Temporal Synchrony and the Capture of Attention in Young Children with Autism

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A dissertation submitted to the faculty of the University of North Carolina at Chapel Hill in partial fulfillment of the requirements for the degree of doctorate in philosophy in the Division of Speech and Hearing Sciences in the Department of Allied Health Sciences of the School of Medicine.

Chapel Hill
2010

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ABSTRACT

ELENA PATTEN: Temporal Synchrony and the Capture of Attention in Young Children with Autism
(Under the direction of Linda R. Watson)

In order to successfully intervene on language impairments present in autism, attention must be captured and sustained, yet little is known about features that successfully capture attention. In typically developing children, temporally synchronous presentations of information across two sensory modalities result in increased attention. This study investigated visual looking behavior of twenty-three preschool children with autism given presentations of synchronous and asynchronous linguistic stimuli paired with movement of related toys. Significant to this experiment is that the speaker's face was not present but the objects used in play were. The results indicated that children with autism attended significantly more to the synchronous presentation when off-screen looking was covaried. Also, the amount of time attending to synchrony was correlated with receptive language. Findings may suggest multisensory processing in a linguistic context may be enhanced by temporal synchrony and early multisensory impairment may be related to attention to synchrony and language development.

ACKNOWLEDGEMENTS

I would like to thank my dissertation committee for their wisdom and willingness to guide my path. I especially want to thank Linda Watson for her patience, kindness and expert mentoring. Most of all, I am grateful for Evelyn, Trevor and Charlie who became Tar Heels when they were just four years old. Thank you for always going the extra mile with me (even when it meant sitting through a stats lecture).

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Introduction

Statement of the Problem

Impairment in communication comprises one of the three core features of autism and therefore speech and language intervention is almost always warranted, whether it is to provide a basic means of expressing wants and needs or to target improvements in social language. However, unless the interventionist is able to adequately engage the child, chances for success using any communication intervention technique are limited. This poses a significant problem because the ability to share attention with a communication partner is often defective in autism (4^{th} ed., text revision; DSM-IV-TR; APA, 2000).

Atypical features of attention and unusual responses to sensory stimuli are widely acknowledged as common symptoms of autism (e.g. Dawson et al., 2004; Landry & Bryson, 2004; Paul, Chawarska, Fowler, Cicchetti & Volkmar, 2007). At early ages, separating attention and sensory responsiveness can be difficult as they often go together naturally: children demonstrate attention toward something that captures them visually, tactually, or auditorily. Logically, the ability to orient and sustain attention is important in order to facilitate learning. If early in development, children with autism are not attending to stimuli that capture and sustain the attention of typically developing children, such as a parent calling their name to engage them in a social or communicative routine, participation in learning opportunities may be diminished or altered. These differences and diminished opportunities may contribute to the difficulties with communication and socialization experienced by children with autism.

Consider one type of stimulation often directed at young children: mothers using heightened suprasegmental speech characteristics synchronously paired with exaggerated facial expressions. This type of stimulation is multisensory and requires integration of sensory input to be effectively processed. Impairments in multisensory processing have been found in autism. Thus, the overarching goal of the current research is to determine if multisensory stimuli can be enhanced to yield improvements in attention in children with autism in order to address early, pervasive deficits in communication and social development.

Attention and Sensory Processing in Autism

Young children with autism demonstrate differences in attention particularly related to attention orienting (the capture of attention) and shifting attention from one stimulus or environmental event to another (e.g. Dawson et al., 2004; Landry & Bryson, 2004; Paul et al., 2007; Swettenham et al., 1998; Zwaigenbaum et al., 2005). These aspects of attention are primarily associated with exogenous as opposed to endogenous attention. Exogenous attention requires that some sensory feature is salient enough to result in attention being directed toward that stimulus. It is exogenous attention that appears to be most impaired in autism and the features of the stimuli are critical when considering exogenous attention.

Endogenous attention is related to ongoing self-directed attention generated within the individual. Children with autism can demonstrate adequate sustained attention directed at objects (Landry & Bryson, 2004; Swettenham et al., 1998; Zwaigenbaum et al., 2005); however, it is important to note that these children show decreased sustained attention when attending to stimuli that are social in nature (people or their voices) (Dawson et al., 2004; Kuhl, Coffey-Corina, Padden & Dawson, 2005; Osterling, Dawson & Munson, 2002; Paul et al., 2007; Sigman, Kasari, Kwon & Yirmiya, 1992; Swettenham et al., 1998). Exogenous attention orienting primarily serves to initially capture attention or cause attention to shift and reorient, but it is mainly sustained attention, dependent upon endogenous, self-driven motivation, that allows the learner to benefit from the stimuli.

Difficulty with the capture of attention among children with autism may have roots in sensory hyporesponsiveness; that is, failure to demonstrate attention toward a stimulus may be due to impaired sensory processing resulting from a lack of perceived salience of the target. The majority of children with autism demonstrate unusual sensory sensitivities (e.g. Baranek, David, Poe, Stone & Watson, 2006; Tomchek & Dunn, 2007), and these differences have been observed from infancy through adulthood (Baranek, 1999; Crane, Goddard, & Pring, 2009. Sensory differences in hyporesponsiveness, hyperresponsiveness and sensory seeking characteristics all have been found early in autism, but it is sensory hyporesponsiveness, or a diminished responsiveness to sensory stimuli, that is a distinguishing feature of autism (e.g. Baranek et al., 2006). Hyporesponsiveness is evidenced behaviorally in poor attention orienting. A child who does not orient to stimuli will not have the opportunity to process information associated with those sensory stimuli, including linguistic and social information. A factor that impacts both attention and sensory processing is the social versus nonsocial context of the stimuli. For children with autism, both attention and sensory responsiveness appear to be more atypical in social compared to nonsocial contexts (e.g. Baranek et al., 2006; Kuhl et al., 2005). This feature yields an even more complex problem when attempting to intervene on communication development, as communication, particularly in young children, is social in nature.

To date, strategies that facilitate increasing salience of targets in order to improve attention are scarce (Patten & Watson, in press). A few strategies, such as labeling objects or pointing and giving a verbal cue, have been found to increase the salience of the target and result in better attention and more typical responses toward target stimuli (Leekam, Hunnisett & Moore, 1998; Yoder & Stone, 2006).

Multisensory Processing and Temporal Synchrony

In typical development, salience of a target is increased by multisensory stimulation, such as seeing and hearing the same event. Further, multisensory stimulation is related to improvements in attention and learning (Gogate & Bahrick, 1998; Gogate, Bolzani & Betancourt, 2006). A further boost in salience occurs if the multisensory information is produced with temporal synchrony, which is a form of multisensory stimulation that delivers information simultaneously over two senses. The impact of temporal synchrony in typical development has been well studied. First, awareness of temporal synchrony occurs in infancy and draws attention to salient aspects of the environment (Bahrick, 1987; Bahrick & Lickliter, 2000; Bahrick & Pickens, 1994). The importance of this phenomenon is clear in that infants are being drawn to engage in important communication and social events and those interactions set the trajectory for early learning.

Mothers naturally use a great deal of synchronous multisensory communication directed at their infants in the form of movement or touching paired with words or sounds (Gogate, Bahrick, & Watson, 2000). Importantly, mothers who use more temporal synchrony have infants who demonstrate more attention to targets, show better learning of new words, and engage in more joint attention with their mothers (Gogate et al., 2000). The value of joint attention cannot be understated given that longitudinal studies demonstrate joint attention is predictive of later language skills in typically developing children (Mundy & Gomes, 1998; Morales, Mundy & Rojas, 1998) and impaired in many young children with autism (Charman et al., 1997, Leekam, Lopez, & Moore, 2000; McArthur & Adamson, 1996). Perhaps multimodal stimulation in the form of temporal synchrony could improve joint attention and subsequent language, communication and socialization for children with autism. Before benefits of temporal synchrony can be realized, the child must be able to detect and discriminate synchrony and then choose to attend to the synchrony. This naturally occurs in typically developing children, and mothers' use of temporal synchrony is high when children are six to eight months (76%), when children likely benefit the most from synchrony, but then decreases as the child ages (36% when children are 21-30 months).

Multisensory processing or intersensory processing in children with autism is not well understood at this time. Evidence mainly supports the notion that multisensory processing is impaired in children with autism, but evidence of the opposite has been found as well. For example, anecdotal evidence suggests multisensory processing is impaired in autism (Cesaroni & Garber 1991; Iarocci & McDonald, 2006), and Kern et al. (2007) found multisensory processing to be impaired in people with autism based on self or parent reports; yet, evidence exists that children with autism show better learning in multisensory learning environments such as a total communication paradigm as opposed to using only a single modality such as gestures alone or spoken language alone (Barrera, Lobato-Barrera & Sulzer-Azaroff, 1980). Further, the two techniques mentioned above to enhance the capture of attention (labeling a seen object and pairing a gesture with the word "look") resulted in improvements in attention and are multisensory in nature (Leekam, Hunnisett & Moore, 1998; Yoder & Stone, 2006).

Regarding the impact of temporal synchrony on children with autism, findings are limited and inconsistent. One study found that children with autism lack awareness of temporal synchrony in both linguistic and nonlinguistic contexts (Bahrick, Todd, Valiant-Molina, Sorondo, & Ronacher, 2010); another study showed deficits related to linguistic contexts but not with non-human stimuli such as objects and related sounds (Bebko, Weiss, Denmark, & Gomez, 2006), and still another study indicated detection and discrimination of temporal synchrony in a linguistic context (Klin, Lin, Gorrindo, Ramsay, & Jones, 2009). Understanding the impact of temporal synchrony on the attention of children with autism to linguistic stimuli is arguably more critical than the impact of temporal synchrony on their attention to non-linguistic stimuli for two reasons. First, children with autism already attend to objects more than to people in behavioral studies (e.g. Swettenham et al., 1998); further, electrophysiological studies demonstrate more typical processing of objects and atypical processing of faces (e.g. Dawson et al., 2002). A bias toward orienting attention toward nonsocial stimuli rather than social stimuli has been reported as early as six months of age in children later diagnosed with autism (Maestro et al., 2002). Second, because it is the social and communication skills that are ultimately impaired in autism, enhancing attention toward linguistic information is critical.

The studies that found temporal synchrony did not influence the attention of children with autism to linguistic stimuli featured headshot videos of an actor talking as the stimuli (Bahrick et al., 2010; Bebko et al., 2006); no objects or referents were present. The ecological validity of these studies is certainly questionable given that communication toward young children usually features tangible referents. Further, joint attention, which has been shown to be impaired in children with autism (Charman et al., 1997; Leekam et al., 2000; McArthur & Adamson, 1996), can only occur given the presence of a speaker and a referent by definition. Perhaps benefits from temporal synchrony related to linguistic stimuli can be realized without forcing the attention of children with autism to a speaker's face but to objects instead. This might be a more plausible scenario for children with autism given the natural propensity for children with autism to attend to objects (Sigman et al., 1992; Swettenham et al., 1998) and to demonstrate difficulties in face processing (e.g. Dawson, Webb, & McPartland, 2005; Webb, Dawson, Bernier, & Panagiotides, 2006). It is also important to note that even though children with autism tend to attend more to objects, they erroneously map linguistic referents based upon their own visual locus of attention significantly more than typically developing children or children with other developmental disabilities (Baron-Cohen, Baldwin, & Crowson, 1997). So, ensuring that the important objects (i.e. referents of communication) are salient enough to capture attention is critically important. Also, visual attention to the correct referent while linguistic information is being produced is imperative, regardless of whether or not visual attention goes to the speaker's face. For example, linguistic mapping likely can occur if a child is looking at a puppy while hearing "puppy," but may not occur if the child is looking only at the speaker's face while hearing "puppy".

