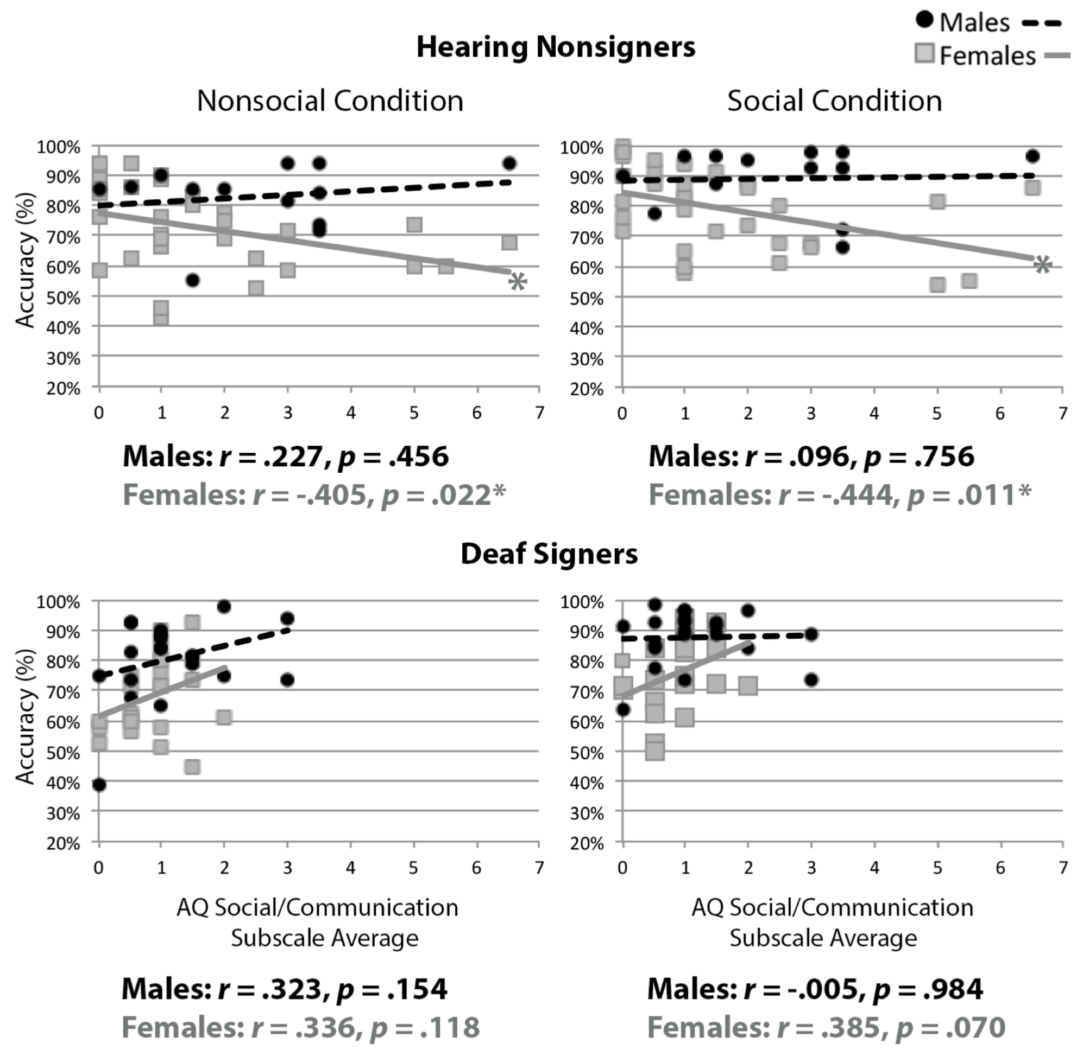

Figure 3.5. Scatterplots and correlation coefficients in the social and nonsocial conditions plotted separately for each gender of deaf and hearing participants. Correlation coefficients were calculated using the arcsine transformations of the percentage data. **p*<.05.

participants for either condition (nonsocial: *r* = .227, *p* = .456; social: *r* = .096, *p* = .756). For deaf females, we found a trend suggesting that lower social scores were associated with better VSPT performance (nonsocial: r = .336, p = .118; social: r = .385, p = .070). Deaf males showed a weaker but similar trend in the nonsocial condition (nonsocial: r = .323, p = .154; social: r = -.005, p = .984). Overall, the stronger relationship between social/communication abilities and performance on the VSPT task for females as compared with males suggests that social/empathic abilities may be more strongly related to embodied perspective-taking for females than males (similar to Mohr et al., 2010).

In order to determine whether the relationship between AQ Social/Communication average score and VSPT accuracy was significantly different between the groups, we compared correlation coefficients and slopes of the linear regression line between deaf and hearing males and females in the social and nonsocial conditions (see Table 3.4). For comparison of the correlation coefficients of independent groups (male/female compared across deaf/hearing groups), we converted the r values to z scores using the Fisher r-to-z transformation. The r values for deaf females significantly differed from that of the hearing females in both the nonsocial, z = 2.68, p = .007, and social conditions, z = 3.04, p = .002 (Fig. 3.5: comparing the solid gray lines within each column). The difference in r values between hearing males and females in the nonsocial VSPT condition was marginally significantly (r = -1.80, p = .072). All other comparisons were nonsignificant, including comparison of r values for deaf and hearing males (ps > .1).

Slopes were compared using a Student's t test using the slope and standard error for each regression line. The only slopes that were significantly different were between the deaf and hearing females for each condition: social, $t(51) = 2.20$, $p = .032$, and nonsocial, $t(51) = 2.64$, $p = .011$. The difference in slopes between hearing males and hearing females was marginally significant within the nonsocial condition, $t(41) = -1.94$, $p = .059$, and the social condition, $t(41) = -1.76$, $p = .087$. This trend suggests that the amount of influence social/communication abilities has on VPST performance may differ for hearing males and females. All other slope comparisons were not significantly different ($p > .1$), including the difference in slopes between deaf males and females. These results, coupled with the correlation coefficient results, suggest that while gender seems to play a role in how social abilities are related to VSPT performance, the experience of being a deaf signer seems to have more impact on the relationship between social abilities and VSPT performance than gender.

Table 3.4. Comparing Correlations for AQ Social/Communication Score and VSPT Accuracy Across Groups.

	Comparing *r*s	**Comparing Slopes**
Deaf vs. Hearing		
Females	z scores	*t* values
Nonsocial	2.68*	2.20*
Social	3.04*	2.64*
Males		
Nonsocial	0.26	0.93
Social	-0.26	-0.22
Males vs. Females		
Deaf	z scores	*t* values
Nonsocial	0.04	0.45
Social	1.26	1.63
Hearing		
Nonsocial	-1.80*	-1.94‡
Social	-1.56‡	-1.76‡

*$p<.05$; ‡=marginally significant ($p<.1$)

3.4.4. PTSO and MRT Results

Correlations between the PTSO, MRT, AQ, and VSPT tasks are presented in Table 3.5. Significant correlations between the PTSO and the MRT are consistent with previous reports indicating mental rotation and perspective-taking abilities are highly correlated (e.g., Hegarty & Waller, 2004). Additionally, the PTSO dependent measure of average angular disparity is a measure of response accuracy during a perspective-taking task; therefore, correlations between the PTSO and VSPT accuracy scores suggest that both tests tap similar spatial orientation abilities. Similarly, significant correlations between the MRT and the VSPT accuracy measures are consistent with similar underlying cognitive abilities for both tasks. Therefore, abilities that support both the PTSO and the MRT tasks seem to contribute to the ability to perform the three-dimensional VSPT task. Since overall AQ score was significantly related to VSPT accuracy for deaf signers (but not hearing nonsigners) and the PTSO and VSPT tasks seem to draw on similar cognitive mechanisms, it is unsurprising that we found a significant correlation between overall AQ and PTSO for deaf signers.

Table 3.5. PTSO and MRT Correlations For Deaf and Hearing Groups.

	PTSO		MRT	
	Deaf	Hearing	Deaf	Hearing
PTSO: Average Angular Disparity	–	–	-.53**	-.50**
MRT: Number Correct	-.53**	-.50**	–	–
VSPT Nonsocial RT	.12	.09	-.20	-.07
VSPT Social RT	.18	.25	-.31*	-.16
VSPT Nonsocial Accuracy	-.57**	-.57**	.65**	.51**
VSPT Social Accuracy	-.56**	-.52**	.62**	.52**
Overall AQ	-.47**	.06	.24	-.04

*p<.05, **p<.01, ***p<.001

Note: Perspective-taking Spatial Orientation test (PTSO), Mental Rotation Test (MRT), VSPT Three Buildings test (3Bldgs). VSPT *r*-values are based on arcsine transformations of the percentage data.

3.5. Discussion

We investigated the relationship between social abilities and visual-spatial perspective-taking performance for deaf signing adults and hearing nonsigning adults. Additionally, we examined whether the influence of social abilities differed for males and females, as has been suggested for hearing nonsigners (e.g., Mohr et al., 2010). We also examined whether experience with visual-spatial transformations within a signed language improved performance in nonlinguistic VSPT tasks compared with individuals with no sign language experience.

We found no difference between deaf and hearing groups on the Three Buildings VSPT task in either RT or accuracy. Both deaf and hearing individuals were more accurate and faster for the social than nonsocial condition; however, this finding is likely a result of practice effects. The nonsocial condition was always presented first because of the carry-over effects that occur if the social condition is presented first

(Clements-Stephens et al., 2013). The fixed order of conditions meant that all participants had already experienced 80 experimental trials by the time they began the social condition and thus likely performed better due to this previous experience. However, since we did not show evidence that either group's performance resulted in differing correlations between AQ score and VSPT performance in the social and nonsocial conditions, this extra practice did not seem to affect the strategy the participants adopted. Further, there were no significant interactions between group and condition for either RT or accuracy, suggesting both groups' performance increased similarly from the nonsocial to the social condition.

We also found no difference between deaf and hearing groups on the PTSO, a paper-based perspective-taking task, and the MRT, a paper-based mental rotation task (although we did find that males outperformed females on the MRT task, consistent with previous findings; Peters, 2005). The lack of mental rotation difference between deaf and hearing groups in our results may be due to the pencil-and-paper nature of the measure. While the task had a time limit imposed to encourage rapid responses, it did not allow for measurement of the RTs for individual trials. Emmorey et al. (1993) found that deaf signers were faster (but not more accurate) than hearing nonsigners at determining whether a rotated figure was a mirror image. If we had employed a method that could capture RTs on individual items, the deaf group may have shown faster RTs than the hearing group. Altogether, we found no evidence to suggest that experience with VSPT within a signed language affects performance within the nonlinguistic domain: in either accuracy or RT in a three-dimensional perspective-taking task or accuracy in a two-dimensional perspective-taking task.

As with previous reports, we found that males scored significantly higher than females on the AQ. These higher AQ scores are frequently interpreted as reflecting a more highly systemizing or 'male brain' cognitive style (e.g., Baron-Cohen, 2002; Kessler & Wang, 2012; Hoestra et al., 2008; Wakabayashi et al., 2006). In addition to higher overall AQ scores, males reported fewer social tendencies than females on the Social and Communication subscales as previously reported in the literature (e.g., Austin, 2005; Baron-Cohen et al., 2001). This pattern for males to exhibit more ASD-like traits overall and to provide less social responses was found for both the deaf and hearing groups indicating similar 'less social' characteristics for deaf males versus deaf females as has been reported for the hearing population. The hearing group's average overall AQ score and average subscale scores were similar to previous reports (e.g., Baron-Cohen et al., 2001; Hoestra et al., 2008; Wakabayashi et al., 2006), indicating that the social and communication skills of the hearing participants in this study were typical.

Somewhat surprisingly, we found that the deaf group reported more highly social responses than the hearing group overall, as well as for each individual subscale (except the Imagination subscale). This positive self-perception of social and communication abilities is in line with previous results indicating that deaf adults may experience more positive self-talk than do hearing adults (e.g., the more positive: "That went really well" versus the more negative: "Whatever I do seems wrong;"

Zimmermann & Brugger, 2013). This strategy of employing positive self-talk may bolster deaf individuals' self-perceptions of social situations resulting in high social ratings in the Social Skills and Communication subscales of the AQ (e.g., for items such as "Social situations with my Deaf friends are easy for me" or "I enjoy social occasions with my Deaf friends"). Additionally, by directly referring to communication ease with Deaf friends (i.e. those who sign and are part of the Deaf community), deaf participants may have contrasted these interactions with those involving hearing nonsigning people, reporting a greater degree of ease and success for social interactions with Deaf friends in an implied comparison with hearing nonsigning friends. The hearing group would not experience this same subtle contrast between types of interactions for the social and communication questions on the AQ.