It may be that children with autism are poorer at multisensory processing and at recognizing temporal synchrony than their typical peers, but that they still benefit from temporally synchronized multisensory presentation over input in a single modality alone. Or, it could be that the benefit of temporal synchrony is not realized until later than in typical development for children with autism, and because of the child's older chronological age, caregivers have stopped using multisensory communication naturally. In this latter scenario, children with autism would not have access to additive benefits of temporal synchrony at the optimal point in their development. Whatever the case, we do not currently know with certainty whether children with autism benefit from temporally synchronous multisensory stimuli or even show awareness of multisensory stimuli, particularly in linguistic contexts. A first step in determining the benefits of multisensory stimulation is to determine if children with autism can detect, discriminate and choose to differentially attend to temporal synchrony in a linguistic context.

Atypical Neural Connectivity in Autism

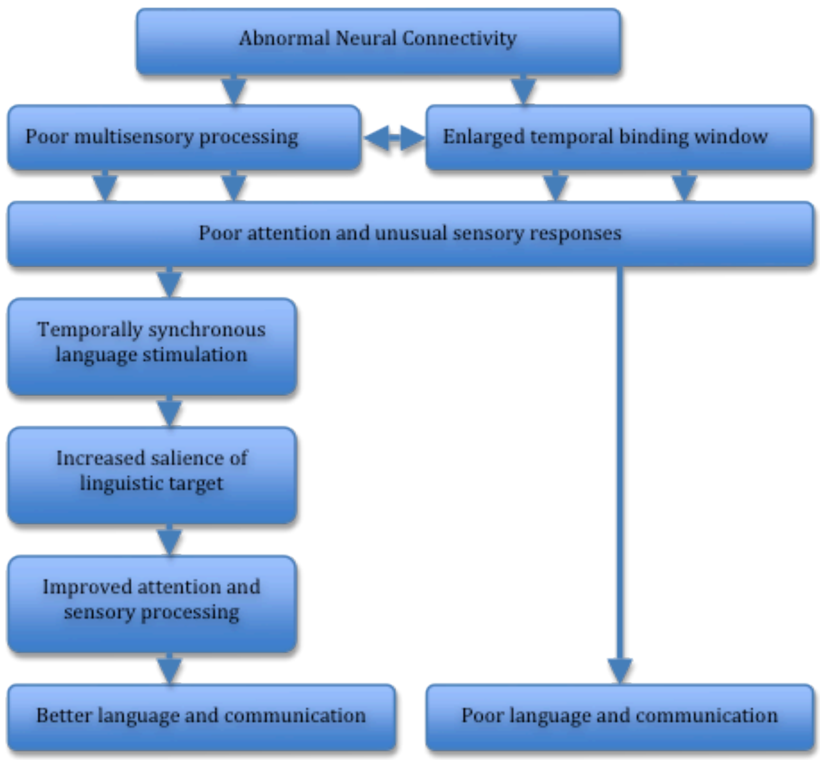
The temporal binding theory (Brock, Brown, Boucher, & Rippon, 2002; Rippon, Brock, Brown, & Boucher, 2007) and the temporo-spatial processing disorder hypothesis (TSPD) (Gepner & Feron, 2009) may shed light on underlying mechanisms related to atypical attention, sensory processing and responses to temporal synchrony. Proponents of both models argue that autism is associated with abnormalities in information integration and multisensory synchronization that is caused by impairments in neural connectivity. Behavioral, structural, and functional evidence exists in support of theories of aberrant neural connectivity in autistic brains. Abnormal development could logically result from atypical neural connectivity, including significant deficits in attention, sensory processing, cognitive functioning, and overall participation in everyday living.

One measure related to multisensory temporal function is the temporal binding window, which is a period of time during which two stimuli are bound as a single perceptual entity. Typically developing school-aged children and adolescents have a temporal binding window of approximately 150 milliseconds compared to a 300 millisecond window in age-matched children and adolescents with autism (Foss-Feig et al., 2010). This extended window may allow too many unrelated stimuli to be processed and lead to misalignment and mismatching of sensory stimuli, particularly highly complex stimuli such as communication. The result would be a dysfunctional and confusing representation of one's environment. It might be the case that an extended temporal binding window in infants with autism yields significant early multisensory binding deficits and ultimately impacts development, producing symptoms commonly associated with autism. If this is the case, the degree of atypical response to temporal synchrony may be correlated with social and communication symptoms of autism.

Conceptual Model

This conceptual model proposes that poor attention and unusual sensory responses to environmental stimuli lead to impairment in language and communication presented in autism. However, temporally synchronous language stimulation can mediate the relationship of attention and sensory responsiveness to language and communication outcomes by increasing the salience of linguistic targets. This in turn would yield improvements in attention and sensory processing. Ultimately, language and communication would improve due to the improved engagement in linguistic interaction (see Figure 1.1).

Figure 1.1: Conceptual Model



Underlying attention and sensory deficits is abnormal neural connectivity, which impacts multisensory processing. This in turn is linked to an enlarged temporal binding window, which may have developed as a compensatory mechanism to allow additional time for correct stimuli to be bound (Foss-Feig et al., 2010), but enlargements in the window could further negatively impact multisensory processing by decreasing accurate binding of related stimuli. This larger temporal binding window negatively impacts the ability to detect, discriminate and attend to temporal synchrony. However, this is not to say that temporal synchrony can never be detected under any circumstance. If temporal synchrony were performed in an ideal manner (exaggerated and without faces present), salience of the linguistic content would be heightened to the extent that attention would be captured and sustained.

Summary

Interventions targeting communication are nearly universal in the treatment of autism; however, problematic attention and sensory responsiveness create a roadblock to the social and communicative engagement required for successful participation in treatment. Multisensory processing of social stimuli is a critical component of early communicative interaction and has been found to be particularly impaired in autism. However, at least some evidence exists that multisensory stimulation may still be beneficial over unimodal input in language intervention.

Stimuli presented in a temporally synchronous manner naturally and significantly draw the attention of typically developing children and are linked to social and linguistic development. However, the impact of temporal synchrony on the attention of children with autism, particularly in a linguistic context, is poorly understood. If it were discovered that children with autism could detect, discriminate and differentially attend to temporal synchrony between objects and spoken words, they may receive the benefits of temporal synchrony similar to typically developing children and interventions could be modified to include temporal synchrony during social and communicative interactions. For example, caregivers and interventionist could move objects in synchrony with labels. Further, such a simple modification could be accomplished by any caregiver with little training or associated cost. Because such an intervention is simple and occurs naturally for caregivers of typically developing infants, it is expected that it would be well received by caregivers and interventionists. This intervention could be implemented with very young children who are at-risk for a later diagnosis of autism or with young children who already have a diagnosis. If attention to meaningful communication and social interactions can be enhanced early in development, this could lead to long-term improvements including better social and communication skills. In addition, determining if a relationship exists between responsiveness to temporal synchrony and language development could add to the knowledge base of the impact of early multisensory processing on development in children with autism.

Research Questions

The overarching goal of this research is to determine if multisensory processing can be enhanced in children with autism in order to improve attention to social and linguistic stimuli. The purpose of this study is to determine if temporal synchrony of spoken words with moving objects will result in detection, discrimination and attention to temporal synchrony versus asynchrony. The specific questions are:

1. Do children with autism demonstrate attention toward temporally synchronous audio-visual linguistic stimuli presented without faces?
2. To what extent is the amount of attention to synchrony related to children's receptive language?

The central hypothesis is that children with autism will demonstrate a preference for temporal synchrony in a linguistic context without faces present, but that the amount of attention to synchrony will be related to receptive language skills.

CHAPTER 2

Review of the Literature

Overview of Chapter

Impairments in communication are universal in the diagnosis of autism; however, children demonstrate a wide range of skills with some experiencing a complete lack of verbal communication while others persist with more mild pragmatic language deficits (Tager-Flusberg, Joseph, & Folstein, 2001). Interventions targeting communication range from relationship-based interventions to more prescriptive behavioral interventions, but the need to draw the attention of the child to linguistic content for interactive engagement is imperative.

Difficulty with attention and joint engagement are common in autism. Abnormalities in attention occur early in life and difficulty with attention has been implicated as a significant contribution to the developmental sequelae that result in the triad of core features of autism (e.g. Mundy & Neal, 2001; Swettenham et al., 1998). Abnormalities in sensory processing are also a commonly acknowledged feature of autism in children as well as adults (e.g. Baranek et al., 2006; Liss, Laulnier, Fein & Kinsbourne, 2006; Tomcheck & Dunn, 2007), and in childhood and possibly beyond, attention to stimuli and sensory responses to stimuli are difficult constructs to separate. Diminished attention to social stimuli, including communicative stimuli, can be observed in infants who eventually receive a diagnosis of autism (e.g. Baranek, 1999; Watling, Deitz & White, 2001). It stands to reason that if an infant does not adequately attend to pertinent stimuli in his or her environment, important learning and socialization opportunities will be missed. Furthermore, a great deal of learning in infancy and early childhood is directly related to communication and socialization, which are two of the three features that are universally impaired in autism.

Temporal synchrony is a means of multisensory stimulation that draws the attention of typically developing children and may be linked to development of linguistic and social processing. Diminished responses to temporal synchrony and atypical multisensory processing have been found in autism; however, this is not to say that multisensory stimulation is not at all beneficial. Perhaps, multisensory stimulation in the form of temporal synchrony can result in detection, discrimination and attention toward pertinent stimuli, although not to the extent that it occurs in typically developing children. If this is the case, some benefit of temporal synchrony may be realized.

The goal of this review is to describe how the presence of temporal synchrony may affect attention in autism. To accomplish this, features of communication development, attention and sensory responsiveness in young children with autism will be described, highlighting the importance of social and nonsocial contexts. Temporal synchrony will also be described relative to its importance in typical development – particularly regarding lexical development. The limited body of research related to temporal synchrony and autism will be presented as well. This present research aims to assess the impact of temporal synchrony in a linguistic context on the attention of children with autism, with the idea that if children with autism detect, discriminate and differentially attend to temporal synchrony, then perhaps these children may receive the benefits of synchrony similarly to typically developing children.

Wrapping up the review, theories of atypical neural connectivity will be presented as a possible explanation for impaired multisensory processing and related to temporal synchrony, attention and sensory responsiveness. The temporal binding window will be explained as related to multisensory processing and its impact on responses to temporal synchrony. Emphasis will be placed on the potential for impaired communication resulting from early impairments in multisensory processing as well as an unusual temporal binding window.