Furthermore, because of the visuospatial nature of ASL, deaf signers must communicate face-to-face which requires eye-contact and visual attention (e.g., the comprehender cannot be looking/attending towards another activity while conversing). Even when using technology, deaf signers often continue to sign "face-to-face" via video streams. The AQ Communication subscale includes many questions geared towards face-to-face communication, an activity that the deaf signers may engage in more frequently than hearing nonsigners because of the visual nature of their language. Finally, deaf signing individuals often belong to a unique cultural group denoted by a capital 'D' in 'Deaf' which may encourage stronger social/communicative relationships and abilities (see Padden & Humphries, 1988, for discussion of Deaf culture). Therefore, the highly social responses for the deaf signing group likely reflect cultural and experiential differences between deaf and hearing individuals with respect to communication, self-talk, and face-to-face interactions.

It is important to note that the reduced range of AQ responses observed for the deaf signers (Appendix B) means that the correlations involving AQ score should be interpreted with caution. Less variation on AQ responses also has implications for the use of this measure as a metric for social/communication abilities in the deaf population. This study is the first description of an adaptation of the AQ for use with a deaf, signing population. It was intentionally kept in a written format in order to be parallel to the original AQ format in stimulus presentation and participant responses. Additionally, the questions were designed such that for some questions 'agree' responses received a score of 1 whereas for other questions 'disagree' responses received a score of 1. Thus, the deaf signers were not uniformly responding either 'agree' or 'disagree' to all questions; rather, they were systematically selecting the less ASD-like answer. Neither did the deaf signers appear to be guessing randomly; if they had been, scores would have been approximately 25 (i.e., half of the responses receiving a score of 1 and the other half a score of 0). Therefore, we can say with relative certainty that participants were able to understand the written questions and that responses accurately reflect their self-perception.

Like with the AQ, the VSPT task also showed a significant effect of gender in accuracy (but not RT) with males outperforming females. Gardner et al. (2012) found that males were significantly faster than females to adopt a figure's perspective when that figure faced the participant (versus when its back faced the participant, requiring no perspective-taking). While Gardner et al. (2012) did not find differences in accuracy between males and females on the task, their VSPT task was much less complex than the 3Bldgs task used here. In their task, the participant could see either the front or back of a figure that held a black ball in either its right or left hand. Participants were instructed to adopt the visual-spatial perspective of the figure in order to determine which hand was holding the ball. Thus, participants saw only two variations of stimuli and made a left/right binary decision each time. In the 3Bldgs task, participants saw a complex three-dimensional scene with eight different possible perspectives. The relative ease of the Gardener et al. task compared to the 3Bldgs task is reflected in the average percent error rates: the mean (*SD*) for Gardner et al. (2013) was 3.2% (2.4%) whereas the overall mean (*SD*) for deaf and hearing groups in the present study was 22.4% (12.5%). Thus, task accuracy for the 3Bldgs task seems to be a more sensitive measure, but for the Gardner et al. task, RT appears to be more sensitive. Gender differences may be detectable with the measure that exhibits the greater degree of sensitivity (e.g., RT for Gardner et al., 2013; accuracy in the present study). Therefore, the type of measure (e.g., RT or accuracy) that shows a gender advantage for VSPT tasks seems to depend on the difficulty of the task.

Unlike previous studies using the 3Bldgs task, we did not find a difference in the effect of social skills as a function of the social context of the VSPT task. Therefore, the participants in this study seemed to approach both social (triangles with eyes) and nonsocial (plain triangles) conditions with similar strategies, suggesting that what establishes a context as ‘social’ versus ‘nonsocial’ may be highly variable and subject to individual characteristics.

The main research question of interest in this study involved the relationship between social/communication abilities (AQ score) and VSPT accuracy. Surprisingly, we found that deaf signers who reported *reduced* social abilities tended to perform better on the VSPT task. The relationship between the AQ Social/Communication subscale and VSPT for the hearing group was nonsignificant but trended in the direction that has been previously reported – individuals with better social abilities perform better on the VSPT task (e.g., Clements-Stephens et al., 2013; Shelton et al., 2012). However, from the correlations with each individual subscale, it is clear that the Communication subscale is primarily driving the correlations in both deaf and hearing groups.

Scores on the Imagination subscale additionally related to performance on the social VSPT condition for deaf signers. Deaf signers with better Imagination subscale scores performed worse on the social VSPT condition. Many of the questions on the Imagination subscale also involved social abilities (e.g., imagining a character’s intentions, playing pretend games with children, imagining what it would be like to be someone else, preferring a theater show to visiting a museum). The deaf signers who reported weaker imagination abilities also tended to report weaker social abilities, as evidenced by a significant positive correlation between the Imagination and Social Skills subscales (r = .374; p = .012). Therefore, the relationship seen with the

Imagination subscale is consistent with the findings from the Social/Communication subscale.

When males and females were analyzed separately, the female hearing group showed a significant relationship between social abilities and VSPT performance: females who reported higher social abilities performed better on the VSPT task. However, the lack of correlation for the hearing males should be treated with caution because of the lower *n* for this group. Like with the hearing participants, deaf females showed a stronger relationship between AQ and VSPT accuracy than deaf males, but the direction of the correlation was reversed: more social females performed worse on the VSPT task. Therefore, while males seem to show the relationship less strongly across both groups, evidence from the female group (supported by a trend in the deaf male group) suggests a stark difference in how the deaf and hearing groups approach the VSPT task.

Overall, the results suggest that deaf signers seem to approach the VSPT task nonsocially. Individuals who reported decreased social abilities (e.g., on the social components of the Social/Communication subscales and the Imagination subscale) also tended to achieve better accuracy in the VSPT task suggesting that the deaf signers who are less social experienced little interference from their social abilities. On the other hand, deaf signers with strong social tendencies seemed to experience interference from their social abilities when using a nonsocial strategy. This use of a perceptual, nonsocial strategy for deaf adults is in keeping with Howley and Howe's (2004) previous proposal for deaf children. Whereas better social skills seem to facilitate better perspective-taking performance for the hearing nonsigners, reduced social/communicative abilities seem to facilitate better perspective-taking performance for deaf signers. This pattern reflects what would be expected if signers adopted a nonsocial strategy: those with more nonsocial tendencies should experience little interference from social abilities when adopting a nonsocial VSPT strategy. However, individuals with more social tendencies are likely to experience interference from their social abilities (i.e., a tendency to use a social strategy) when attempting a nonsocial VSPT strategy (which may be the preferred strategy for deaf signers).

A preference for a visual/perceptual (or a nonsocial) approach to performing the VSPT task for the deaf signers may be a result of a combination of different factors. First, deaf individuals could approach the task nonsocially because of the relatively more overt and perceptible nature of visual strategies, as suggested by Howley and Howe (2004). Signers may experience a bias toward using visual-spatial strategies because of their extensive experience with a language in the visual modality. Visual strategies may also be present within the speech domain. Deaf individuals (including those with cochlear implants) rely more heavily on visual cues to speech than do typically hearing individuals (e.g., Rouger, Fraysse, Deuine, & Barone, 2008). Similarly, in an educational setting, deaf students seem to depend more on visual information than hearing peers but are also more prone to becoming distracted by visual information (Marschark, Lang, & Albertini, 2001). Therefore, visual access to language and education may lead signers to a heavier reliance on visual strategies in perspective-taking tasks.

Another possibility is that deaf individuals may prefer to adopt a nonsocial strategy based on previously experiencing difficulties in social interactions with the hearing nonsigning population. In a review article examining social interactions between children who are deaf or hard-of-hearing and their hearing peers within inclusive educational environments, Xie et al. (2014) report that deaf and hard-of-hearing individuals experience considerable difficulty in their social interactions with hearing peers. The review uncovered several major areas in which deaf and hard-of-hearing children experience difficulties in social interactions with their hearing peers: initiation and maintenance of social interactions as well as quality of communication within the exchange. Overall, the review determined that deaf and hard-of-hearing children were less likely to in engage lengthy, meaningful communicative exchanges with their hearing peers than hearing children with one another, contributing to feelings of loneliness and isolation within the classroom. Therefore, deaf individuals may adopt a perspective-taking strategy that avoids relying on social abilities during childhood and then continue with the nonsocial strategy into adulthood. Even though many of the deaf individuals in the present study had at least one deaf parent and thus full access to social interactions in the home from birth, they would have still interacted with hearing individuals outside the home and thus may have experienced similar social difficulties with hearing nonsigners.

Furthermore, immersion in different cultural communities (i.e., East Asian versus Western culture) has been shown to impact strategies adopted during a Level 2 VSPT task (Kessler, Cao, O'Shea, & Wang, 2014). Kessler et al. (2014) hypothesized that differences in VSPT strategy for the different cultures may arise from an East Asian cultural tendency towards being more 'other' focused rather than a more 'self' focus seen in Western culture. Although not aligning to the same cultural differences as between East Asian and Western culture, Deaf cultural differences may also play a role in the strategy that individuals use for the VPST task. However, further investigation in necessary for more definitive conclusions as to the impact of Deaf culture on VSPT task performance.

In sum, deaf signers' preference for using a nonsocial strategy may arise as a result of an overall preference for visual, perceptual strategies, perhaps due to their access to language in the visual modality. Preference for a nonsocial strategy may also be due to experience with difficulties in social interactions with hearing peers during childhood or differences in cultural environment thus steering deaf signers away from a social strategy. Results from the present study clearly suggest a difference in visual-spatial perspective taking strategies for deaf signers compared to hearing nonsigners. Future research should further examine what cognitive processes are involved in this nonsocial strategy by explicitly examining whether deaf signers employ a systemizing and object-based mental rotation strategy or an embodied perspective transformation strategy during nonlinguistic tasks (following Kessler and Wang's suggested divisions of VSPT strategies).

Overall, this research provides evidence that experience with a visuospatial language does not cause a generalized improvement in nonlinguistic perspective-taking ability. However, examination of individual differences reveals that social skills are related to visual-spatial perspective-taking for deaf signers but in a very different way than for hearing nonsigners. Deaf signers seem to adopt a nonsocial VSPT strategy as compared with a social strategy adopted by hearing nonsigners. This research further indicates that VSPT strategy can be influenced by the modality of an individual's language as well as characteristics of their cultural and linguistic environment.

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3.6. Appendix A

Adapted Autism-Spectrum Quotient (AQ)

1. I like to do things with others more than by myself.
2. I prefer to do things the same way over and over again.
3. If I try to imagine something, it is very easy for me to create a picture in my mind.
4. I frequently focus so much on one activity that I do not pay attention to anything else around me.
5. I often notice small vibrations when other Deaf people do not.
6. I usually notice car license plates or other similar sequences of letters or numbers.
7. Other Deaf people frequently tell me what I've said is impolite, even though I think it is polite.
8. When I'm reading a story, I can easily imagine what the characters might look like.
9. I am fascinated by calendar dates.
10. In a social group with Deaf friends, I can easily pay attention to several people's conversations.
11. Social situations with my Deaf friends are easy for me.
12. I tend to notice details that others do not.
13. I'd rather go to a library than a party with my Deaf friends.
14. I can create stories easily.
15. I am attracted more strongly to people than to things.
16. I tend to have strong interests which I get upset about if I can't pursue.
17. I enjoy chatting socially with my Deaf friends.
18. When I sign with others, I usually take control of the conversation
19. I am fascinated by numbers.
20. When I'm reading a story, it is difficult for me to understand what the characters are trying to do.
21. I don't like fiction (made-up) stories.
22. It is hard for me to make new Deaf friends.
23. I notice patterns in things all the time.
24. If I had a choice, I would rather go to a theater show than to a museum.
25. It does not upset me if my daily routine is disturbed.
26. I frequently realize that I don't know how to keep a conversation going with my Deaf friends.
27. It is easy for me to figure out what my Deaf friend really means when he/she signs with me.
28. I usually concentrate on the whole picture and not on small details.
29. I'm not very good at remembering phone numbers.
30. I don't usually notice small changes in a situation or a person's appearance.
31. I know how to tell if someone signing with me is getting bored.
32. It is easy for me to do more than one thing at once.
33. When I'm using the videophone with someone, I'm not sure when it's my turn to sign.