Communication Symptoms in Autism

Given the pervasive nature of communication deficits in autism, language intervention is almost always required. On average, preschoolers with autism tend to have more severe receptive and expressive language delays than children with other developmental delays (Luyster, Kadlec, Carter, & Tager-Flusberg, 2008), and approximately 50% fail to acquire speech adequate for normal communication (i.e. language age equivalents below 30 months) by adolescence and adulthood (Sigman & McGovern, 2005). Deficits in pragmatic language continue to persist, even when children with autism do develop spoken language (Tager-Flusberg et al., 2001). Pragmatic deficits can involve unusual eye-gaze and difficulty in using and interpreting nonverbal cues such as facial expressions and tone of voice, representing a crossroad between social skills and communication.

As mentioned earlier, social and communication symptoms in autism are difficult to separate in early childhood and are consequently combined into a single construct in research (e.g. Frazier, Youngstrom, Kubu, Sinclair, & Rezai, 2008; Georgiades et al., 2007; Gotham, Risi, Pickles & Lord, 2007; Snow, Lecavalier & Houts, 2009). Children with autism demonstrate fewer gaze shifts and have more difficulty following others' foci of attention (Leekam et al., 1998; Swettenham et al., 1998), which are critical components of joint attention. Joint attention is arguably the most important feature of early social-communication in autism and refers to the coordination of visual attention between communication partners and a third person or object. In typical development, joint attention skills emerge during the first year of life and enable children to be active social communication partners and learn from their caregivers (e.g. Carpenter, Nagell, & Tomasello, 1998; Tomasello & Farrar, 1986). But in autism, impairment in joint attention is evidenced at early ages (e.g. Charman et al., 1997, Leekam et al., 2000; McArthur & Adamson, 1996) and likely hinders children from becoming active social communication partners.

Joint attention can be broken into two distinct skills: initiating joint attention (IJA) and responding to joint attention (RJA). The importance of joint attention in typical development (e.g. Tomasello & Farrar, 1986; Carpenter et al., 1998) and autism (Dawson et al., 2004; Sigman & Ruskin, 1999) has been well documented. Impairments in joint attention logically have a negative impact on communication and social development because much early learning occurs in the context of caregivers applying language to environmental occurrences (e.g. objects or activities). The predictive association of joint attention on later developing language skills in children with autism supports this logic. Several longitudinal studies demonstrated a predictive relationship between the receptive and expressive language skills of these children and earlier developing joint attention skills (e.g. Charman et al, 2003; Sigman & Ruskin, 1999). One study demonstrating the link between difficulty with joint attention and later language impairment revealed that compared to typically developing children, children with autism demonstrated more word mapping errors as they were more likely to assign incorrect names to objects based on their own locus of attention rather than the speakers' locus of attention (Baron-Cohen et al., 1997); this is a likely outcome of decreased gaze shifting and visual attention following during communicative interactions (Leekam et al., 1998; Swettenham et al., 1998). Again, the importance of directing attention toward important stimuli during communicative interactions and language interventions cannot be understated yet features of attention are known to be unusual in autism.

Attention in Autism

The topic of attention in autism is vast and can be measured either behaviorally or physiologically. For purposes of this review, attention will be discussed in terms of behavior and specifically, in relation to orienting, sustaining and shifting attention in children with autism.

Orienting attention is defined as the initial physical adjustment toward a stimulus. This is often measured through eye gaze, but in some instances when the stimulus is auditory only, a head turn toward the stimulus is considered to reflect orienting attention (e.g. Dawson et al., 2004; Paul et al., 2007; Landry & Bryson, 2004). Children with autism orient less to environmental stimuli than typical peers and other children with developmental disabilities (e.g. Dawson et al., 2004; Paul et al., 2007). In the aforementioned studies, exogenous as opposed to endogenous attention was assessed. Exogenous attention refers to a spontaneous capture of attention by environmental stimuli, whereas endogenous attention is initiated within the individual and is more effortful and goal-driven. This is important because in autism, exogenous attention appears to be more impaired relative to endogenous attention (Renner, Klinger, & Klinger, 2006). However, the social or nonsocial context appears to play an important role and will be discussed later in this review. Therefore, children need to orient to exogenous stimuli to take full advantage of the language and social opportunities present in the environment.

Once the initial capture of attention occurs, the individual must choose to sustain attention to some degree in order to benefit from engagement. When attention is goal-driven, originating from the individual, it is endogenous in nature. Sustained attention refers to the ability to maintain attention to a stimulus and is behaviorally measured by the duration of visual orientation toward an object. In measures of sustained attention, children with autism appear to remain fixated on stimuli longer than typically developing peers and peers with other disabilities (Landry & Bryson, 2004; Zwaigenbaum et al., 2005; Swettenham et al., 1998). Liss et al. (2006) found that 43% of a sample of 143 participants with autism was "overfocused" with exaggerated or over-selective attention. Results regarding sustained attention in children with autism should be interpreted with caution: perhaps higher levels of sustained attention may be better explained by the individual's resistance to exogenous capture of attention, and therefore actually may be related to orienting skills or a lack of salient of competing stimuli (Landry & Bryson, 2004; Swettenham et al., 1998; Zwaigenbaum et al., 2005). The interplay between endogenous and exogenous attention as well as orienting and sustaining attention can be thought of as follows. Initial capture of attention is often exogenous in nature and reliant on the salience of the stimuli. After the initial capture, the individual, using endogenous attention, chooses to sustain attention to the target stimulus. Both of these must occur in order to engage in social and communicative exchanges.

The ability to shift attention requires disengagement from one stimulus and then shifting and reorienting to a new stimulus. Shifting attention has been found to be impaired in children with autism (Swettenham et al., 1998; Zwaigenbaum et al., 2005). Again, findings should be interpreted with caution because of the dual processes (first disengage and then shift) required to shift attention. Because the ability to disengage from one stimulus and shift to reorient to a new stimulus cannot be separated in the natural environment, experimental paradigms have been designed to specifically test the difference between disengaging and shifting attention (Landry & Bryson, 2004).

Experiments separating disengagement and shifting begin with a central stimulus fixation to a symbol on a computer screen or object, then a peripheral stimulus is activated either with the central stimulus remaining visible or not. Both conditions require shifting of attention, but disengagement is also required when the central stimulus remains visible. The latency with which eye movement is initiated is typically the dependent variable and the time difference between the latency in the two conditions reflects the ability to disengage. Using either computerized stimuli or tangible objects, children with autism have been found to have impairments in their ability to disengage but not in their ability to shift their attention given adequate time (i.e., rapid shifts are impaired) (Courchesne et al., 1994; Landry & Bryson, 2004; Leekam et al., 2000). Therefore, if attention is engaged in one place, a competing stimulus may fail to capture attention.

Sensory Differences

Such abnormalities in attention may be linked to unusual sensory processing features observed in young children with autism. Although not universal, approximately 69% of children with autism demonstrate atypical sensory responsiveness that seems to improve as the child physically ages and developmentally matures (Baranek et al., 2006). Children with autism can be both hyperresponsive (showing exaggerated responses) as well as hyporesponsive (showing decreased responses) to sensory stimuli. Hypersensitivity appears to be similarly prevalent in autism and in other developmental disabilities, thereby having little differential value for autism diagnoses; however, hyposensitivity seems to be more specifically related to autism (e.g., Baranek et al., 2006; Rogers & Ozonoff, 2005). This hyposensitivity is related to the lack of responsiveness (hyporesponsiveness) to stimuli that is considered a behavioral indication of abnormal attention. Therefore, abnormalities in attention and sensory processing in young children with autism are difficult to separate.

Characteristics of sensory processing of communicative contexts are important to consider given the focus of this present research is ultimately related to communicative function and intervention. Basic processing of communication almost always requires processing multisensory auditory and visual stimuli. To benefit from multisensory information, one must be able to integrate sensory stimuli into a single event. Anecdotal evidence indicates people with autism have difficulty processing sensory stimuli from multiple modalities (Cesaroni & Garber 1991; Iarocci & McDonald 2006). Kern et al., 2007 also found multisensory impairment based on a questionnaire. On the other hand, a direct comparison of communication outcomes in autism using a multisensory, auditory-visual language intervention (total communication) compared to using signs or words alone revealed superiority of the multisensory approach (Barrera et al., 1980). This might indicate that although impairment in sensory integration exists, multisensory stimulation is still beneficial over unimodal stimulation for attention and learning for children with autism. Besides the multisensory nature of communication, the social aspect, almost always inherent in communication, is an important feature.

Social versus Nonsocial Contexts

The social or nonsocial nature of stimuli appears to play an important role in both attention and sensory responsiveness in autism with social contexts resulting in higher degrees of atypical behavior (Baranek et al., 2006; Dawson et al., 2004; Dawson, Meltzoff, Osterling, Rinaldi & Brown, 1998; Kuhl, Coffey-Corina, Padden & Dawson, 2005; Osterling et al., 2002; Paul et al., 2007; Sigman et al.,1992; Swettenham et al., 1998) although the exact nature of the influence not well understood. For example, Dawson et al. (1998 & 2004) studied behaviors of young children with autism and found that they were less likely to orient to both social (e.g. hands clapping and calling the child's name) and nonsocial stimuli (e.g. a shaking rattle and a jack-in-the-box) compared to typically developing children and children with Down syndrome, with the effect more extreme for social stimuli. Regardless of the underlying causes of more unusual responses to social stimuli, it logically impacts social and communicative development and results in additional challenges related to language interventions.

Sustained attention also appears to be influenced by the social or nonsocial context of the stimulus. Compared to typically developing children or those with other developmental disabilities, children with autism spend less time looking at adults and more time looking at objects (Sigman et al., 1992; Swettenham et al., 1998), but less time looking at objects if they are held by a person (Osterling, et al., 2002). Furthermore, attention shifting behaviors are also impacted by context, with more shifts occurring between two objects than between two people or an object and person (Swettenham et al., 1998). In a similar vein, visual processing of human faces and objects have also been found to be abnormal in young children with autism, with enhancement related to objects and impairments related to faces (Webb et al., 2006). These findings may reflect a bias toward nonsocial information processing.

The social vs. nonsocial nature of *auditory* stimuli also appears to yield different responses in children with autism compared to typically developing children. Typically developing children demonstrate a strong preference for human voices, particularly child-directed speech (e.g. Fernald, 1985), which has been associated with increased brain activity in infancy (Zangl & Mills, 2007). In contrast, children with autism have been shown in one study to orient their attention more toward non-speech analogs of natural speech (Kuhl et al., 2005), and in another study to show a less strong preference for natural speech compared to typically developing children (Paul et al., 2007). Some researchers posit that it is not the social nature of stimuli that results in more pronounced abnormalities in attention; rather, it is the complexity of the stimulus. They hypothesize that simple stimuli draw attention over complex stimuli and highlight the highly complex, dynamic and unpredictable nature of social stimuli (e.g. Minshew, Sweeny & Luna, 2002). That is a plausible suggestion, because as mentioned earlier, social communication is highly dynamic and often includes faces, voices, emotions and touch.

Deficits related to hyporesponsivity and hyperresponsivity are present for children with autism in both social and nonsocial contexts, with hyporesponsivity slightly more exaggerated in social contexts (Baranek et al., 2006). This finding is consistent with findings of decreased attention to social stimuli in infancy. Infants with autism may demonstrate hyporesponsivity because stimuli that capture the attention of typically developing infants fail to capture the attention of infants with autism. Some have speculated that symptoms of hyporesponsiveness were actually an avoidance behavior triggered by extreme hyperresponsiveness, but physiological measures have not supported that hypothesis (Iarocci & McDonald, 2005).