34. I enjoy doing things spontaneously.
35. I am often the last to understand the point of a joke that my Deaf friend signed.
36. It is easy for me to figure out what someone is thinking or feeling just by looking at their face.
37. If there is an interruption, I can switch back to what I was doing very quickly.
38. I am good at chatting socially with Deaf friends.
39. People often tell me that I continue to discuss the same thing again and again.
40. When I was young, I enjoyed playing pretend games with other children.
41. I like to collect information about categories of things (e.g., types of cars, types of birds, types of trains, types of plants, etc.).
42. It is difficult for me to imagine what it would be like to be someone else.
43. I like to carefully plan ahead of time any activities that I participate in.
44. I enjoy social occasions with my Deaf friends.
45. It is difficult for me to figure out what people are trying to do.
46. New situations make me anxious even when everyone knows ASL.
47. I enjoy meeting new Deaf people.
48. I am a good diplomat.
49. I'm not very good at remembering people's date of birth.
50. It is very easy for me to play games with children that involve pretending.

3.7. Appendix B

Percentage of Participants At or Above Each AQ Score

AQ Score	Hearing Group (n=45)	Deaf Group (n=44)
0	100	100
1	100	100
2	100	100
3	100	100
4	100	100
5	100	97.7
6	100	90.9
7	95.6	90.9
8	95.6	88.6
9	93.3	79.5
10	91.1	63.6
11	80.0	47.7
12	71.1	38.6
13	64.4	31.8
14	57.8	18.2
15	55.6	9.1
16	44.4	4.5
17	40.0	4.5
18	37.8	4.5
19	26.7	2.3
20	22.2	2.3
21	17.8	2.3
22	13.3	2.3
23	11.1	2.3
24	11.1	0
25	8.9	0
26	6.7	0
27	6.7	0
28	6.7	0
29	6.7	0
30	4.4	0
31	2.2	0
32	2.2	0
33	0	0
34	0	0

Note: No participants received an AQ score greater than 34.

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Chapter 4: Visual-Spatial Perspective-Taking in Spatial Scenes and in American Sign Language (Experiment 3)

4.1. Abstract

Sign languages are produced in space and thus entail spatial cognitive processes that are not involved for spoken languages. Each interlocutor has a different visual perspective of the signer's hands which requires a mental transformation for successful communication about spatial scenes. For example, in a canonical face-to-face interaction in American Sign Language (ASL), a classifier construction depicting the location of an object produced on the signer's right is perceived on the addressee's left. It is unknown whether nonlinguistic perspective-taking or mental rotation abilities support signers' comprehension of such perspective-dependent structures within ASL. To address this question, 33 deaf ASL signers were asked to complete a nonlinguistic visual-spatial perspective-taking task, a mental rotation test, the ASL-Sentence Repetition Test, and an ASL comprehension test involving perspective-dependent classifier constructions. The results revealed a significant positive correlation between performance on the linguistic and nonlinguistic perspective-taking tasks. Mental rotation ability was also positively correlated with performance on both perspective-taking tasks. Results from linear regression for both response time and accuracy suggest that nonlinguistic perspective-taking abilities predict linguistic perspective-taking better than mental rotation ability. Performance on the ASL-Sentence Repetition Task also correlated with the classifier comprehension assessment but not nonlinguistic perspective-taking. Thus, the ability to comprehend perspective-

dependent ASL classifier constructions involves overall ASL abilities as well as nonlinguistic visual-spatial perspective-taking and mental rotation abilities.

4.2. Introduction

If language researchers only consider spoken languages, it is logical to focus on linguistic features and structures rather than on the modality of transmission. However, since the 1970s, sign language researchers have delved into the myriad of questions that can be asked about the nature of language by examining a language in another modality – the visuospatial modality. Because two modalities are possible for online expression and perception of language, it is important to examine what linguistic properties are specific to the modality by which that language is conveyed and which properties are applicable to language regardless of modality.

Rather than the oral articulators used in speech, sign languages (such as American Sign Language, ASL), are produced by the hands, face, and body, and utilize the space in front of the body, called *signing space*. Sign languages can use space topographically to schematically map the spatial arrangements of signs or spatial classifier constructions within signing space onto real or imagined spaces and the objects therein. For example, a signer can produce classifier[9] handshapes that refer to a

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[9] Classifier constructions (Supalla, 1986; also called polycomponential verbs, e.g., Schembri, 2003; and depicting verbs, e.g., Valli et al., 2011) in sign languages are predicates that express motion, position, stative-description, and handling information. Different classifier handshapes combine with movements in a constrained manner to express meaning. For instance, a specific handshape representing a vehicle can move through space to show the movement of that vehicle (see papers in Emmorey, 2003).

person and a bicycle and place them next to each other in signing space to indicate a person standing next to a bicycle. The classifiers' spatial arrangement maps directly onto the spatial relationship of those two objects in real or imagined space. This iconic use of space stands in contrast to the way spoken languages express spatial relations, namely via specific lexical items (e.g., prepositions) or spatial morphemes (e.g., locative affixes).

Evidence from neuroimaging studies has suggested that these different linguistic structures (i.e., prepositions in English and spatial classifier constructions in ASL) are represented differently in the brain. For example, Emmorey et al. (2002) found that the right supramarginal gyrus was activated when signers produced classifier constructions, but this region was not engaged when English speakers produced prepositions (Damasio et al., 2001). Emmorey et al. suggest that greater involvement of the right hemisphere may be due to the topographic use of space in ASL. These findings are consistent with reports that suggest right hemisphere damage can disrupt a signer's topographic use of space in sign language while leaving use of simple English prepositions relatively intact (Corina, Bellugi, Kritchevsky, O'Grady-Batch, & Norman, 1990; Emmorey, Corina, & Bellugi, 1995; Emmorey, 1996). Emmorey (1996) reported the case of a signer with right hemisphere damage (originally described by Corina et al., 1990) who maintained the ability to follow simple spatial commands in English (e.g., "Put the pen on the book"), but could not

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For this study, discussion will be limited to spatial classifier types (rather than stative-description or handling type classifier constructions).

follow the same command in ASL – even though the ASL classifier constructions were iconic (e.g., placing the handshape representing the pen – a fist with the index finger extended – on top of a flat open-hand representing the book). This discrepancy is likely due to the spatial decoding that is necessary for comprehending the spatial relationship in ASL that is not required to parse the prepositional phrase in English. Such spatial decoding seems to critically involve the right hemisphere.

In addition, Emmorey et al. (2005) examined the neural activation for the production of spatial classifier constructions and lexical prepositions in hearing ASL-English bilinguals and again found bilateral activation of parietal cortex for classifier constructions, as found by Emmorey et al. (2002). Emmorey et al. (2005) additionally demonstrated greater activation in the left inferior frontal gyrus when producing ASL nouns and lexical prepositions (compared to a baseline task that did not involve lexical retrieval), but not when producing spatial classifier constructions. When production of locative or motion classifier constructions was directly compared with production of the classifier handshapes for different types of objects (e.g., long thing object such as a pencil, or flat round object like a coin), Emmorey, McCullough, Mehta, Ponto, and Grabowski (2013) found that retrieval of handshape morphemes involved left inferior frontal gyrus activation, but production of motion and location information within a classifier construction involved bilateral superior parietal cortex. Emmorey et al. (2013) hypothesized that the motion and location components of classifier constructions are not stored as lexical items because of the gradient nature of this type of information. Production of classifier handshapes, on the other hand, recruited left inferior frontal regions, which may be due to the retrieval of object-specific information denoting the class of the object in order to select the correct classifier handshape. The types of handshapes for classifiers represent a closed class of morphemes that are treated categorically rather than as a gradient (e.g., Emmorey & Herzig, 2003). Therefore cognitive demands seem to differ for retrieving and producing locative information lexically (like with English prepositions) as compared with the more gradient topographic representation with ASL motion and locative classifier constructions. These differing cognitive demands arising from the topographic use of space may result in cognitive advantages in specific areas of spatial cognition.

While knowing a sign language does not seem to result in a generalized advantage in spatial cognition (e.g., Marschark et al., 2015), there is evidence that sign experience can result in specific enhancements in spatial cognition. When deaf signers and hearing nonsigners were asked to generate mental images of block letters, the deaf signers showed significantly faster reaction times than the hearing nonsigners when forming mental images of complex letters, but not with maintaining those images mentally over time (Emmorey, Kosslyn, & Bellugi, 1993; Emmorey & Kosslyn, 1996). Similarly, deaf signers showed faster reaction times compared with hearing nonsigners during a task requiring a decision about whether two rotated block figures were mirror images of one another; however, the deaf signers were not faster to perform the mental rotation overall (Emmorey et al., 1993). Emmorey et al. hypothesized that the enhanced image generation and detection of mirror reversals (and not image maintenance or overall mental rotation speed) may be due to the specific requirements of ASL for topographic use of space, imagining referents, and perspective shifting within signed productions.

Further, Emmorey, Klima, & Hickok (1998) showed that deaf signers remembered objects' orientations within a scene better than nonsigners. Deaf signers additionally outperformed hearing nonsigners at recreating a visual scene (e.g., a room with furniture) when 180° mental transformation of the scene was required, but performance was similar across groups when no mental transformation was required (Emmorey et al., 1998). They suggest, as with others who report advantages in spatial cognition for deaf signers (e.g., Bavelier et al., 2001; Talbot & Haude, 1993), that the specific spatial processes involved in sign language processing can provide measurable advantages for similar nonlinguistic tasks. For example, Klima, et al. (1999) showed that deaf signers were better able to decompose a moving light display (e.g., Chinese characters) into its discrete components than were hearing nonsigners. Klima et al. hypothesized that the advantage for deaf signers stemmed from the requirement to parse transitional and meaningful movements from streams of connected signs. The enhanced performance seen in deaf signers for these spatial cognitive tasks suggests that similar nonlinguistic skills may support performance in linguistic and nonlinguistic domains.

Evidence supporting a nonlinguistic cognitive advantage in spatial tasks has also been shown during development for native deaf signing children. Bellugi et al. (1990) demonstrated that deaf signing children outperformed hearing nonsigning children on a spatial arrangement and manipulation task. Like with adults, the signing children also were better able to remember, analyze, and decode components of moving light displays of Chinese characters. These spatial cognition advantages were particularly pronounced for the younger children (ages 3-5). Thus, sign experience may lead to earlier developmental success with specific aspects of spatial cognition that are involved in processing sign language; however, the use of space in ASL may also introduce additional layers of complexity for certain structures such as classifier constructions.

The acquisition of spatial classifier constructions in ASL follows a protracted developmental trajectory (e.g., Schick, 1990), in part because of the perspective-dependent use of signing space. For example, Martin and Sera (2006) tested the ability of deaf signing and hearing nonsigning children (4;11 – 9;0 years old) to comprehend perspective-dependent locative structures (left, right, front, behind, towards, away) and perspective-independent structures (above, below) in ASL (classifier constructions) or in English (prepositions). The experimenter (seated face-to-face with the participant) described a card from his or her own perspective and asked the child to pick which of two cards matched the experimenter's card. The ASL-signing and English-speaking children were equally accurate when selecting the perspective-independent (above, below) cards, but the ASL signers were significantly less accurate than the English speakers for perspective-dependent trials (left, right, etc.). Martin and Sera suggested that there is an added layer of complexity arising from the conflicting visual perspectives between signer (the experimenter in their study) and addressee (the child) that results in the ASL signing children acquiring these perspective-dependent items later than their hearing peers. Thus, while sign language experience may lead to earlier development in some aspects of spatial cognition (e.g., Bellugi et al., 1990), the visuospatial modality also seems to create additional cognitive demands arising from conflicting visual perspectives that are unique to signed languages.