Given the literature around social and nonsocial influences, the consensus is that poorer attention and unusual sensory responsiveness are exaggerated in social contexts. These behavioral features, which have been observed early in development, are likely linked to social and communicative impairments that are universal in autism and pose challenges for the interventionist targeting language development.

Attention Interventions

Given that attention is necessary for learning but impaired in autism, considerable focus on research to support attention in children with autism is warranted. Unfortunately, very few interventions specifically targeting attention exist in research literature. Most intervention research addresses core features of autism, with communication skills being paramount in treatment approaches such as discrete trial training and various relationship-based interventions (Green et al., 2005; Kohler, 1999; Thomas, Ellis, McLaurin, Daniels & Morrissey, 2007; Thomas, Morrissey & McLaurin, 2006). A literature search specifically targeting attention-based interventions in young children with autism yielded only twelve intervention studies, and not surprising, ten of them targeted joint attention (Patten & Watson, in press). These types of interventions are habilitative in nature in that they seek to improve attention skills in the individuals. They tend to require intensive intervention over relatively long periods and are primarily delivered by specialists (e.g. Ingersoll & Schreibman, 2006; Kasari, Freeman, & Paparella, 2006; Martins & Harris, 2006; Vismara & Lyons, 2007; Whalen & Schreibman, 2003; Yoder & Stone, 2006).

Another way to address attention deficits is by accommodating attention through factors external to the child. Accommodations are commonplace in educational settings for achieving specific outcomes (e.g., using preferential seating to improve attention and participation in classroom activities). The same concept can apply to children with autism in the form of tangible supports or techniques to immediately improve attention. Any accommodation that increases the differential salience of the target stimuli relative to any competing stimuli could be a strategy for improving attention. Although only six studies relevant to accommodations for attention characteristics of children with autism were identified (Patten & Watson, in press), evidence was found in support of (1) using labels when referencing materials (Yoder & Stone, 2006), (2) incorporating perseverative interests, (Vismara & Lyons, 2007), (3) using adult imitation of the child (Field, Field, Sanders & Nadel, 2001), (4) using child-centered intervention deliveries (Lewy & Dawson, 1992), (5) using token economies (Tarbox, Ghezzi, & Wilson, 2006) and (6) using combined verbal and visual cues (Leekam et al., 1998). The final accommodation mentioned (using verbal and visual cues) studied the effects of the verbal cue "look," plus a gesture (i.e. pointing) and found the combination of these two methods significantly increased orienting to objects in children with autism over using just a head turn to draw attention. This finding might indicate the importance and effectiveness of increasing the salience of targets through a multisensory combined linguistic auditory and visual cue. This furthers the notion that although multisensory processing appears to be impaired in autism, it still may be beneficial.

Perception of Dynamic Visual and Auditory Stimuli

The influence of multisensory sensory perception on the attention and communication development of typically developing children has been studied through observing their responses to intersensory redundancy (e.g. Bahrick, Flom, & Lickliter, 2002; Bahrick & Lickliter, 2000; Frank, Slemmer, Marcus & Johnson, 2009; Gogate & Bahrick 1998; Jordan, Suanda & Brannon, 2008). Intersensory redundancy is spatially coordinated and temporally synchronous presentation of the same information across two or more senses including, but not limited to, vision and audition. Information that is not specific to a single sense is amodal and includes properties such as shape, texture and rhythm: these properties can be seen and felt or heard. The ability to attend to redundant, amodal information is thought to be fundamental to perceptual development because it allows the learner to selectively attend to relevant aspects of stimulation and disregard irrelevant events nearby. The infant develops a unified perception of the world by recognizing sights and sounds that go together, selectively attending to the most salient stimuli and effectively filtering irrelevant stimuli. The intersensory redundancy hypothesis described by Bahrick et al., (2002) states:

> a) Intersensory redundancy recruits infant attention, causing amodal properties of events to become ‘foreground’. (b) This leads to perceptual processing, learning,

> and eventually memory for bimodally or unimodally specified properties before other properties. (c) The perceptual precedence of amodal information ensures unitary perception of single multisensory events and constrains further processing. (p. 191).

Traditionally, responses to temporal synchrony have been measured with the same indicators as behavioral measures of attention (i.e. looking behaviors) (e.g. Bahrick, 1987; Bahrick & Lickliter, 2000). Physiological measures have been used as well and also indicate enhanced responses to spatially and temporally coordinated stimuli (Meredith & Stein 1983, 1986).

How does temporal synchrony impact stimulus processing in typically developing infants? Lewkowicz (2000) describes the developmental significance of temporal synchrony in that perception of intersensory temporal synchrony occurs early in infancy and therefore may be the earliest basis for the perception of a multimodally unified world. Infants are able to detect bimodal auditory-visual stimuli at birth (Bahrick & Lickliter, 2000; Morrongiello, Fenwick & Chance, 1998), and two-day old infants are able to learn arbitrary audio-visual object-sound relations when information is presented contiguously (Slater, Quinn, Brown & Hayes, 1999). Infants are able to distinguish the correct sound track to video pairings when presented with single objects and multiple objects hitting a surface (Bahrick, 1987) and learn audio-visual pairings at 3 months (Morrongiello, Lasenby, & Lee, 2003). Not only are infants able to discriminate differences as they occur, but infants as young as five months are able to habituate to rhythms and then discriminate changes that are presented bimodally (visually and auditorily) and synchronously, thus demonstrating the ability to learn the bimodal relationship. However, when the same information is presented via one modality or is presented asynchronously, no discrimination is evident (Bahrick & Lickliter, 2000). This underscores the importance of temporal synchrony guiding attention and perceptual learning early in development for relationships that are amodal and naturally occurring.

Arbitrary Intermodal Relationship

Infants have an attention bias toward temporally synchronous presentation of amodal information that predictably occurs in nature, such as the sight and sound of clapping hands or bouncing balls. But later in development, infants also attend to and learn arbitrary intermodal relations, which are pairings that do not occur naturally, such as color and shape (Hernandez-Reif & Bahrick, 2001) or syllables and objects (Gogate & Bahrick, 1998). Names of objects are arbitrary and *temporal contiguity* exists when the object is present when named. *Temporal synchrony* exists only when the object is moved in synchrony with the spoken name. This is also referred to as multisensory naming and is a form of intermodal redundancy. Hearing the name of an object is unimodal; seeing an object is unimodal. Only when an object is moved in synchrony with its name is the presentation considered amodal or having an arbitrary intermodal relationship.

Intermodal relationships are thought to have organizing influences on early social and linguistic processing, as infants need both voices and faces to recognize emotional expressions. In this sense, redundant information serves to increase the salience of important events in the environment, which encourages the development of social and communicative competence. Later, they can use voice alone and eventually facial expressions alone to recognize emotions (Flom & Bahrick, 2007).

Intersensory Redundancy and Lexical Development

Regarding the development of communication, lexical learning entails the detection of arbitrary but conventional relations between labels and specific objects and events in the environment. Redundant information is present in terms of synchrony between the auditory signal and the motion of the mouth, which likely facilitates the detection of arbitrary syllables – this information is amodal and naturally occurring. The production of vocalic syllables and movement of objects facilitates learning object labels or mapping of syllables onto objects - this information is intermodal and arbitrary. Seven-month-old infants can learn to associate syllables with objects given redundant synchronous presentations but fail to learn the same information when presented asynchronously or in still conditions (Gogate & Bahrick, 1998). Furthermore, infants at 7 months require phonetically distinct syllables to distinguish two syllables presented with temporal synchrony but 8 month-old are able to distinguish minimal pairs given temporal synchrony (Gogate 2010), possibly reflecting a maturing of auditory processing. By fourteen months, toddlers can relate syllables to moving but not still object pairings without the presence of temporal synchrony (Werker, Cohen, Lloyd, Casasola, & Stager, 1998). It appears that as children develop, they are able to process more ambiguous auditory-visual pairings. Likewise, developmentally younger children require more enhancements to correctly process auditory-visual pairings. Therefore, in early development, temporal synchrony during object labeling facilitates attention and learning in terms of early word-mapping, but during the second year of life, the child is able to attend to and process the object-word pairing with less overt enhancements of the target stimuli. This appears to be the natural order of typical development – requiring less overt stimulus enhancement to orient attention. But in atypical development, perhaps temporal synchrony is beneficial beyond the first year of life, reflecting the need for enhanced salience to draw attention.

The idea that stimulus enhancement is required to assist infants in auditory-visual processing appears to be reflected in caregiver behavior toward typically developing infants. It seems that caregivers naturally acknowledge the benefit of temporal synchrony, although perhaps unintentionally, in that early communication to infants is multisensory and characterized by redundant information across the senses. Mothers intuitively synchronize their spoken words and the movement of objects for infants during the first two years (Gogate et al., 2006). Multisensory features of communication include rhythm, pitch and intensity shifts common to the face and voice during speech as well as temporal synchrony in terms of naming and showing an object, and even touching the infant simultaneously. Gogate et al. (2000) found that mothers of infants and toddlers (5-30 months) used multisensory communication 99.9% of the time and used temporally synchronous naming and showing approximately 60% of the time. As the child ages, maternal usage of temporal synchrony in bimodal communication decreases (i.e. 76% use at five to eight months and 36% use at 21-30 months) (Gogate, 2000), likely reflecting less dependence on maternal cues for correct label-referent pairing.

During the second year of life, infants are able to reliably use the speaker's eye-gaze to identify a static object to detect the referent of a label (Baldwin, Markman, Hill, Desjardins, & Irwin, 1996). It appears that as children become more adept at determining more subtle indicators of the referent, the less overt mothers are at indicating them. Rather than requiring movement of an object, children become able to locate the correct referents through their communication partners' eye gaze. The ability to use the speaker's eye-gaze to shift one's locus of attention to a target is important in order to respond to joint attention, and this ability to respond to bids for joint attention in the first and second years of life is predictive of later language skills (Mundy & Gomes, 1998; Morales et al., 1998). Attention to multisensory naming may play a role in the development of joint attention, as temporal synchrony during multisensory naming results in infants attending more to object naming as well as switching gaze from mother to object (i.e. joint attention). Specifically, synchronous naming resulted in six to eight month-olds switching eye gaze from mothers to objects 17 of 24 opportunities while asynchronous naming resulted in eye gaze switching only seven of 24 opportunities (Gogate et al., 2006). And, mothers who use more temporal synchrony during object naming have infants who show better learning of word-object relations (Gogate, Bolzani & Betancourt, 2006). Therefore, in typical development, mothers use temporally synchronous object naming, and children benefit by (a) increasing their attention to the target object, (b) increasing their joint attention between the mother and the object, and (c) learning more words, compared to children whose mothers used less temporal synchrony.

An important distinction may exist between auditory-visual processing of objects and related natural sounds (e.g. a ball bouncing) and auditory-visual processing of objects and their verbal labels (e.g. a ball paired with the word "ball"). In support of this notion, three month-old infants require temporal synchrony to learn audio-visual pairings of objects and environmental sounds, but seven month-olds can learn the same audio-visual parings in still conditions (Morrongiello, Lansenby, & Lee, 2003). As stated earlier, seven month-old infants require temporal synchrony to learn syllable-object relations

(Gogate & Bahrick, 1998). This may suggest that non-linguistic audio-visual pairings can be learned without synchrony earlier in development than linguistic audio-visual pairings, perhaps indicating the complexity of linguistic stimuli.

Temporal Synchrony in Autism

The importance of intersensory redundancy and temporal synchrony is established in terms of the capture of attention and clarification of social and linguistic information. This leads to the development of communication and social competence for young typically developing children. Although relatively unstudied, some evidence indicates that temporally synchronous auditory and visual stimuli capture attention in children with autism. Therefore, it might be that although multisensory processing is different in autism, the presence of multisensory information still serves to enhance attention compared to unimodal stimuli as indicated by the increased attention toward referents when the verbal command "look" is paired with a gesture over gesture alone (Leekham et al., 1998).

Responses to temporal synchrony in children with autism are inconclusive based on research thus far. Studies include both linguistic and nonlinguistic (i.e. social and nonsocial) contexts. In general, nonlinguistic stimuli, such as objects colliding, induce detection, discrimination and attention to synchrony (Bebko et al., 2006), whereas linguistic stimuli result in a lack of attention to synchrony (Bebko et al., 2006, Bahrick et al., 2010).

Bebko et al., (2006) assessed the impact of temporal synchrony on preschoolers with autism (four to six year olds) in both linguistic and nonlinguistic contexts, compared to typically developing children and children with other developmental delays. Three tasks were used: a non-linguistic task (a ball rolling through a mousetrap maze), a simple linguistic task (a woman counting slowly), and a complex linguistic task (a woman reading a story). A single sound source presented the audio stimuli and two monitors featured the same recording of each task, with one monitor either forwarded or delayed by 3 seconds and the other monitor in sync with the auditory stimuli. A preferential looking paradigm (Spelke, 1976) was used to determine detection, discrimination and attention to synchrony. Children with autism demonstrated a significant preference for the synchronous video of the non-linguistic task but showed no preference for either the simple-linguistic or complex-linguistic task. The control groups also showed a significant preference for synchrony during the non-linguistic task but showed a significant preference (or approached significance) during the simple linguistic and complex linguistic tasks as well. Another finding of this study was that the lower the adaptive language score according to the Vineland Communication subscale (VABS; Sparrow, Balla, & Cicchetti, 1984), the more time spent looking away during the complex linguistic task for children with autism. However, this was not true for the control groups, nor was severity of autism among the children with autism related to looking behaviors.

Recently, Bahrick and colleagues (2010) presented similar research aimed at parsing out the impact of social and nonsocial events on responses to temporal synchrony. Children with ASD, developmental delay, and typical development between the ages of two and five were shown side-by-side videos with one monitor displaying audio-visual synchrony and the other monitor out of synchrony with the auditory stimuli. The stimuli were a) socially positive: a woman speaking with exaggerated positive affect, b) socially neutral: a woman speaking with neutral affect, and c) nonsocial: objects impacting a surface. The typically developing group demonstrated detection and discrimination of the synchronous presentation on all three conditions whereas the group with developmental disability was only able to detect synchrony in the socially neutral and nonsocial linguistic conditions. Unlike Bebko et al., (2006), who found children with autism were able to detect temporal synchrony with objects but not with speech, Bahrick et al., (2010) found children with ASD did not demonstrate detection of temporal synchrony in any condition.

One additional study that was not initially designed to target detection of synchrony was by Klin et al. (2009). He serendipitously found that children with autism are driven by physical contingencies (auditory and visual) that feature temporal synchrony. Specifically, preferential attention to biological motion was studied in 21 toddlers with autism given point-light animations of child games such as pat-a-cake and peek-a-boo in simultaneously presented upright and inverted conditions (the inverted condition disrupts perception of biological motion). Typically developing children showed a strong preference for the upright conditions, which featured biological motion, but the children with autism did not demonstrate that preference. In previous research, Klin and Jones, 2008 found that a single toddler with autism demonstrated significant preferential looking to the upright animation when the actor's hands collided and the audible "clap" co-occurred. When the data for just the pat-a-cake animation were analyzed, this child demonstrated significant preferential viewing for the upright animation. It appeared that the temporal synchrony of the physical appearance with the auditory cue of the clap impacted not only the capture of attention, but also the ability to sustain attention of this child with autism to the upright version.

After Klin and colleagues (2009) observed the powerful capture of attention to the synchronous auditory and visually presented clap, they developed an algorithm to assess the impact of audio-visual temporal synchrony on capture of attention. Basically, a specific degree of change in the auditory stimuli paired with a specific degree of change in the trajectory of the visual stimuli was considered a temporally synchronous audio-visual event. The data were recoded with these parameters, and the children's preference for audio-visual synchrony accounted for 90% of the variance in looking behaviors. Therefore, while typically developing children are drawn to biological information as conveyed through the upright point light animation of the human figure, children with autism might be drawn to audio-visual temporal synchrony. Based on these findings, it is not possible to determine if the semantic content of the auditory stimuli was meaningful or better processed. However, this finding may indicate that the temporal synchrony of auditory information and physical movement serve to capture the attention of children with autism and provide intersensory redundancy that would ultimately enhance the development of communication and social competence. This is in contrast with the implication that multisensory stimuli result in poorer processing then unimodal stimuli.

The three studies above yielded disparate findings and there were several methodological differences. Bebko et al. (2006) both found discrimination of temporal synchrony of non-linguistic stimuli while Bahrick et al. (2010) did not. This may be related to the fact that the mean age in Bahrick et al.'s (2010) sample was younger than Bebko et al.'s sample. Typically developing children seem to improve in their ability to recognize temporal synchrony, with differences becoming obvious as early as three months (Bahrick, 1992). Perhaps children with autism also experience a trajectory where awareness of and benefit from synchrony occurs, but later than in typical development.

The stimuli used in each experiment may also indicate why findings were not consistent across studies. Bebko et al. (2006) used video clips of real objects colliding with solid surfaces and found evidence for increased attention related to stimuli presented in synchrony with the soundtrack. Bahrick et al. (2010) did not find children with autism able to discriminate synchrony from asynchrony in their non-linguistic stimulus event. The stimuli used by Bahrick et al. (2010) were animated shapes colliding with walls. If children with autism need to learn the importance of amodal presentations of temporally synchronous events for guiding learning and perception, then perhaps moving, animated shapes are not familiar and therefore not salient and predictable. Furthermore, "real" stimuli versus computer generated animations are more ecologically valid and possibly yield a better understanding of types of stimuli that appear to enhance attention and processing in children with autism during their everyday experiences.

An additional consideration is the notion that temporally synchronous linguistic information does not recruit attention in children with autism. It is true that the studies featuring "talking heads" did not result in children with autism showing discrimination of the temporally synchronous versus asynchronous events, but the presence of the faces may have confounded the results. Perhaps the root of the looking differences is related to atypical face processing in autism (e.g. Dawson et al., 2005; Webb et al., 2006). However, linguistic information can be presented without the presence of faces. Recall the impact of arbitrary intermodal detection on novel word learning in typically developing infants (Gogate et al., 2006). In these cases, the redundancy was between spoken word and object movement, and resulted in improved attention and learning. Bebko et al. and Bahrick et al. presented linguistic information focusing on faces only, with no objects or referents present. If faces were not the only visual stimuli, perhaps temporally synchronous presentation of linguistic information and a visual target would yield attention enhancements. This possibility is supported by the Klin et al. (2009) study that found looking preferences based on temporal synchrony of physical contingencies in a linguistic context without faces present.

Although all oral communication can be described as social in nature, one can consider the possibility that some contexts are "more" social. Consider a person giving directions compared to a person telling an emotional personal account. The latter would likely require that the listener be able to process more dynamic facial expressions and prosodic fluctuations as well as discrimination of emotions for accurate interpretation. Bahrick et al. (2010) may have been alluding to this by comparing effects of temporal synchrony given socially neutral communication to socially positive communication in the form of child-directed speech. Interestingly, typically developing children and children with other developmental disabilities showed more looking toward the synchronous event in the socially neutral presentation: this could reflect increased endogenous attention toward the temporally synchronous event in an attempt to better process meaning of communication, since less social and communicative information was conveyed in the social neutral condition in comparison to the socially positive presentation featuring infant-directed speech. In other words, there is probably more burden on the listener for comprehension of socially neutral communication compared to socially positive communication.

If the reason children with autism did not show a preference for temporal synchrony was that speech was paired with faces only, it still may be possible for children with autism to benefit from temporal redundancy of linguistic information if presented with words and objects. To date, the possibility of discrimination of and attention toward temporally synchronous presentations of words and objects has not been tested.

One final methodological critique relates to the time delay used to describe temporal asynchrony. Lewkowicz (1996) determined that infants bind information from two modalities that are offset by less than 350 milliseconds (i.e. they perceive temporal synchrony). Gogate, et al., (2006) described asynchronies greater than 700 milliseconds as independent events rather than asynchronous. If these definitions are true in autism, then all three studies compared a synchronous event to a completely unrelated event rather than an asynchronous event, because all three studies offset the asynchronous event by greater than 700 milliseconds. However, there are no studies empirically demonstrating a difference between information presented "asynchronously" (i.e. off-set by 350 – 700 milliseconds) versus unrelated (off-set by >700 milliseconds). It might be concluded that any auditory-visual offset greater than 350 milliseconds is processed as asynchronous and the distinction is inconsequential. At this point, no consensus exists regarding the definition of synchrony, asynchrony and unrelated stimulus presentation.

Neurological Correlates of Multisensory Processing and Autism

Several brain structures and processes that appear to be disordered or disrupted in autism are also implicated in multisensory processing. Specifically, the cerebellum, the superior temporal sulcus, the amygdala, and fusiform gyrus have been identified as necessary for multisensory processing and are thought to be impaired in autism. Cerebellar structural and activation abnormalities have been found in autism (e.g., Allen & Courchesne, 2003; Bauman, & Kemper 1985; Courchesne et al., 1994) and are linked to disruptions in attention, particularly shifting between auditory and visual stimuli (Courchesne et al., 1994). Such disruptions would impact adequate processing of audio-visual stimuli.

The superior temporal sulcus (STS) is activated during multisensory processing of auditory-visual linguistic signals (Calvert, 2001) and is important for processing biological stimuli such as mouth movements (Fadiga, Craighero, Buccino, & Rizzolatti, 2002) and emotional stimuli (Redcay, 2008). Differences in STS activation have been found between participants with autism and typical controls (Boddaert, Chabane, 2003; Gervais, Belin, Boddaert, 2004; Castelli, Frith, Happe, 2002).

The amygdala and the fusiform are two more structures linked to multisensory processing. Donan, Morris, and de Gelder (2001) found that given multisensory stimuli of congruent productions of fearful faces and fearful voices, enhancements in the amygdala and fusiform areas were observed in typical adults. The amygdala and fusiform structures, which are important for emotion and face processing, have also been implicated as impaired in autism (e.g. Corbett et al., 2009; Monk et al., 2010; Pierce & Redcay, 2008; Schultz, 2005), and recently, Dziobek, Bahnemann, Convit, and Heekeren (2010) demonstrated volumetric differences in the amygdala and thickening of the fusiform in adults with autism. Pelphrey, Adolphs and Morris (2004) offer a more detailed review of neuroanatomical findings related to the STS, fusiform, and amygdala in autism.