Sign researchers have long recognized that the spatial nature of signed languages creates conflicting visual perspectives between the signer and the addressee when conversing in the canonical face-to-face arrangement: what is produced on the signer's right is viewed on the addressee's left (e.g., Emmorey, 2002a, Emmorey et al., 1998; Emmorey & Tversky, 2002; Pyers, Perniss, & Emmorey, 2015; Pyers, Perniss, & Emmorey, 2008). This perspective conflict only arises when signers describe nonpresent scenes. When describing objects that are visible in their environment, the location of the objects and of the signer's hands are both visible, and such spatial descriptions are produced in what has been termed *Shared Space* (Emmorey & Tversky, 2002). For Shared Space, there is no need for perspective-taking because each interlocutor can maintain his or her perspective of the jointly-viewed scene, and this perspective does not conflict with the view of the signer's hands. When describing nonpresent scenes, the signer and addressee do not view the signer's hands from the same perspective - even when they are not face-to-face (e.g. in a group setting where the signer may be viewed from the side). Therefore, some sort of mental process is required in order for both interlocutors to arrive at the same understanding of what is being signed. The convention in ASL (and many other unrelated sign languages) is for the signer to produce egocentric descriptions for non-jointly viewed scenes using what we will term "Signer Space" (i.e., from the signer's perspective), which contrasts with Shared Space (Pyers et al., 2008; Pyers et al., 2015). For descriptions in Signer Space, the addressee(s) must perform a mental transformation in order to understand from the signer's perspective. Although this perspective conflict has been discussed previously, little work has been done to examine the cognitive mechanisms that underlie the resolution of this perspective conflict.

Emmorey et al. (1998) discussed the required transformation in terms of mental rotation of a scene (e.g., of the description of a room). While mental rotation and perspective-taking abilities are highly related, they are dissociable processes (Hegarty & Waller, 2004; Zacks, Mires, Tversky, & Hazeltine, 2000). Visual-spatial perspective-taking (VSPT) seems to involve an imagined self-projection through space to align with another's physical location and their visual-spatial perspective of a target object or scene (Kessler & Rutherford, 2010; Kessler & Thomson, 2010), which is in contrast to the process of mentally rotating a two- or three-dimensional object or array (e.g., Michelon & Zacks, 2006; Zacks et al., 2000). While gender effects on object-based mental rotation ability have been well documented (e.g., Peters, 2005; Voyer, Voyer, & Bryden, 1995), reports are mixed as to the role of gender in VSPT tasks (e.g., Kessler & Wang, 2012; Mohr, Rowe, & Blanke, 2009; Zacks et al., 2000). Although gender is often an important factor in spatial tasks, particularly for mental rotation type tasks, it may play less of a role during comprehension of spatial language in ASL. Emmorey et al. (1998) found that males outperformed females on an object-based spatial task, but male and female signers performed similarly when the task involved comprehending spatial ASL descriptions.

To date, the nature of the spatial transformation necessary for the addressee to adopt the signer's perspective and the potential effects of gender on this spatial transformation remains unspecified. Recently, Pyers et al. (2015) suggested that embodied or cognitive control mechanisms might underlie the ability for an addressee to ignore his or her own visual perspective of a signed or gestured production in order to adopt another's visual perspective. One way to examine what processes contribute to this spatial or perspective transformation is to compare an individual's relative abilities in mental rotation and nonlinguistic, visual-spatial perspective-taking tasks with their ability to perform the necessary spatial or perspective transformation within sign comprehension.

Evidence from atypical sign language development during childhood has provided some clues about whether nonlinguistic VSPT ability may be related to the spatial transformations seen in ASL. Quinto-Pozos et al. (2013) presented a case study of a native signing deaf teenager, pseudonym Alice, who achieved highly fluent levels of ASL proficiency, but selectively struggled with aspects of ASL that depended on understanding perspectives (e.g., role/referential shift, classifier constructions). She also struggled with nonlinguistic visuospatial tasks (e.g., assembling puzzles) and with nonlinguistic perspective-taking tasks (e.g., imagining how an array would look from another perspective). Quinto-Pozos et al. hypothesized that Alice had a developmental perspective-taking visuospatial deficit which selectively impaired her ability to master the topographic aspects of ASL that depend on these nonlinguistic abilities.

Similarly, Shield and Meier (2012) reported data from native signing children who have been diagnosed with Autism Spectrum Disorder (ASD). These children produced palm reversal errors, a pattern of errors not seen in typically developing native signing children. The children with ASD produced manual fingerspelled[10] letters with the palm facing inward, towards their own body, rather than with a correct outward-facing palm. Typically developing children learning ASL do not produce this kind of inward facing error. Such errors seem to reflect a lack of perspective shifting because the ASD children simply copy what they visually perceive. For instance, if the child observes a parent fingerspelling with an outward-facing palm orientation (normal fingerspelling) and mimics the observed handshape and orientation, such a production would result in an incorrect inward-facing palm orientation. Shield and Meier suggest that this kind of error may arise from a difficulty with self-other mapping. One part of successful mapping between one's own body and another's body may depend on a visual-spatial perspective-taking process which seems to be impaired in individuals with ASD (e.g., Hamilton, Brindley, & Frith, 2009; Shield, Pyers, Martin, & Tager-Flusberg, 2016).

Thus, evidence from atypical sign language acquisition suggests that nonlinguistic perspective-taking abilities may underlie linguistic perspective-taking

[10] In ASL (and other sign languages), a system of handshapes maps to the written system of the surrounding spoken language (i.e., English for ASL) allowing for manual spelling of words letter by letter.

abilities in ASL, particularly for perspective-dependent structures in ASL. Furthermore, as described above, behavioral studies with both typically developing signing children and neurotypical adults suggest that extensive practice with specific aspects of spatial cognition within a signed language context can result in enhancements in nonlinguistic visuospatial abilities. However, whether nonlinguistic perspective-taking abilities relate to linguistic perspective-taking abilities in neurotypical signing adults remains to be empirically tested.

If the spatial transformation required to reconcile the spatial conflict between the signer's and addressee's views of the signer's hands involves mental rotation processes as Emmorey et al. (1998) suggested, then an individual's performance on a mental rotation task should correlate with performance on an ASL task involving spatial perspective transformation. However, nonlinguistic perspective-taking abilities may also be related to an addressee's ability to adopt the signer's perspective, and thus performance on linguistic and nonlinguistic perspective-taking tasks may be correlated. Both mental rotation and perspective-taking abilities may relate to a signer's abilities to reconcile the perspective conflict within ASL due to the highly related nature of mental rotation and embodied perspective-taking (e.g., Hegarty & Waller, 2004). In that case, linear regression would be able to determine whether one of the two cognitive abilities relates more strongly with ASL perspective-taking performance. Since perspective-taking within ASL also involves comprehension of ASL (e.g., phonological, lexical, and syntactic processing), general ASL proficiency should also relate to comprehension of perspective-dependent ASL structures.

However, we would not expect overall ASL proficiency to relate to nonlinguistic VSPT abilities since only the ability to comprehend and produce specific ASL structures (e.g., classifier constructions) is hypothesized to relate to VSPT abilities. As Quinto-Pozos et al. (2013) showed, nonlinguistic VSPT deficits can disrupt the proposed perspective-dependent ASL structures in spite of achieving a high proficiency in overall ASL ability.

Therefore, the present study examined the relationship between deaf signers' performance on a nonlinguistic visual-spatial perspective-taking (VSPT) task, a mental rotation task, and a task that taps proficiency in comprehending specific ASL structures hypothesized to rely on a visual-spatial transformation. Secora and Emmorey (2016) previously reported the VSPT and mental rotation performance of this group of deaf signers in comparison to a group of hearing nonsigners – both groups performed similarly on the two tasks. The aim of the present study is to clarify what cognitive abilities play a role in reconciling the visual-perspective conflict that can arise as a result of the topographic use of space in ASL spatial descriptions.

4.3. Method

4.3.1. Participants

Thirty-three deaf signers (16 F; M_{age} = 30.4 years, *SD* = 8.1; range: 20.4 – 48.5 years) were recruited from the community in San Diego, CA. Demographic information is presented in Table 4.1. Twenty participants were native signers (learned ASL from birth from deaf parent/s; 13F) and thirteen were early signers (learned ASL prior to age 6; 3F). Additionally, participants reported no history of Autism Spectrum

Disorder (ASD). ASD screening information was unavailable from one male participant. There were no significant differences in age between males and females or between native and early signers (all *p*s > .20).

Table 4.1. Mean Demographic Information (SD).

	Age	**KBIT (Raw Score)**	**Years of Education**
Total	30.4 (8.1)	40.6 (3.3)	16.7 (3.1)
Males (*n* = 17)	30.4 (8.3)	41.6 (2.3)	17.1 (3.1)
Females (n = 16)	30.3 (8.2)	39.3 (3.8)	16.2 (3.0)
Native signers (n = 20)	29.0 (7.2)	40.7 (2.9)	16.7 (2.7)
Early signers (*n* = 13)	32.6 (9.3)	40.4 (3.9)	16.8 (3.7)

Nonverbal intelligence was measured by the matrices subtest of the *Kaufman Brief Intelligence Test, Second Edition* (KBIT, Kaufman & Kaufman, 2004). Raw KBIT scores are presented in Table 4.1 (maximum possible correct = 46). KBIT scores for the male participants were marginally higher than for the female participants, $t(30) = 2.00$, $p = .054$. One female participant's KBIT score was unavailable. There were no significant differences in years of education between males and females or between native and early signers (all *p*s > .30).

Participants' self-report of race consisted of Caucasian (N = 26), Black/African American (N = 2), Asian (N = 1), more than one race (N = 3), and unknown (N = 1). Five participants reported Latino/Hispanic ethnicity, twenty-seven reported Not Latino/Hispanic ethnicity, and one reported unknown ethnicity.

4.3.2. Materials and Procedure

4.3.2.1. Nonlinguistic tasks

4.3.2.1.1. Visual-Spatial Perspective-Taking: Three Buildings task

This three-dimensional nonlinguistic VSPT task was based on the task used by Clements-Stephens et al. (2013) and Shelton et al. (2012). Participants viewed two different displays each containing three unique buildings and made decisions about which view of the buildings was represented by a photograph. The buildings were placed on a 36-inch diameter wooden disk that was covered in a faux grass mat (see Fig. 4.1). Around the edges of the disk were placed seven, uniquely-colored perspective-taking targets, at 45° intervals with the participant seated at the 0° heading. A laptop computer showed participants photographs of the display which were taken from the perspectives corresponding to the targets. The participant's task was to decide for each photograph, "Which triangle is at this view?" Participants responded by pressing the key on the keyboard that corresponded to the location/color of the perspective target. The 'v' key was labeled with a sticker corresponding to the color of the perspective target 45° to the participant's left. The 'f' key corresponded with the target 90° to the participant's left. Other response keys followed the same key/perspective target pairing: 't' = 135° target, 'y' = 180° target, 'u' = 225° target, 'j' = 270° target, 'n' = 315° target, and 'b' corresponded with the participant's view of the displays (labeled with a black sticker and no perspective target). The colors of the perspective-taking targets were randomly assigned for each participant and remained fixed for that participant throughout the experiment. Reaction times and key responses were collected. Trials timed out after seven seconds if no response had been made.

Perspective targets consisted of a colored wooden triangle (and cube) affixed to the top of a wooden candlestick holder. Participants completed two conditions, a nonsocial (triangles without eyes) and a social condition (triangles with eyes). Previous research indicated that this social context manipulation impacted whether hearing participants adopted a social or a nonsocial (e.g., visual) strategy during the VSPT task (Shelton et al., 2012; Clements-Stephens et al., 2013). However, Secora and Emmorey (2016) found that both the deaf and hearing participants utilized the same strategy regardless of the social or nonsocial context. Therefore these conditions were collapsed for the analyses in the current study.

Figure 4.1. Example of experimental set-up for the VSPT task.

Instructions were presented in written English and in ASL via a prerecorded video featuring a native signer. Prior to beginning the practice trials, participants walked around the building display to familiarize themselves with the views from all perspectives. Participants viewed 160 trials presented in a pseudorandomized fixed order. Half of the trials were presented in each of the nonsocial or social conditions, and half with each building display. Conditions and building displays were randomly selected for each person with the exception that each person saw the buildings in a fixed order (i.e., the same building display was presented first in each condition).

4.3.2.1.2. Mental Rotations Test (MRT)

For this test, participants were shown black-and-white line drawings of three-dimensional blocks on paper (Peters et al., 1995; Vandenburg & Kuse, 1978). Participants' task was to decide which two of four possible response figures matched a target figure. Each response figure was rotated so that a slightly different angle/face of the figure was visible. Participants were given three practice items with feedback and then twelve items in each of two four-minute blocks. Items were only scored correct if both target responses were correctly identified. The dependent variable was number of problems correctly answered (total possible = 24).

4.3.2.2. Sign Language tasks

4.3.2.2.1. ASL Spatial Perspective Comprehension Test (ASPCT)

This computerized task is an adaptation of the ASL Perspective Taking Comprehension Test developed by Quinto-Pozos et (2013). Participants viewed a video of a signer producing two one-handed ASL classifier constructions either facing the camera or at a 90° angle to the camera (see Fig. 4.2). All videos were approximately the same duration (average duration = 2732 ms, *SD* = 282 ms; range =

2090 – 3262 ms). Participants selected which of four possible response pictures corresponded to the signed description by pressing a key labeled with a letter on a sticker (A = 'f' key, B = 'g' key, C = 'h' key, and D = 'j' key). Trials timed out after seven seconds if no response was made. The two objects in the response pictures were selected from a set of three toys: a dog, truck, or man (see Fig. 4.3). The toy objects were arranged side by side with either an x-axis (i.e., left-right) or z-axis (i.e., front-back) arrangement relative to the signer. Objects could be upright, upside down, on their left or right side, or on their front or back side. Fig. 4.3 displays the vehicle, small animal, and "standing human" classifier handshapes, along with the corresponding objects. Each classifier handshape maps onto the object with a strict intrinsic frame of reference, e.g., the front of the car maps to the index/middle fingertips in the vehicle classifier, the front of the knuckles maps to the front of the dog, etc. (see Emmorey, 2002b, for further discussion).

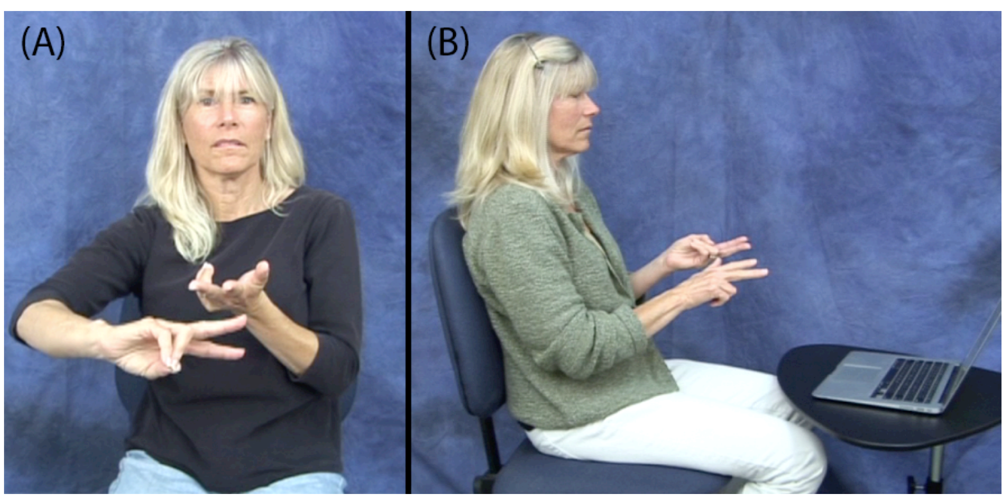

Figure 4.2. ASPCT sample stimulus items. (A) Still frame from a face-to-face Shared Space stimulus item. (B) Still frame from a sideways 90° Signer Space stimulus item.

Figure 4.3. Classifier handshapes (above) and the corresponding object (below).

Participants completed 18 experimental trials in each of four blocks, preceded by two practice trials (with feedback) per block. Blocks consisted of two ‘angle’ conditions nested within two ‘space’ conditions: face-to-face or 90° (sideways to the camera) with descriptions that used Shared Space or Signer Space. To succeed on the Shared Space items, participants simply mapped from the signer’s hands to the objects without any kind of perspective transformation. Therefore these items serve as a control. Because the Signer Space items required adopting the signer’s perspective in order to succeed, this is the condition of interest for the present analysis. Therefore, the correlation analyses were only conducted with data from the Signer Space condition (both the face-to-face and 90° angle items).

Trial types were blocked because intermixing conditions would have resulted in RT costs for switching between Shared and Signer Space as well as errors stemming from failure to switch. Additionally, intermixing would have necessitated the addition of a cue as to which space condition should be followed (e.g., whether to interpret a face-to-face description in Shared or Signer Space). To eliminate these confounds, conditions were blocked resulting in four conditions: Signer Space face-to-face, Signer Space 90°, Shared Space face-to-face, and Shared Space 90°. Order of conditions was counterbalanced across participants with the constraint that both conditions of one type of space were viewed consecutively (i.e., Signer Space face-to-face and 90°; Shared Space face-to-face and 90°) counterbalanced with respect to which angle condition occurred first (i.e., face-to-face or 90°).

To establish Shared Space, the instructions provided a sample item showing that the sign model was describing physical objects visible on a small table in front of her. For the experimental stimuli, the video zoomed in on the sign model so that the table was not visible in the frame; however, the model continued to look down at the table before looking to the camera while producing the classifier descriptions. In Shared Space, participants were instructed to select the picture that matched the signer's description from the participant's own perspective. In contrast, for the Signer Space items, the model produced descriptions after viewing items on a laptop computer screen visible only to the sign model. Participants could only see the back of the laptop from their perspective. The laptop was physically turned around during the practice items to show a sample picture item as it appeared on the laptop. For Signer

Space items, participants were instructed to select the picture that matched what the signer saw on the laptop from her perspective. Pilot testing revealed that participants sometimes struggled to distinguish between Shared and Signer Space for the face-to-face condition. Therefore, as an additional cue, the sign model wore a different colored shirt in the two space conditions.

There were three types of foils (see Fig. 4.4). All foils and the correct answer were balanced across the test with respect to frequency of occurrence in each A, B, C, or D position. In the 180° foil, the correct object arrangement was pictured from the opposite, 180° perspective. In the face-to-face condition, the 180° foil represented the opposite space (e.g., adopting Shared Space when the correct response required adopting the model’s perspective in Signer Space). The second type of foil, Arrangement Swap foil, displayed the two objects with the correct orientation relative to the camera but in the opposite side of space relative to each other. For example, from Fig. 4.4, the dog is on the left side of the picture facing to the right, and the car is on the right facing to the left in the correct picture. Therefore, for the Arrangement Swap foil, the dog continues to face right but is now placed on the right side of the picture, while the car continues to face to the left but is on the left side of the picture. This type of error represents inattention to the correct location and intrinsic orientation of the two classifiers and/or objects. The fourth type of foil was the Object Rotation foil in which one of the two objects was rotated 180° on either the y or z axis from the correct position. From Fig. 4.4, for the Object Rotation foil the dog is correctly placed and oriented, but the car has been rotated 180° on the y axis so that it faces the opposite direction (e.g., facing right instead of correctly facing left). An Object Rotation error represents inattention to the correct intrinsic orientation of the classifiers and/or objects.

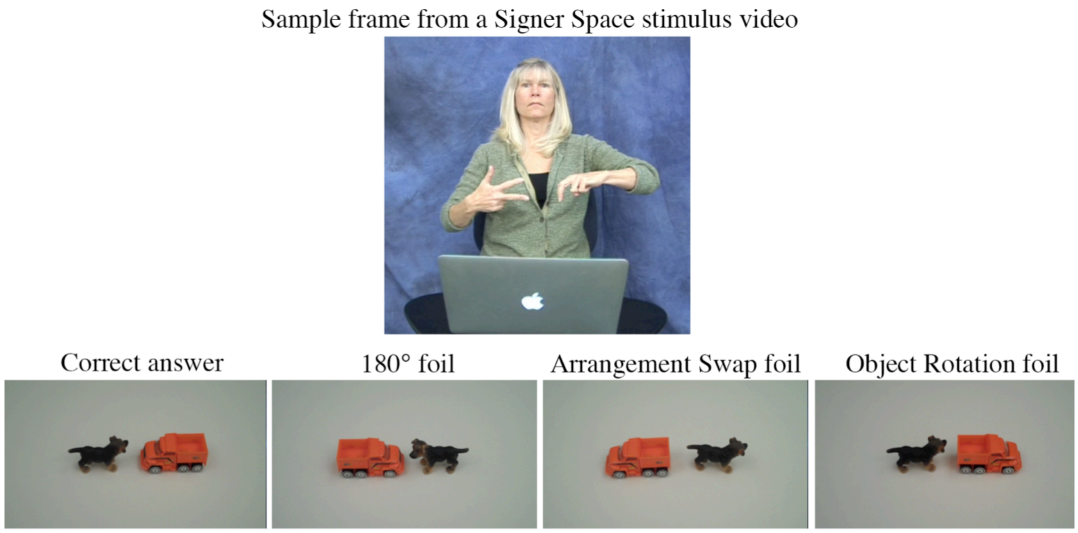

Figure 4.4. Sample Signer Space stimulus item with the correct response picture and foils.

4.3.2.2.2. ASL-Sentence Reproduction Task (ASL-SRT)

The ASL-SRT is a measure of ASL proficiency involving both ASL comprehension and production abilities (Hauser et al., 2008; Supalla, Hauser, & Bavelier, 2014). This test has been shown to differentiate between native signers and those who learned sign late, deaf native signers and hearing native signers, as well as deaf native signing children versus deaf native signing adults (Hauser et al., 2008; Supalla et al., 2014).

For this test, participants viewed prerecorded videos of a woman signing a sentence and were asked to reproduce the sentence exactly as it was signed, including identical morphosyntactic inflection, word order, and lexical items. Participants' signed responses were video recorded for subsequent offline scoring. Following three practice items, participants viewed a 35-item subset from the original 39-sentence test as reported by Hauser et al. (2008). No corrective feedback was provided for the practice items; rather, if participants made mistakes, they were simply reminded to reproduce the sentences exactly as the model had signed them. Participants were only allowed to view each sentence one time but were allowed unlimited time to respond. Sentences were ordered by increasing length and complexity. Only items that were reproduced identically (e.g., no added/deleted/changed signs, no modifications in sign order, etc.) were marked as correct. A native deaf signer scored all productions for accuracy. Due to a technical malfunction, several items for three participants were unable to be scored resulting in 28, 30, and 32 total items for these participants. Percent accuracy was calculated for each person out of the total scored items (prorated for the three participants who were missing items).

Additionally, while not classified as errors, for some items participants could produce mirrored productions (i.e., productions on the signer's left side are produced on the participant's right side) or reversed productions (e.g., productions on the signer's left side are also produced on the participant's left side). Since these types of productions are informative for an analysis of perspective-taking, the number of mirrored and reversed productions was also scored for each participant. Fourteen test items allowed for possible mirrored or reversed productions.

4.4. Results

Accuracy and response time (RT) averages for the ASPCT task were limited to the perspective-dependent Signer Space items because these items were of the most theoretical interest with regard to perspective-taking. Similarly, VSPT items were limited to items requiring a perspective shift (e.g., excluding items that corresponded to the participant's own self view). RT analyses included only correct responses, and responses for which participants timed out were included in the accuracy analysis as errors. Means and *SD*s for the spatial and linguistic tasks are presented in Table 4.2.

Table 4.2. Means and SDs for Spatial and ASL Tasks Divided by Gender and Sign Exposure Groups.

	Females	Males	Early	Native
ASL-SRT (%)	67 (14)	69 (7)	64 (9)	71 (12)*
ASPCT Accuracy (%)	68 (16)	75 (13)	69 (15)	73 (14)
ASPCT RT (ms)	3823 (696)	4052 (619)	3793 (466)	3742 (505)
MRT (Number correct)	12 (6)	16 (5)*	15 (6)	14 (6)
VSPT Accuracy (%)	69 (12)	86 (7)**	80 (13)	76 (13)
VSPT RT (ms)	3725 (685)	3597 (536)	3665 (611)	3655 (619)

*p<.05, **p<.001

Note: ASL Spatial Perspective Comprehension Test (ASPCT); Visual-Spatial Perspective-Taking (VSPT); ASL Sentence Reproduction Test (ASL-SRT); Mental Rotation Test (MRT)

Significance values for two-tailed t tests[11] within each group are denoted with asterisks. Males had significantly higher accuracy than females on the spatial tasks

[11] Results showed a similar pattern whether percentage or arcsine transformations of the percentage data were used. MANOVA and t test results depict analyses that were

(VSPT and MRT) but were no different on the ASL language tasks. Native signers were significantly more accurate than early signers on the ASL-SRT but were no different on the spatial tasks or the classifier comprehension task (ASPCT). Separate MANOVAs for RT and accuracy were conducted for the dependent variables for the tests (ASPCT, MRT, and VSPT) with sign exposure group as a between-subjects factor. There were no differences between early and native signers for RT or accuracy (*p*s $>.50$). Therefore, aside from native signers being more accurate than early signers on the ASL-SRT, there were no differences in performance on the ASPCT or spatial tasks. Emmorey et al. (1993) similarly found no difference in performance between native signers and early signers on spatial tasks (i.e., mental rotation and image generation). Therefore, we collapsed these groups to increase power in subsequent correlation analyses.