Abnormal Neural Connectivity

Inherent in multisensory processing is that sensory signals initially travel modality specific pathways and are processed by modality-specific primary sensory cortices while also being processed in association areas for integration of information from different sensory modalities (Iarocci & McDonald, 2006). Therefore, functional cortical networks are required for accurate multisensory processing. Theories of autism related to abnormalities in neural connectivity are widely cited and tend to indicate high local connectivity and low long-range connectivity (e.g. Bachevalier & Loveland, 2006; Brock et al., 2002; Castelli & Frith, 2002; Gepner & Feron, 2009; Just, Cherkassky, Keller, & Minshew, 2004; Minshew & Goldstein, 1998; Minshew & Williams, 2007; Rippon, Brock, Brown, & Boucher, 2007).

Several neurobiological studies have sought to quantify differences in connectivity. Researchers posit early brain overgrowth in autism, as indicated by early measures of head circumference, reflects disruptions in normal connectivity (Courchesne, Carper & Akshoomoff, 2003; Courchesne & Pierce, 2005). More directly related to connectivity are measures of connection fibers. Measurement of white matter differences, thought to affect intrahemispheric and corticocortical connections, have been found in autism (Herbert et al., 2004). Furthermore, the corpus callosum consists of projection fibers and is considered an index of interhemispheric connectivity; a reduction in volume is associated with autism (e.g. Hardan, et al., 2009; Piven, Bailey, Ranson, & Arndt, 1998). Diffusion tensor imaging (DTI) technology provides a means of directly measuring cortical networks, and findings for children with autism indicate differences in both long and short range fibers compared to typically developing peers (Sundaram et al., 2008). Measures of multisensory integration have also been obtained through gamma activity, which is an EEG response that is thought to reflect the linking together of stimulus properties or binding of temporal features (Muller & Gruber, 2001). In autism, gamma activity, thought to reflect feature binding, has been found to be abnormal, given faces as well as shapes (Brown et al., 2005; Grice et al., 2001).

Disrupted connectivity might explain several symptoms of autism. An early inability to successfully integrate multiple stimuli could yield impaired development including significant deficits in attention and sensory responsiveness that might be exaggerated in highly complex contexts, which are inherent in social interaction. As a case in point, Mundy and Newell (2007) suggest disruptions in integrated activation of cortical networks including anterior-posterior attention systems are linked to deficits in joint attention. The temporal binding theory and the temporo-spatial processing disorder hypothesis (TSPD) propose that autism is associated with abnormalities in information integration and multisensory synchronization that is caused by impairments in neural connectivity. If incoming multisensory stimuli is processed incorrectly, the ability to create a coherent and organized picture of one's environment is impossible. Repeated experiences with unusual multisensory processing could potentially result in atypical responses to sensory stimuli leading to abnormalities in attention and ultimately impairments in the development of communication and social interaction.

Brock et al. (2002) suggest that deficits integrating multisensory stimuli are a result of deficits in temporal binding. The "temporal binding window" is a phenomenon in which stimuli from two modalities are bound and perceived as one if they are presented within a certain period of time. In typical development, one can hear beeps and see flashes, and if the duration between the beeps and flashes is brief, the person will report seeing more flashes based on the number of beeps presented. In adolescents and adults with typical development, the window is between +/-150 ms, but it is between +/-300 ms in adolescents and adults with autism (Foss-Feig et al., 2010). This larger temporal-binding window is likely to impact multisensory processing of more naturally occurring stimuli as well.

How might an enlarged temporal binding window impact multisensory processing? Foss-Feig et al. (2010) suggests that perhaps the larger window occurred as an adaptive mechanism because of problems time-locking stimuli to an event, yielding temporal variability in perception of multisensory stimuli; therefore, an extended temporal binding window could allow more time to bind multisensory features. However, the extended temporal binding window could then further negatively impact multisensory processing by allowing misalignment of multisensory stimuli and inaccurate binding. Even in typically developing brains not all aspects of multisensory integration is completely developed at birth, as evidenced by more accurate detection of temporal dissynchrony as children develop to adults (Lewkowicz, 1996). This suggests a learning period needs to occur. Perhaps early impairment in multisensory processing in the autistic brain leads to poorer temporal binding, which in turn worsens multisensory processing that the developmental trajectory leads to poorer outcomes. In order to effectively participate in daily life, including social and communicative interactions, the nervous system must be able to precisely align sensory stimuli from divergent modalities to create a unified perception of events.

Unusual sensory responses could theoretically arise as a result of an extended temporal binding window. If concurrent sensory stimuli were being processed with little suppression of irrelevant stimuli, responding to novel stimuli could be hindered and result in sensory hyporesponsiveness. For the same reasons, hyperresponsiveness may also be a result of an overtaxed sensory system in which few irrelevant stimuli are suppressed, leaving the individual “on edge”. Sensory seeking behaviors may occur as an adaptive means to heighten desired sensations in the midst of the additional sensory “noise”. This interpretation is consistent with findings that individuals with autism demonstrate all three features of unusual sensory responsiveness (e.g., Schoen, Miller, Brett-Green, & Nielsen, 2009; Watling et al., 2001).

Foss-Feig and colleagues (2010) posit that binding occurs in the autistic brain, but over an atypically large set of temporal intervals. If this is the case, then perhaps the nature of multisensory stimulus presentation can impact processing. Similar research indicates that typically developing infants are able to detect asynchronies of environmental sound-object pairs off-set by 350 milliseconds (Lewkowicz, 1996), but require between 500-660 milliseconds to detect asynchronies of linguistic sounds-object pairs (Lewkowicz, 2010). This finding may suggest that a larger temporal binding window may exist for linguistic events as opposed to amodal environmental events such as hands clapping. The discrepancy between detection of asynchronies in object auditory-visual stimuli and linguistic auditory-visual stimuli may be echoed in findings that, given temporal synchrony, three-month olds are able to learn auditory-visual pairings of objects (Morrongiello et al., 2003), whereas seven-month olds are able to learn auditory-visual pairing of syllables and objects (Gogate & Bahrick, 1998).

Although processing auditory-visual linguistic stimuli appears to be more difficult than processing auditory-visual object related stimuli, there is some evidence that the linguistic signal can be altered to improve processing. Slowing simultaneous auditory and visual cues enhances comprehension and imitation in children with autism (as cited in Gepner & Feron, 2009). Perhaps the slowed presentation allows adequate processing even with the presence of an enlarged temporal binding window. This may also indicate that alterations to multisensory stimulus presentations can yield more typical responses and provide benefits to children with autism similar to typically developing children, but perhaps to a lesser degree.

To highlight the potential relationship between impairment in audio-visual multisensory processing and communication symptoms of autism, Grossman, Schneps and Tager-Flusberg (2009) found intact temporal processing of auditory-visual information among adolescents with ASD. Given phrase-length meaningful language stimuli, the adolescents with ASD were able to determine clips that were synchronous or out-of-synchrony between 0 and 500 milliseconds with comparable accuracy to age-matched typical controls. This study indicates that adolescents with ASD do not require a larger temporal window to determine asynchrony. Of significance in this study is that the adolescents with autism had a mean verbal IQ of 109.24, nonverbal IQ of 113.20 and receptive vocabulary score mean of 113.08, with a test mean of 100 for all three measures. This supports the idea that adequate detection of temporal synchrony is related to language development. What is debatable is whether detection of temporal synchrony leads to benefits similar to those experienced by typically developing children attending to temporal synchrony, ultimately better language development, or if better language processing encourages seeking temporal synchrony and thereby encourages more typical temporal binding.

Conclusion

Children with autism demonstrate early impairments in attention and sensory processing including multisensory integration, which likely relate to the core features of autism. Specifically considering the social and communication symptoms of autism, the ability to orient one's attention to salient targets in the environment is necessary for linguistic and social development. Improvements in orienting attention will likely result in a better developmental trajectory for children with autism. However, very few therapeutic strategies to improve attention orienting among children with autism have been validated. Strategies that can be cost-effective and widely administered without specialized training are even rarer. One means of improving orienting of attention is to increase the salience of a target.

Intersensory redundancy captures attention and facilitates linguistic development in young typically developing children. The impact of intersensory redundancy on children with autism is not well studied and the few existing studies yield disparate findings, but there is some evidence that auditory-visual temporal synchrony captures the attention of children with autism. Furthermore, using a multisensory, auditory-visual approach (total communication compared to signs or words alone) can boost word acquisition compared to training via single modalities (Barrera et al., 1980). This might indicate that although impairment in sensory integration exists, multisensory stimulation is still beneficial over single-modal stimulation for attention and learning for children with autism.

Purpose

Given that features of autism include poor attention and unusual sensory sensitivities, understanding how to draw and maintain attention to social and communicative interactions in autism is critical to effectively targeting social-communication skills in the treatment of autism. In young typically developing children, temporally synchronous presentations of auditory and visual stimuli yield better attention and processing. Typical environmental stimuli in social-communicative contexts fail to capture the attention of children with autism to the same degree as typically developing children. However, if environmental referents in linguistic contexts could be enhanced by temporally synchronous presentation of multisensory information, capture of attention would improve, yielding better sustained attention to the target. In turn, improvements in processing of the social and communicative content could occur, ultimately impacting social and communicative development. Also, if it were discovered that temporal synchrony could enhance multisensory processing, it would likely be beneficial even if only used intermittently. Once typically developing infants detect an amodal property in multisensory stimulation, attention to that property has been found to improve toward unimodal stimulation of that property (Bahrick & Lickliter, 2000). In other words, if attention is gained through detection of multisensory stimulation of one event, attention remains focused on that event even if multisensory features are removed.

The primary purpose of the proposed research is to determine if temporal synchrony of spoken words with moving objects will result in detection, discrimination and attention to temporal synchrony versus asynchrony. This study is unique in that linguistic information is conveyed in the context of the target object without a face present. If the hypothesis is correct, that children with autism demonstrate a preference for temporal synchrony in a linguistic context without faces present, it may be possible to develop interventions that draw attention to social-communication. Also, the influence of social stimuli is still not well understood in autism and these results will add additional evidence to that body of knowledge.

The secondary research goal is to determine the extent to which a correlation exists between receptive language and attention to synchrony as well as to video presentations featuring linguistic content. The hypothesis is that the ability to detect, discriminate and choose to attend to synchrony or any linguistic video presentation is positively related to receptive language.

CHAPTER 3

Methods

The purpose of this study is to determine if temporal synchrony of spoken words with moving objects will result in detection, discrimination and attention to temporal synchrony versus asynchrony. The central hypothesis is that children with autism will demonstrate a preference for temporal synchrony in a linguistic context without faces present, but that the preference for temporal synchrony, as well as overall looking to video presentations featuring a linguistic context, will be related to receptive language skills. In this study, preference is determined behaviorally by looking and is also considered to reflect detection, discrimination, and a choice to attend to a preferred stimulus.