In order to examine the effects of gender on the VSPT, MRT, and ASPCT tasks, separate MANOVAs were performed for accuracy and RT with gender as a between-subjects variable. Because MRT is a measure of accuracy (i.e., number correct), MRT was only included in the MANOVA for accuracy. For accuracy, using Pillai's trace, there was a significant effect of gender on performance on the perspective-taking tasks, $V = .486$, $F(3, 29) = 9.15$, $p < .001$, $\eta_p^2 = .486$. Follow up individual ANOVAs for each dependent variable revealed that males were

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calculated using the arcsine transformation data. The correlational results shown are from percent correct.

significantly more accurate than females on the VSPT task, $F(1, 32) = 25.0$, $p < .001$, $\eta_p^2 = .447$, and the MRT task, $F(1, 32) = 4.24$, $p = .048$, $\eta_p^2 = .120$, but not the ASPCT task, $F(1, 32) = .778$, $p = .385$. For RT, the MANOVA revealed there was no effect of gender for either the VSPT RT or ASPCT RT, $F(2, 30) = 1.08$, $p = .352$, Because gender did not affect RT performance for either VSPT or ASPCT, gender was collapsed for correlations with RT. However, because gender was shown to affect accuracy performance, correlations involving accuracy were additionally examined separately for males and females.

Since the main question of interest concerned the relationship between an individual's linguistic and nonlinguistic perspective-taking abilities, Pearson's correlation coefficients were calculated for accuracy and RT for the VSPT, MRT, and ASPCT tasks (see Table 4.3). VSPT and ASPCT accuracy were significantly related ($r = .47$), as were VSPT and ASPCT RT ($r = .38$). Accuracy on the mental rotation task correlated with both linguistic perspective-taking skill (ASPCT accuracy and RT) and nonlinguistic perspective-taking skill (VSPT accuracy and RT). ASL-SRT accuracy was positively correlated with ASPCT accuracy: individuals with better overall ASL comprehension also tended to comprehend the perspective-dependent ASL structures better.

Table 4.3. Correlation Coefficients for Linguistic and Nonlinguistic Spatial and Perspective-Taking Tasks.

	1	2	3	4	5	6
1. VSPT Accuracy						
2. VSPT RT	-.50**					
3. ASPCT Accuracy	.47**	-.39*				
4. ASPCT RT	-.08	.38*	-.28			
5. ASL-SRT Accuracy	.29	-.26	.50**	-.05		
6. MRT Number Correct	.62**	-.45**	.45**	-.36*	.38*	

*p<.05, **p<.01, ***p<.001

Note: ASL Spatial Perspective Comprehension Test (ASPCT); Visual-Spatial Perspective-Taking (VSPT); ASL Sentence Reproduction Test (ASL-SRT); Mental Rotation Test (MRT)

Table 4.4. Correlation Coefficients Separated by Gender.

Males (*n* = 17)	1	2	3	4
1. VSPT Accuracy				
2. ASPCT Accuracy	.06			
3. ASL-SRT Accuracy	-.06	.12		
4. MRT Number Correct	.32	.10	-.04	
Females (n = 16)	1	2	3	4
1. VSPT Accuracy				
2. ASPCT Accuracy	.63**			
3. ASL-SRT Accuracy	.43	.67**		
4. MRT Number Correct	.72**	.63**	.60*	

*p<.05, **p<.01, ***p<.001

Note: ASL Spatial Perspective Comprehension Test (ASPCT); Visual-Spatial Perspective-Taking (VSPT); ASL Sentence Reproduction Test (ASL-SRT); Mental Rotation Test (MRT)

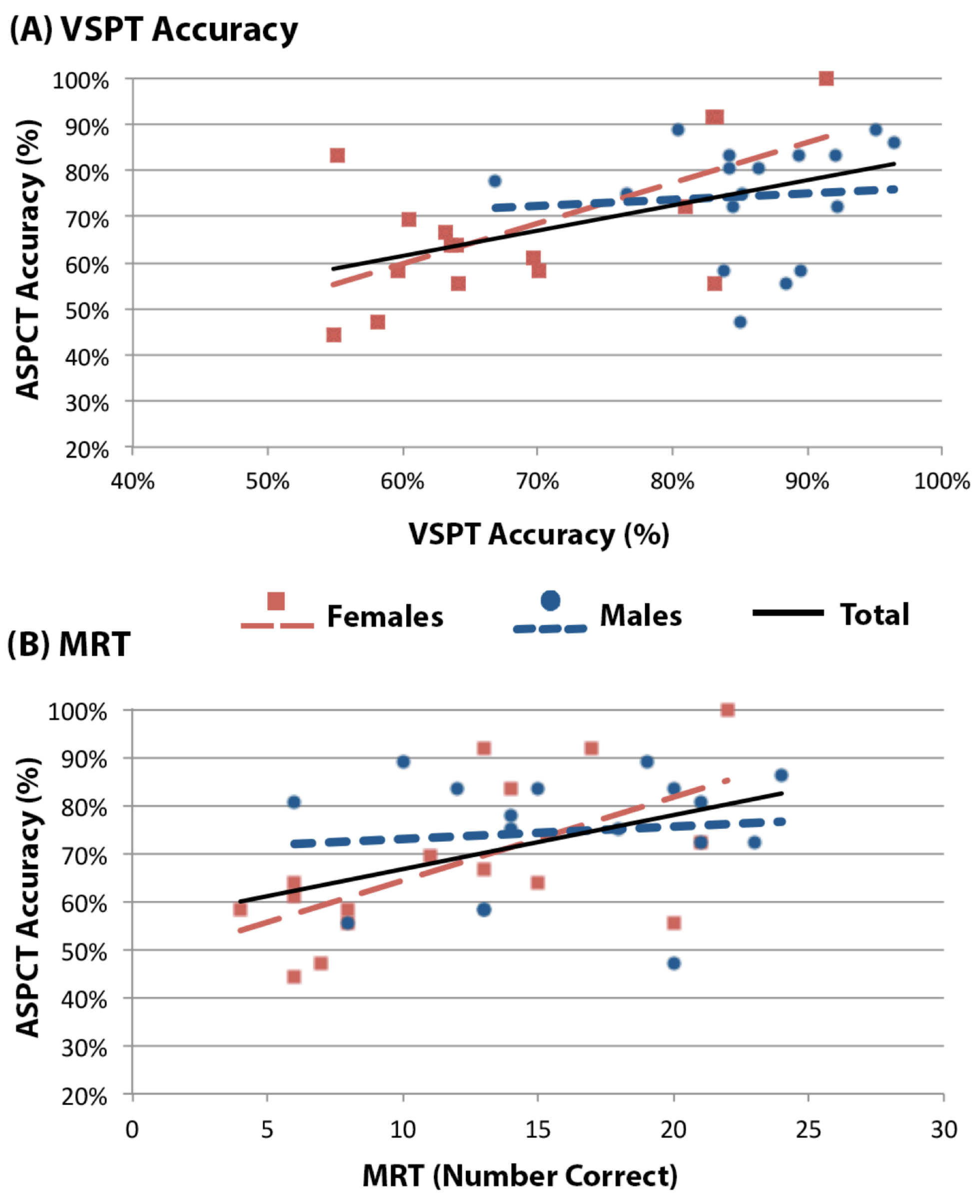

Figure 4.5. Correlation scatterplots for VSPT and ASPCT perspective-taking tasks and the MRT. (A) VSPT and ASPCT accuracy for females (dotted red line), males (dotted blue line), and total for both males and females together (solid black line). (B) MRT and ASPCT accuracy for males, females, and overall.

Table 4.4 presents the correlations between accuracy on the tasks for each gender separately (see Fig. 4.5 for scatterplots). For males, no significant correlations were observed among the tasks. For females, however, accuracy on the linguistic

(ASPCT) and nonlinguistic (VSPT) perspective-taking tasks were significantly related. Both perspective-taking tasks additionally correlated with the accuracy on the mental rotation task.

Table 4.5. ASPCT RT and Accuracy Backwards Linear Regression Model Comparisons.

	Unstandardized Coefficients		**Standardized Coefficients**		
	β	***SE***	**β**	***t***	***p***
RT Model 1					
Constant	3235	907		3.57	.001*
VSPT RT	0.30	.20	0.27	1.48	0.15
MRT Number Correct	-26.7	20.7	-0.24	-1.29	0.21
RT Model 2					
Constant	2432	668		3.64	.001*
VSPT RT	0.41	0.18	0.38	2.29	0.03*
Accuracy Model 1					
Constant	0.340	0.150		2.27	.031*
VSPT Accuracy	0.365	0.233	0.314	1.57	.128
MRT Number Correct	0.006	0.005	0.252	1.26	.219
Accuracy Model 2					
Constant	0.286	0.145		1.98	0.057
VSPT Accuracy	0.548	0.184	0.472	2.98	0.006*

$^*p<.05$

Note: Visual-Spatial Perspective-Taking (VSPT); Mental Rotation Test (MRT)

Separate backward linear regression models for ASPCT RT and accuracy were conducted to examine the relative strength of VSPT and MRT performance as predictors (Table 4.5). For both models, a single predictor (not both variables) best explained the variance in ASPCT. MRT was removed from both RT and Accuracy models for not meeting the criterion of $p > .1$ leaving VSPT as the best predictor of the model (RT Model 2 and Accuracy Model 2, Table 4.5). When both predictors were included in the model, neither significantly predicted a unique amount of the variance in ASPCT (RT Model 1 and Accuracy Model 1 in Table 4.5).

We additionally examined whether there was a relationship between performance on the perspective-taking tasks and perspective-dependent responses on the ASPCT and ASL-SRT assessments. In the ASPCT test, selection of the 180° response foil for the Signer Space condition indicated failure to adopt the signer's perspective. In the ASL-SRT, the number of Mirrored productions indicated failure to adopt the signer's perspective, while Reversed productions indicated that the participant had adopted signer's perspective. Correlations are presented in Table 4.6.

With respect to VSPT accuracy, the number of times individuals selected the ASPCT 180° foil (Signer Space) was significantly related to their accuracy on the nonlinguistic perspective-taking VSPT task. Participants with more 180° ASPCT errors tended to achieve lower VSPT accuracy. The number of Reversed items from the ASL-SRT assessment (indicating that the producer had adopted the signer's perspective) significantly correlated with accuracy on the ASPCT assessment – individuals who were more likely to adopt the signer's perspective in the ASL-SRT were also better at adopting the signer's perspective in the ASPCT assessment. Similarly, the number of 180° ASPCT errors significantly correlated with accuracy on the ASL-SRT assessment – individuals who made more 180° errors on the linguistic perspective-taking task (ASPCT) achieved lower accuracies on the ASL proficiency measure (ASL-SRT).

Table 4.6. Correlation Coefficients for Perspective-Dependent Responses on Spatial and Perspective-Taking Tasks.

	1	2	3	4	5	6	7
1. VSPT Accuracy							
2. ASPCT Accuracy	.47**						
3. ASL-SRT Accuracy	.29	.50**					
4. Number Mirrored Items	-.20	-.33‡	-.004				
5. Number Reversed Items	.28	.40*	.23	.92***			
6. Number ASPCT 180° Errors	-.48**	-.75***	-.50**	.15	-.22		
7. MRT	.62***	.45**	.38*	.08	.02	.45**	

*p<.05, **p<.01, ***p<.001, ‡p<.10
Note: ASL Spatial Perspective Comprehension Test (ASPCT); Visual-Spatial Perspective-Taking (VSPT); Mental Rotation Test (MRT); ASL-Sentence Reproduction Test (ASL-SRT)

In order to better understand what underlying cognitive abilities best explain the variance in perspective-dependent errors within the ASPCT assessment (i.e. 180° errors), a backwards linear regression was run including ASL-SRT accuracy (i.e., general ASL proficiency), VSPT accuracy (nonlinguistic perspective-taking ability), and mental rotation ability (see Table 4.7). ASL-SRT and VSPT accuracies explained a significant amount of the variance in linguistic perspective errors; however, mental rotation accuracy did not (t = -0.679, p = .503).