Participants and Settings

A total of 23 children (19 male; 4 female) were recruited to participate in this study. An a priori power analysis based on previous research (Watson et al., 2010) targeting looking behaviors of a similar population (preschoolers with autism), indicated that 23 participants would be required to find a difference with alpha set at .05 given similar differences in looking behaviors. Children were recruited from Chapel Hill, Raleigh, Durham and Greensboro, NC as well as Columbia, SC through flyers distributed to existing research projects targeting young children with autism and to preschools serving children with autism. Inclusion criteria were an age between 3 years and 5 years, 11 months and a diagnosis of autism. All participants met strict criteria for autism (not pervasive developmental disorder or Asperger syndrome) through the Autism Diagnostic Observation Schedule (ADOS) (Lord, Rutter, Dilavore, & Risi, 1999) previously administered by the public school system or other research groups. The age range was selected because deficits in attention are observed in infancy and probably impact the child's developmental trajectory from birth; therefore, methods to improve attention should address children at the earliest ages of diagnosis making earlier age ranges an important target in research of this type. Although diagnosis is occurring at younger ages, the 3 to 5 year range is likely to include more children with a stable diagnosis. Children were excluded if they had concomitant genetic diagnoses (Fragile X syndrome, tuberous sclerosis, etc). Vision and hearing were required to be within normal limits or corrected to within normal limits and confirmed by record review and/or parent report.

Participants were seen during a single visit lasting less than one hour. The testing environments were child-friendly settings that were quiet and away from distraction of other activity, either in a lab or a separate room in the child's preschool.

Measures

To gage the overall severity of autism for the sample, the Social Responsiveness Scale-Preschool for Three-Year-Olds (SRS-P) (Pine, Luby, Abbacchi & Constantino, 2006), a validated 65-item parent questionnaire designed to measure severity of social symptoms of autism was completed by each child's caregiver. The SRS-P is based upon the original version, the Social Responsiveness Scale (SRS) (Constantino, 2002), and is only slightly different from the original version consisting of changes in wording of some items to make them more appropriate for younger children. Specifically, 51 of the 65 items are identical. Ten of the altered items have minimal differences. For example, item 35 on the original version states “has trouble keeping up with the flow of a normal conversation” and item 35 on the 3-year-old version adds the qualifier “with other children” at the end of the statement. A total of four of the 65 items are more significantly changed but were still related. For example, item 57 on the original version states “gets teased a lot” and item 57 on the three- year-old version states “other children do not like to play with him/her”. Due to these minimal differences, the SRS-P for 3-year-olds was used for the entire sample. The SRS uses a rating scale from zero to three and a score of 60 or greater is associated with an autism spectrum disorder (Constantino et al., 2003).

The Auditory Comprehension portion of the Preschool Language Scale – 4 (PLS-4) (Zimmerman, Steiner & Pond, 2002) was administered to measure receptive language skills to allow statistical evaluation of receptive language skills as a covariate in the data analysis. The PLS-4 is a standardized test of expressive and receptive language skills designed for use with children from birth through 6 years, 11 months. Scores for each subscale include age equivalent (A-E) scores, as well as percentile and standard scores. In this study, the receptive language A-E scores were used to compute a receptive language ratio score (receptive language A-E / child’s chronological age), due to 8 of the 23 children having standard scores at the floor for the PLS-4 (i.e., a score of 50 or below). Table 3.1 summarizes the characteristics of the sample.

Design and Apparatus

The design of this experiment was similar to that used in the Spelke (1976) looking paradigm, with the competing stimuli being displayed on two separate video monitors. This method has been used in autism research more recently (Bahrick et al., 2010; Bebko et al., 2006). It was selected for the current because positive results (i.e. preferential looking toward synchrony) are thought to reflect intersensory matching and integration by requiring that the participant detect and discriminate the intersensory relationship and then perform an explicit response (Lewkowicz, 2000). Benefits of temporal synchrony can only be derived given those conditions.

Two 19-inch computer monitors were placed side by side with a six-inch gap between them. A Canon VIXIA HF R100 camcorder, used to record looking behaviors, was placed behind and above the two monitors, and a speaker to broadcast the auditory stimuli was placed in between the monitors with the volume set at a comfortable listening level similar to conversation. Video clips were held on a Macintosh mini-computer and stored in I-Tunes.

Table 3.1: Sample Characteristics

Participant Characteristics	%	mean (sd)
Gender (male)	85%	
Chronological age (mos)		55.45 (7.54)
PLS-4 Receptive language A-E		38.05 (15.30)
Receptive Language ratio*		.69 (.06)
Social Responsiveness Scale-P		83.32 (29.56)

* receptive language ratio = PLS-4 receptive language A-E / chronological age

Stimuli

Four 30-second video clips featured four different dolls, each paired with a different name and different play set. Two male and two female dolls that are not widely advertised (e.g., *not* Dora the Explorer) were selected in order to decrease the likelihood that children would already be familiar with the dolls. The dolls were called “Kiku,” “Pilou,” “Nuwa,” or “Barra,” names selected because they were not likely to be familiar to the child and presentation of bisyllabic audio-visual synchronous movement was possible.

The mid-portion of the investigator was recorded holding each doll and vertically bouncing the doll in synchrony with the doll’s name each time she uttered the name. Each video clip segment contained five statements about the play activity and included the doll’s name once per statement. Therefore, each doll’s name was presented a total of five times during each segment. The name of the doll was uttered with movement of the doll in synchrony with the double syllables resulting in a “double bounce”. The bounce was always done vertically and spanned approximately 6 inches. For example, the investigator said, “Kiku likes milk” while moving the doll during the production of her name and then demonstrating the doll drinking milk. Deliberate movement paired with auditory stimuli only occurred on screen during production of the doll’s name. The doll drinking milk occurred after the statement was complete. The doll’s name paired with movement was evident in only the synchronous version. The name of the doll came at the beginning of the sentence in 14 of 16 opportunities. A slight pause after the name of the doll occurred allowed the movement in the asynchronous video to occur before the initiation of the rest of the utterances. For 2 of the 16 utterances, the name of the doll was embedded in the utterance: “let’s put lotion on Kiku’s feet” and “let’s clean Nuwa’s booboo.” In the asynchronous version, the word “feet” was being produced during movement but did not follow the synchronous two-syllable movement pattern. The word “booboo” was produce in synchrony with movement of the doll in the asynchronous video. This unintended synchrony was not felt to invalidate the segment because adults viewing the segment were immediately able to tell which condition was synchronized, as was the case in a similar design by Bahrick (1983).

The investigator held the doll and materials at chest level and her face was not captured on tape. This prevented confounds of sound and lip movement synchrony, as the target linguistic event was the pairing of the referent (doll) with the auditory cue (name) and not the mouth with the auditory cue. In addition, this intentional avoidance of the investigator’s face removed the need for face processing, a known deficit (and potential aversion) for children with autism (e.g. Monk, et al., 2010; Pierce & Redcay, 2008). Each video monitor featured identical recordings, but one video was delayed by 700 milliseconds in order to provide the same auditory and visual stimuli with only temporal synchrony being manipulated (see Figure 3.1). A 700-millisecond delay was selected because the minimum delay required for infants to identify auditory and visual stimuli as asynchronous is 350 milliseconds (Lewkowicz, 1996) and synchronies greater than 700 milliseconds are considered independent events rather than asynchronous (Gogate et al., 2006). Furthermore, according to recent findings on adolescents and adults with autism, temporal-binding windows occur between +/-300 milliseconds, and it would be expected that young children with autism might have even larger temporal-binding windows (Lewkowicz, 1996). Therefore, the 700-millisecond delay was assumed to allow for adequate detection of asynchronies for the participant children.

Figure 3.1: Synchronous and Asynchronous Audio-Visual Stimulus Start/End

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(0 milliseconds) Start Audio______________________End at 30 seconds

(0 milliseconds) Start Synchronous Video___________End at 30 seconds

__(700 milliseconds) Start Asynchrony Video________End 30 seconds + 700 ms

Procedure

Each child was centered between the two monitors, at a comfortable viewing distance (25 inches away) with the monitors at eye-level. They were told that they were going to get to watch a video. A brief intermission (30 seconds) occurred between each video segment and attention was cued between the monitors to serve as a fixation point prior to the commencement of each segment. The examiner cued attention by activating a brief noise between the two monitors. Counterbalancing occurred with order of doll presentation and side of synchrony (i.e. two segments were created for each doll – one with synchrony on the right, one with synchrony on the left). Each condition (synchronous and asynchronous) was presented twice on each side.

Occasionally a child required cues to remain in his or her seat. This was accomplished by gently cuing him or her around the waist. No incidents of extreme fussiness occurred. No child was ever coaxed to look at one or the other monitor.

Data Collection Methods & Coding

Two coders were trained to measure looks directed toward each monitor (right versus left) and looks directed away from the monitors. Attention was operationally defined as looking at one of the two video monitors. Using digital video manipulation, each second of looking behaviors was divided into two 500 millisecond intervals with a single freeze frame of the child representing each interval. Given 30-second segments, each segment yielded 60 intervals, which appeared as a single "snap-shot" every 500 milliseconds. This allowed coders to easily view eye gaze in that photo snap-shot. Although a saccade (rapid simultaneous movement of both eyes) can be as fast as 300 milliseconds in typically developing preschoolers (Fukushima, Hatta, & Fukushima, 2000), coding 500 millisecond frames was thought to be acceptable because there were no examples of rapid saccades back and forth between screens that would potentially change the results; that is, participants tended to look at a screen for several seconds before shifting attention either off screen or to the other screen.

The primary coder coded data for all 23 participants for looking behavior by assigning a code of "right", "left," or "off" to each interval for each of the four video segments. A second coder coded data from five participants. Agreement was attained on 1166 of 1200 intervals. Reliability of the two coders, calculated as proportion of intervals on which both coders agreed over total intervals, was 97%. Both coders were blind to the stimulus conditions (synchronous or asynchronous) on each monitor. Each child yielded four sets of 60 codes; after coding was complete, each set of codes was matched to condition (synchronous/asynchronous) from a master list.