Table 4.7. Linear Regression for ASPCT 180° Perspective Errors.

	Unstandardized Coefficients		Standardized Coefficients		
Predictors	β	*SE*	β	*t*	*p*
Constant	20.9	3.96		5.27	<.001
ASL-SRT Accuracy	-12.6	4.82	-0.395	-2.62	.014*
VSPT Average Accuracy	-10.4	4.26	-0.368	-2.44	.021*

*p < .05

4.5. Discussion

The current study examined the relationship between deaf signers' performance on an ASL linguistic visual-spatial perspective-taking comprehension task (ASPCT), a nonlinguistic visual-spatial perspective-taking (VSPT) task, a mental rotation task, and an ASL proficiency test (ASL-SRT). We found a significant correlation between nonlinguistic VSPT performance and linguistic perspective-taking performance in both RT and accuracy for adult deaf signers. This finding suggests that similar underlying cognitive abilities support perspective-taking within linguistic and nonlinguistic domains for neurotypical signing adults, similar to what has been suggested by Quinto-Pozos et al. (2013) during sign language development. Quinto-Pozo et al. hypothesized that a specific visual-spatial perspective-taking deficit might interfere with acquisition of ASL structures that depend on perspective-taking to comprehend and produce (i.e., spatial classifier constructions). Our findings support their hypothesis by demonstrating a significant relationship between nonlinguistic and linguistic perspective-taking ability for neurotypical adult signers.

Additionally, mental rotation ability was significantly related to both ASPCT and VSPT performance, suggesting that mental rotation skills also support perspective-taking in both linguistic and nonlinguistic domains. Therefore, mental rotation and nonlinguistic perspective-taking abilities both seem to play a role in the ability to adopt the signer's perspective. However, evidence from the linear regression analyses suggested that VSPT performance (both accuracy and RT) predicts ASPCT performance better than MRT because in both cases MRT was excluded for not meeting inclusionary criteria when both predictors were fed into the model. The backward regression analysis eliminates each variable that does not predict a significant amount of the variance in the dependent variable (performance on ASPCT) in a stepwise fashion, evaluating the remaining variables after each elimination, until only significant predictors remain. These findings are consistent with recent findings from native deaf signing children who have Autism Spectrum Disorder (ASD; Shield et al., 2016). Shield et al. found that linguistic and nonlinguistic abilities were impaired for the signing children with ASD but mental rotation abilities were intact. Thus, for neurotypical adult signers and atypical signing children with ASD, mental rotation ability seems to be less related than VSPT ability for comprehension of ASL perspective-dependent structures.

ASL proficiency (ASL-SRT accuracy) was significantly related to ASPCT accuracy (and not VSPT accuracy) suggesting an additional language component is also required for success on the ASPCT assessment. This result is not surprising given that the ASPCT is a language task. In sum, results from the correlational and regression analyses suggest that the ability to adopt the signer's perspective in order to comprehend perspective-dependent sign structures (e.g., spatial classifier descriptions) seems to involve: overall ASL abilities, nonlinguistic perspective-taking abilities, and to a lesser extent nonlinguistic mental rotation abilities.

Because gender affected the accuracy on the VSPT task (males outperformed females), correlations between VSPT accuracy and ASPCT accuracy were examined separately for each gender. The results indicated that the relationship between perspective-taking and mental rotation tasks was significant for females and not males. This different relationship between linguistic and nonlinguistic perspective-taking between the genders is likely due to differences in nonlinguistic spatial abilities, because males and females did not differ on overall ASL abilities. Decreased nonlinguistic spatial abilities (i.e., females were significantly worse than males on both the MRT and VSPT tasks) may have imposed a limitation on female participants' success with the linguistic perspective-taking task (i.e., ASPCT). Such a relationship would indicate that nonlinguistic VSPT competence may be required for the perspective-taking necessary for comprehension of topographic space, as Quinto-Pozos et al. (2013) suggested. Because the male group had sufficient levels of nonlinguistic spatial and perspective ability, they did not experience a similar bottleneck from nonlinguistic abilities and thus did not show a relationship between VSPT and ASPCT accuracy.

A difference in nonlinguistic mental rotation and perspective-taking abilities, but not in signed language abilities, is consistent with the results of Emmorey et al. (1998). This study tested signers' memory for object location and orientation when the spatial information was conveyed via ASL descriptions or nonlinguistic images of the objects. Emmorey et al. (1998) manipulated whether the description required 180° transformation of the space when participants recreated the scenes or were simply recreated from their own perspective of the linguistic or nonlinguistic stimuli. Emmorey et al. found that signing males were more accurate than signing females when recreating the object's location in a nonlinguistic visual scene when mental rotation was required, but there was no difference between genders under conditions of rotation when the scene was established using ASL. Therefore, consistent with their findings, we also showed that males outperform females in nonlinguistic mental rotation and perspective-taking tasks (VSPT task) but not in linguistic perspective-taking tasks (i.e., there was no difference between the genders for ASPCT). The fact that a significant correlation was only observed for females suggests that limitations in nonlinguistic spatial or perspective-taking ability may interfere with success on the linguistic perspective-taking task. Future work should include males who struggle with the VSPT task to examine whether limited nonlinguistic VSPT abilities (and not another confounding variable associated with gender) explain why the correlation was found only for the females in this sample.

Evidence from analyzing the pattern of Mirror/Reversed items from the ASL-SRT suggests that individuals who tend to reverse productions (i.e., adopt the signer's perspective, which is consistent with ASL convention for interpreting Signer Space) also tend to be better at adopting the signer's perspective when comprehending ASL spatial descriptions using classifiers. Similarly, individuals who were more likely to make perspective-dependent errors when comprehending ASL classifier constructions were also more likely to make errors on the nonlinguistic perspective-taking task and the ASL-SRT proficiency assessment. The linear regression analysis results indicated that nonlinguistic perspective-taking ability and overall ASL proficiency (but not mental rotation ability) significantly explained the variance in number of perspective-dependent errors during the ASPCT task. Therefore, comprehending perspective-dependent constructions within ASL seems to involve both nonlinguistic perspective-taking ability (as measured by the VSPT task) and overall ASL ability (as measured by the ASL-SRT task).

Further, evidence from the developmental literature suggests that hearing nonsigning children's ability to perform VSPT tasks is mastered chronologically before ASL-signing children have achieved mastery of spatial classifier constructions (e.g., VSPT: Flavell, Everett, Croft, & Flavell, 1981; Masangkay et al. 1974; ASL classifiers: Schick, 1990; Slobin et al., 2003). For hearing children Masangkay et al. (1974) suggested that simple visual perspective-taking abilities (e.g., knowing whether or not another person can see an object) are mastered by 3-3 ½ years of age, while the more complicated process of knowing how a scene appears differently from different vantage points is mastered by 5 years of age. Although VSPT development has not been explicitly described for deaf signing children, there is no evidence to suggest they would have a different developmental trajectory than hearing speaking children on this nonlinguistic, spatial ability. With respect to the timeline for acquiring classifier constructions, deaf signing children do not produce classifiers depicting location (including viewpoint-dependent types of classifier constructions) with greater than 70% accuracy until 7-8 years old (Schick, 1990). For classifiers depicting location, Schick found that children produced handling classifiers (e.g., to show how an object would be held – a 'C' handshape for a thick cylinder) more accurately than size and shape classifiers (e.g., stative-description information – a '1' handshape to depict a long thin object). Children produced Class type classifiers (e.g., to depict a standing figure or a vehicle) with significantly less accuracy than both handling and size and shape classifiers. However, deaf signing children did not achieve mastery of the more complex location classifiers (which would include productions that are dependent upon perspective) until well after 5 years of age at which point deaf signing children would be expected to have acquired Level 2 VSPT abilities based on evidence from hearing nonsigning children.

Therefore, converging evidence suggests that intact visual-spatial perspective-taking abilities are necessary for success on the perspective-dependent classifier constructions in ASL. Other cognitive abilities may also play a role in the ability to adopt the signer's perspective, such as inhibitory control (e.g., Pyers et al., 2015; Secora et al., submitted). For example, Samson, Apperly, Kathirgamanathan, and Humphreys (2005) presented a case study involving an individual with damage to brain areas involved in inhibitory control. The patient was unable to respond in accordance with another's perspective if it required him to ignore his own perspective, but he could still calculate another's perspective if he did not simultaneously hold a conflicting perspective. Similarly, Qureshi, Apperly, and Samson (2010) found that inhibitory control was involved in the ability to select another's perspective (i.e., inhibiting one's own perspective) but was not required for sensitivity to another's perspective for neurotypical adults. Because nonlinguistic VSPT abilities seem to underlie, at least in part, the ability to adopt the signer's perspective, inhibitory control may also be involved in the ability to ignore one's own perspective of the signer's hands in order to interpret productions from the signer's perspective, as suggested for hearing gesturers (Secora et al., submitted). Additional work is necessary to determine whether inhibitory control plays a similar role in linguistic as nonlinguistic VSPT abilities for deaf signers.

Although social abilities have been shown to relate to nonlinguistic VSPT task performance for hearing nonsigners (e.g., Clements-Stephens et al., 2013; Gronholm, Flynn, Edmonds, & Gardner, 2012; Shelton et al., 2012), the role of social abilities during linguistic perspective-taking tasks has not been investigated. While Secora and Emmorey (2016) found that deaf signers appear to utilize a nonsocial, perceptual approach to nonlinguistic VSPT tasks, social abilities may play more of a role when directly communicating with another signer than for nonlinguistic VSPT tasks. Future work should examine whether a signer's social abilities are associated with how well they are able to perform the perspective transformation for comprehending from the signer's perspective. If this perspective transformation involves an embodied strategy to adopt the signer's visual-spatial perspective, an individual's ability to comprehend perspective-dependent ASL structures should correlate with his or her social or empathic personality traits as Gronholm et al. (2012) showed for embodied strategies in nonlinguistic perspective-taking tasks. Alternatively, addressees could make use of strategies less reliant on social abilities for the linguistic perspective transformation, similar to the nonsocial or visual strategies that Secora and Emmorey (2016) suggested for signers on nonlinguistic VSPT tasks.

Language expressed in the visuospatial modality adds a layer of complexity not found in spoken languages that arises from conflicting visual perspectives of the signer's articulators. Results from the current study suggest that nonlinguistic VSPT abilities support the ability to comprehend perspective-dependent spatial descriptions. Because of the visuospatial modality, successful perspective-taking within a signed exchange may involve other cognitive abilities than those required for comprehension of similar spatial descriptions in spoken language (e.g., inhibitory control, social abilities). The examination of modality effects in signed languages helps to illuminate the relationship between language and spatial cognition, and contributes to the broader understanding of these two fundamental human cognitive abilities.

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Chapter 4, in part, is currently being prepared for submission for publication of the material. Secora, Kristen; Emmorey, Karen. The dissertation author was the primary investigator and author of these materials.

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CHAPTER 5: GENERAL DISCUSSION

The main aim of this dissertation was to identify the cognitive processes involved in reconciling the different visual perspectives of signed productions that signers and addressees experience as a result of the visuospatial modality of sign languages. Additionally, this dissertation investigated how experience with ASL may affect nonlinguistic visual-spatial perspective-taking (VSPT) abilities for deaf signers. In this final chapter, I return to the questions raised in the introduction (Chapter 1) and summarize how the studies in this dissertation answered those questions. Next, possible applications of this research to education and clinical practice are suggested, and finally, outstanding questions are presented to guide future research directions.

5.1. What cognitive abilities support comprehension and production of perspective-dependent structures in ASL?

Study 1 examined whether differing inhibitory control (IC) demands for producing versus comprehending from non-egocentric perspectives may have driven many unrelated sign languages to adopt the same perspective convention (i.e., producing egocentrically and comprehending non-egocentrically). Results from Study 1 indicated that an individual's IC is related to their ability to comprehend gestured descriptions from a non-egocentric perspective (i.e., from the gesturer's perspective) but not to produce the gestures from a non-egocentric perspective. However, producing and comprehending gestured descriptions from a non-egocentric perspective were both more difficult than producing and comprehending these spatial descriptions from an egocentric perspective. Rather than a straightforward consequence of IC abilities, the language convention may reflect the fact that the conventionalized perspective alignment reflects the *least collaborative effort* for exchanges in the visuospatial modality (Clark & Wilkes-Gibbs, 1986). Therefore, from a language evolution perspective, an individual's IC ability is likely to be one of several influencing factors that contributed to establishing the existing perspective convention for ASL and other sign languages.

Study 3 further examined whether signers' nonlinguistic spatial abilities were related to their ability to perform the spatial transformation for comprehension of perspective-dependent ASL descriptions. The results showed that for deaf signers, individual nonlinguistic VSPT and, to a lesser extent, mental rotation abilities were related to the ability to comprehend perspective-dependent ASL structures (e.g., spatial classifier constructions), particularly for female signers. Individuals with weaker nonlinguistic VSPT abilities tended to have worse performance on a perspective-dependent classifier construction test (ASPCT: ASL Spatial Perspective Comprehension Test). These results support Quinto-Pozos et al.'s (2013) hypothesis that nonlinguistic VSPT abilities may be required for acquiring specific perspective-dependent structures within ASL, and the results extend this hypothesis to include neurotypical adult sign language processing. Thus, individual spatial abilities in nonlinguistic tasks, particularly VSPT, support the ability to perform the spatial, perspective transformation necessary for comprehension of perspective-dependent ASL structures.

5.2. Does experience with ASL result in differences in nonlinguistic VSPT abilities?

While sign language experience has been shown to result in enhanced performance on select nonlinguistic spatial tasks (e.g., Emmorey, Kosslyn, & Bellugi, 1993; Emmorey, Klima, & Hickok, 1998), Study 2 provided evidence that the performance of adult deaf signers did not differ from hearing nonsigners on nonlinguistic VSPT or mental rotation tasks. Therefore, a lifetime of experience with the spatial transformation required for comprehension of spatial perspective-dependent ASL structures does not seem to boost performance on nonlinguistic perspective-taking tasks.

Although signers did not experience an overall enhancement in VSPT performance, differences were apparent in how social abilities affected deaf signers and hearing nonsigners when performing the VSPT task. Results from Study 2 were consistent with previous reports suggesting that hearing nonsigning adults tend to adopt a social strategy for the VSPT task, particularly when a social context has been established (e.g., Clements-Stephens et al., 2013; Shelton et al., 2012). Deaf signing adults, however, seemed to rely on nonsocial, perceptual strategies for the VSPT task, which is consistent with Howley & Howe's (2004) results for deaf children. Study 2 revealed that signers with strong social abilities appeared to experience interference from their social abilities when attempting a nonsocial strategy which resulted in decreased VSPT performance. Thus, social abilities differentially affect deaf signers and hearing nonsigners during a VSPT task. Hearing nonsigners with stronger social tendencies benefited from their increased social abilities for a VSPT task, suggesting use of a social strategy. In contrast, deaf signers with weaker social tendencies performed better on a VSPT task, indicating a very different relationship between social skills and VSPT performance. Overall, the results suggest that signers prefer a nonsocial strategy for solving nonlinguistic VSPT tasks.

This reliance on a nonsocial or perceptual strategy by deaf signers (both children and adults) may arise from differences in language modality and/or cultural experiences. Visual information is important for deaf signers: their language is expressed visually and the visual modality is also a major way they access information from their environment. This tendency to rely on visual information may drive deaf signers to rely on nonsocial, perceptual strategies for VSPT tasks. Furthermore, deaf signing children have been reported to struggle when interacting socially with their typically hearing peers compared with typically hearing children communicating with other hearing children (e.g., Xie, Potměšil, & Peters, 2014; Antia, Kreimeyer, Metz, & Spolsky, 2011). Therefore, a history of difficulty interacting socially with hearing nonsigners, coupled with a potentially larger reliance on the visual modality may drive deaf signers, both children and adults, towards a preferred nonsocial, perceptual strategy on VSPT tasks.

5.3. Applications

There are a number of ways in which the results of this dissertation may affect educators and clinicians who work with deaf and hard-of-hearing signing individuals. These results have particular importance for teachers of deaf and hard-of-hearing students who use sign language. When standing in front of a class, the visual perspectives of the students and teacher conflict and may create confusion if instructions or educational content are spatial in nature. Therefore, teachers of deaf signing students need to be aware of the perspective conflict when giving spatial descriptions either via sign language or co-speech gestures for individuals who also rely on spoken language. Superficially, if the teacher produces all instructions from a non-egocentric perspective, the potential conflict appears to be alleviated. However, because signers have an established convention of comprehending from the producer's perspective, producing already reversed descriptions can lead to confusion and misunderstandings if the students adopt the instructor's perspective.

Additionally, instructors should be aware of the added cognitive burden that arises from reconciling conflicting visual perspectives. For example, a relatively simple instruction in English such as "Put your name at the top right of the paper" requires additional cognitive resources to comprehend if produced topographically in ASL. Comprehenders need to recruit inhibitory control in order to ignore the perceived location of the hands and also need to adopt the signer's perspective via spatial transformation processes (i.e., VSPT, mental rotation). Thus, in order to maximize cognitive resources for the educationally relevant aspects of this instruction, teachers should minimize the resources necessary for resolving the visual perspective conflict. Perspective-based misunderstandings can be solved in a number of ways. For example, explicit descriptions of which perspective is being adopted would clarify the perspective conflict. Additionally, instructors could align their perspective with that of their students (e.g., by facing the same way as the students), or alternatively, instructors could rely more heavily on perspective-independent unambiguous representations (e.g., pictorial representations).

In addition to teachers of deaf signing children, issues of conflicting visual perspectives are also relevant for teachers of ASL as a second language. ASL teachers need to be aware of the different conventions for spoken language and signed language with respect to perspective-dependent structures and explicitly teach the convention to sign language learners. Additionally, ASL teachers may feel that the convention is natural and does not require additional cognitive resources, particularly if they are early or native signers. However, they should be aware of the fact that their students do not share their extensive experience with this spatial transformation and thus may find these structures particularly challenging. Similar instructional methods that reduce perspective conflict (e.g., turning to face the same direction as the students) may be helpful in alleviating the student's cognitive demands allowing them to achieve more success during the early stages of ASL acquisition.

Clinically, a basic competency with visuospatial skills seems to be required for success with comprehension of perspective-dependent structures in ASL. Therefore, instruction and practice with nonlinguistic perspective-taking may improve performance on viewpoint-dependent ASL structures that seem to depend on these skills. Such practice can be implemented with individuals who have a general visuospatial deficit or a difficulty specifically with perspective-taking task. Additionally, all children who are acquiring ASL may benefit from establishing a solid nonlinguistic VSPT foundation before acquisition of the more difficult perspective-dependent structures in ASL. Several possible platforms for implementation of this therapeutic practice include videogames or applications for mobile devices (e.g., the types of stimuli used by Lambrey et al., 2008 for VSPT, or Wang, Ali, Frisson, & Apperly, 2015, for perspective-taking in a shielded communication task). In these fun interactive scenarios, children would achieve extra practice inhibiting their own visual perspective of a scene in order to interpret the visual perspectives of others.

Furthermore, these results are particularly applicable for signing children who have ASD. Although research is just beginning to investigate this clinical population, it is already apparent that deaf signing children with autism struggle with Level 2 VSPT tasks as well as the ASL structures that seems to depend on VSPT abilities (e.g., Shield & Meier, 2012; Shield et al., 2016). In designing therapy with deaf signing children who have ASD, it is critical to consider the potential for added cognitive burdens that arise from the conflicting visual perspectives experienced by each interlocutor. Minimizing these burdens (e.g., by sitting side by side during therapy) as well as explicitly teaching strategies for resolving this perspective conflict are critical steps in creating successful therapy programs for these children.

5.4. Future Directions

Further work needs to be done to identify the nature of the transformation involved in adopting the signer's perspective. This dissertation provides evidence that inhibitory control (IC) abilities are related to nonsigners' ability to comprehend from a non-egocentric perspective. However, whether IC abilities play a role for deaf signers who are experienced in the perspective-taking convention of ASL remains to be seen. If a simultaneous IC task disproportionally disrupts signer's ability to comprehend perspective-dependent structures (as Qureshi et al., 2010, showed for nonlinguistic VSPT tasks), such findings would suggest that IC abilities play an important role in ignoring one's own visual perspective to select that of the signer. Alternatively, signers report instantaneously comprehending from the signer's perspective rather than through a process involving mental rotation (Emmorey et al., 1998). This instantaneous comprehension from the signer's perspective could be parallel to the automatic calculation Surtees and colleagues report for certain nonlinguistic VSPT tasks which are not dependent upon executive control functions (e.g., Surtees & Apperly, 2012; Surtees, Samson, & Apperly, 2016).

Further work should also examine the processes involved in producing gestured or signed descriptions from a non-egocentric perspective. Some evidence from Pyers et al. (2015) suggested that producing from a non-egocentric perspective may be more difficult than perceiving from a non-egocentric perspective; however, evidence from Study 1 of this dissertation suggested that there may be no difference in the cognitive requirements for producing and perceiving from non-egocentric perspectives. Nevertheless, a follow-up study to Study 1 found that sign-naïve gesturers consistently reported producing from a non-egocentric perspective feels more difficult than comprehending from a non-egocentric perspective.

In this ongoing follow up study, pairs of nonsigning, monolingual English speakers performed a similar gesture production and comprehension task as in Study 1 – one participant as the producer and one as the comprehender. The main difference between the follow up study and Study 1 (aside from including pairs of participants) was that the perspective conflict was explicitly described to the participants prior to performing the task. They were given practice with each perspective-alignment and were allowed to discuss and select which perspective alignment they wanted to use for the experiment. Preliminary data showed that ten out of thirteen pairs elected to produce egocentrically and comprehend from a non-egocentric (producer) perspective. Participants reported that this perspective-alignment seemed to be the easier of the two options. Since evidence from Study 1 suggested inhibitory control ability was not related to the ability to produce from a non-egocentric perspective, further work needs to examine what cognitive processes are driving this perceived feeling of increased difficulty for producing from a non-egocentric perspective. This increased difficulty for the hearing nonsigners may be due to cognitive demands involved in producing unfamiliar hand gestures on top of the perspective demands. Signers likely do not experience a similarly additive burden because the signs and classifier constructions are familiar, highlighting the need for future work to examine deaf signers' cognitive demands for resolving perspective conflicts during communicative exchanges.

While evidence presented in Study 2 suggests that signers rely on nonsocial or perceptual strategies to perform nonlinguistic VSPT tasks, it is unknown whether similar strategies are utilized for perspective-taking within linguistic contexts. Signers may rely on more social strategies when performing linguistic perspective-taking given the highly social face-to-face nature of sign language. Alternatively, evidence from Study 3 indicated that nonlinguistic and linguistic perspective-taking abilities are related for adult deaf signers suggesting that similar strategies may be employed for both linguistic and nonlinguistic VSPT tasks. Further work is needed to identify whether comprehension of perspective-dependent ASL structures involves a more social, imagined self-rotation through space or more nonsocial, perceptual strategy which may reflect signers' self-report of an instantaneous alignment with the signer's perspective. Kessler and Thomson (2010) determined that nonsigning individuals employ a strategy of mentally simulating movement through space to align with the other's perspective and that this embodied movement is sensitive to differences in the physical body position of the perspective-taker. A similar method would be able to establish whether signers utilize a similar process of imagined self-rotation through space to comprehend perspective-dependent ASL structures from the signer's perspective.

5.5. Final Conclusions

This dissertation pulls together research involving nonlinguistic VSPT, inhibitory control, and social abilities in order to examine the relationships between these abilities for deaf signers who regularly comprehend perspective-dependent ASL structures expressed in the visuospatial modality. Because of the modality, spatial abilities (e.g., VSPT, mental rotation, inhibitory control) play a crucial role in comprehending and producing viewpoint-dependent spatial descriptions in sign languages. In addition to effects of modality, differences in sociocultural environment can also affect how nonlinguistic abilities (i.e., social skills) impact performance on spatial tasks. This research highlights the importance for considerations of language modality and culture when examining spatial cognition for research and educational practice with the ultimate goal of better understanding how spatial cognition and language collaborate to facilitate successful social interactions.

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