Chapter 4

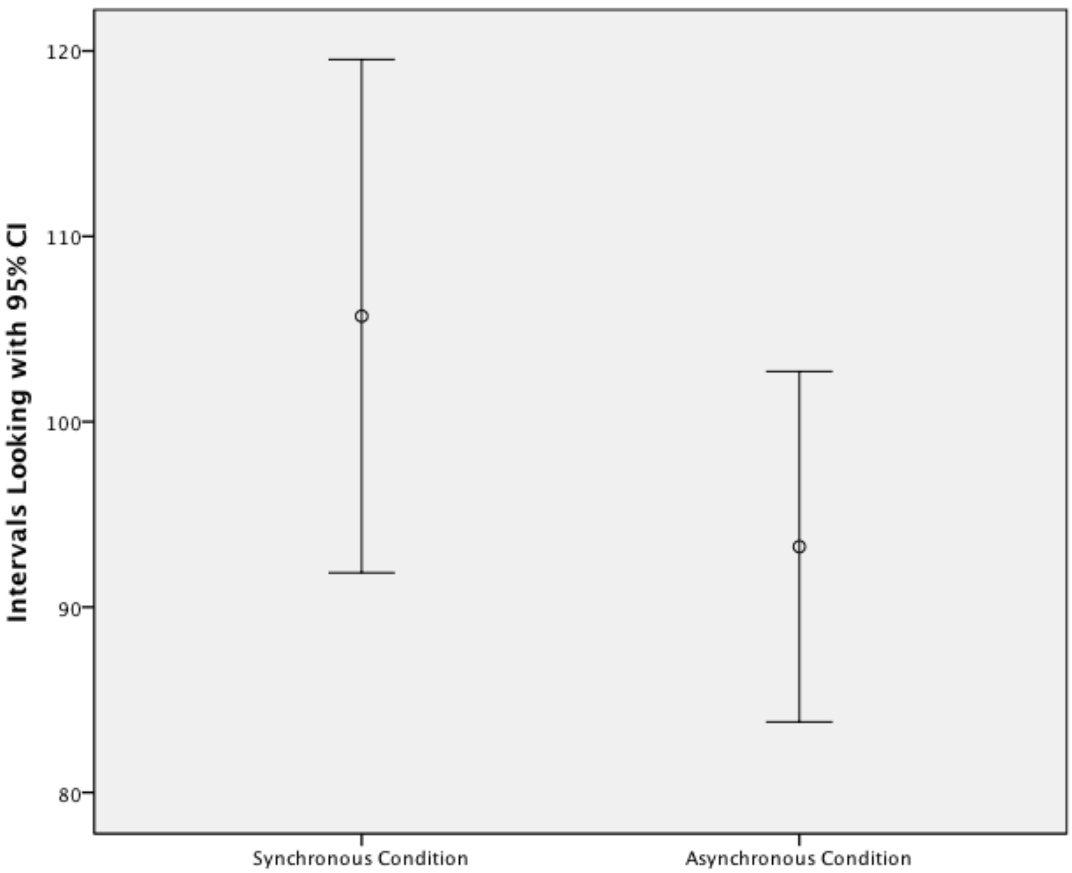
Results

The purpose of the proposed research was to determine if temporal synchrony of spoken words with moving objects results in detection, discrimination and attention to temporal synchrony versus asynchrony. The central hypothesis is that children with autism will demonstrate a preference for temporal synchrony in a linguistic context without faces present, but that preference for synchrony and total looking to video presentation will be related to receptive language. To accomplish this, descriptive statistics first were examined to analyze looking directed toward synchronous and asynchronous conditions as well as looking off-screen, and the data were screened for normality of distributions and outliers. Then a repeated measures ANOVA was conducted using PASW/Statistics 18.0 software. The frequency of looking at each condition was covaried with the frequency of off-screen looks. Effect sizes were also calculated and reported.

Descriptive Statistics

There were 23 participants, each of whom viewed videos in both the synchronous and asynchronous conditions. Each 30-second video segment yielded a total of sixty 500-millisecond intervals; each participant viewed four 30-second clips yielding a total of 240 intervals per participant. Participants' looking time was coded by interval to reflect whether looking was directed at the synchronous condition, the asynchronous condition, or off-screen. Synchronous looking time ranged from 48 to 167 intervals with a mean (SD) of 105.70 (32.02) and 95% confidence interval of 91.85 – 119.54. Asynchronous looking time ranged from 73 to 108 intervals with a mean (SD) of 93.26 (21.86) and a 95% confidence interval of 83.81 – 102.71 (see Figure 4.1).

Figure 4.1: Means and Confidence Intervals by Condition



Data Screening

Examination of histograms for synchronous and asynchronous looking did not suggest that the distributions deviated from normality (Fig 4.2 and 4.3). Further, statistics of skewness and kurtosis (the ratio of absolute values of skewness and kurtosis and respective standard errors less than 2) for both synchronous and asynchronous looking fell within the normal range, again suggesting no significant departure from symmetry.

Figure 4.2: Histogram of Synchronous Looking

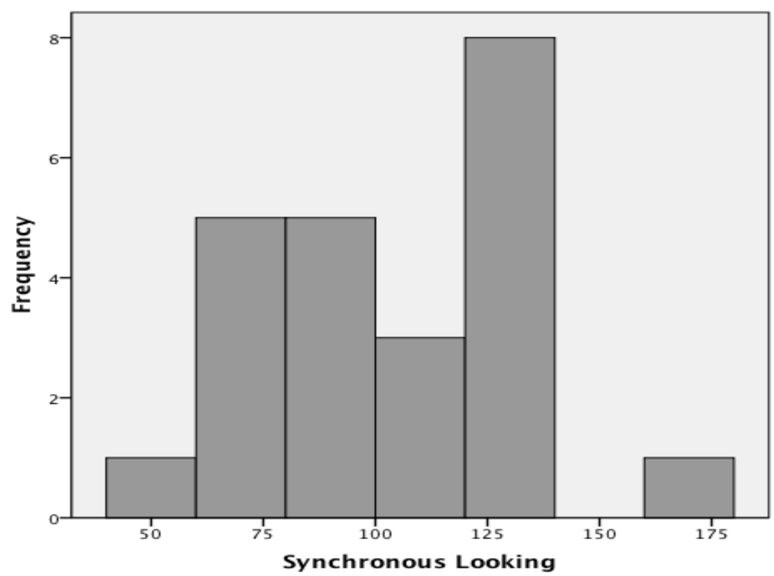
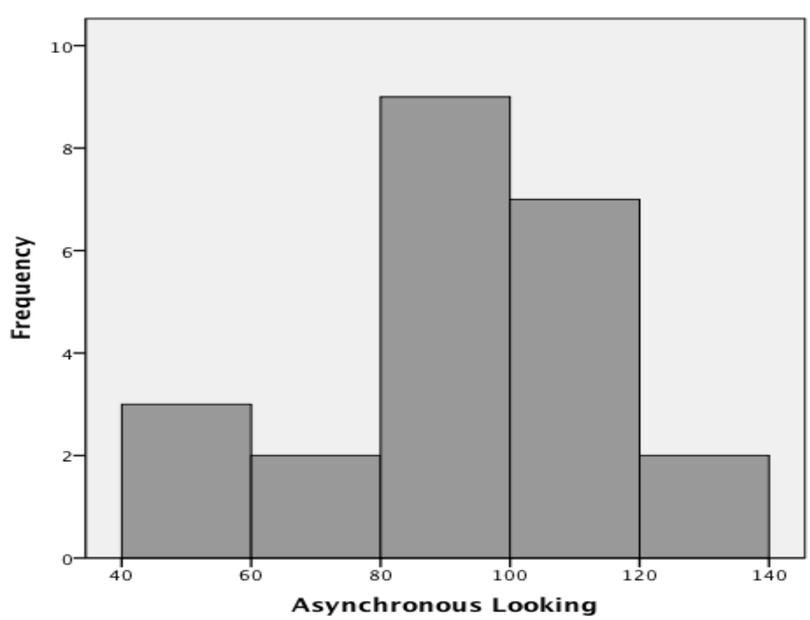


Figure 4.3: Histogram of Asynchronous Looking



These results indicated that distributional assumptions required for a repeated measures ANOVA were reasonable. An additional requirement for conducting repeated measures ANOVA is to assess sphericity. Given that this repeated measures ANOVA contains only two levels (synchronous and asynchronous), the assumption of sphericity is met.

Analysis of Research Question 1

Do children with autism demonstrate attention toward synchronous audio-visual linguistic stimuli presented without faces?

A repeated measures ANOVA was conducted, with the factor being looking condition (synchronous or asynchronous) and the dependent variable being intervals of looking, to determine the extent to which temporal synchrony of multisensory presentations of spoken words with moving objects results in discrimination of temporal synchrony and improvements in attention in young children with autism. Off-screen looking behaviors have been addressed in other studies by either using a proportion of looking time (e.g. Bahrick, 1988; Morrongiello, Lasenby, & Lee, 2003; Spelke, 1976) or requiring a certain amount of looking time to target conditions (Bebko, et al., 2006). In this study, amount of off-screen looking was entered as a covariate, in order to remove the influences of this variable from the comparison of the two conditions. The results show that there was a significant effect of condition on looking time, $F(1, 21) = 3.79$, $p=.027$ (see Table 4.1). Specifically, participants spent significantly more time looking at the synchronous condition compared to the asynchronous condition when controlling for time spent looking off-screen. These results indicate a medium effect size (Cohen's $d = .454$; effect-size $r = .221$). Cook's distances were computed to evaluate the presence of influential cases. No scores above 1.0 were identified, indicating no single cases strongly influenced results.

Table 4.1: Analysis of Variance for Looking Conditions

		Within subjects		
Source	*df*	F	η	*p*
Factor 1	1	5.678	.213	.027
Factor 1 X Off1		3.229	.133	.087
Within group Error	21			

Analysis of Research Question 2

To what extent is the amount of attention to synchrony and total looking to either video presentation related to children's receptive language?

To answer this question, correlations were run between receptive language score age equivalent as well as receptive language ratio (i.e. receptive language age equivalent / chronological age) and looking to synchrony and total time looking to screens. Results revealed significant ($p < .01$) correlations between both types of looking behaviors (to synchrony and total to either video presentation) and receptive language. The amount of time children spent looking to both screens combined was strongly correlated with receptive language and the amount of time children spent looking to synchrony was moderately correlated with receptive language (see Table 4.2).

Summary

These results indicate that when controlling for time spent looking off-screen, children with autism detect, discriminate and demonstrate attention toward temporal synchrony of linguistic stimuli. Children's preference for looking toward synchrony is moderately correlated with their receptive language and their total time spent looking toward presentations of audio-visual linguistic events is strongly correlated with their receptive language.

Table 4.2: Correlations between Looking Behaviors and Receptive Language

	Receptive language age equivalent	Receptive language ratio*
Total looking to screens	.752 **	.734 **
Looking to synchrony	.537 **	.568 **

*Language ratio = receptive language age equivalent / chronological age

** Correlation is significant p<.01

Chapter 5

Discussion

The overarching goal of this research was to determine if multisensory processing could be enhanced in children with autism in order to improve attention to social and linguistic stimuli. The primary goal of this study was to determine if temporal synchrony of spoken words with moving objects would result in detection, discrimination and attention to temporal synchrony versus asynchrony. The secondary goal of this study was to determine the extent to which attention to synchrony and visual presentations in general are correlated with receptive language skills.

This discussion presents a review of the significant findings, their interpretations, and how they relate to the conceptual model presented in chapter one. Then comparisons with other research will be discussed followed by clinical implications, limitations of the study and future research.

Attention to Synchrony and the Conceptual Model

Based on this present study, preschool children with autism demonstrate more visual attention toward synchronous as opposed to asynchronous presentations of linguistic information when accounting for the amount of time they spend looking away from both stimuli. Recall the Lewkowicz (2000) discussion that preferential looking reflects the ability to detect and discriminate synchrony and also requires a choice to direct attention toward synchrony. This sequence is what allows the individual to benefit from temporal synchrony. As mentioned earlier, temporal synchrony is related to improved accuracy of word-object pairing and joint attention skills (Gogate et al., 2006). Also, in the present study, receptive language was positively correlated with looking toward synchrony. These results support the conceptual model described in chapter one.

An early disruption in neural connectivity could result in impairment in multisensory processing including temporal binding. Impairments in multisensory processing are expected to impact processing of both social and nonsocial stimuli with processing of social-communicative stimuli being more impaired given the highly dynamic and unpredictable nature of communication. This in turn could yield unusual responses to sensory stimuli and atypical features of attention, ultimately resulting in more impairment in communication. Likewise, if multisensory processing were more typical, we would expect to see less impairment in both response to temporal synchrony and language. Based on the findings of this study, not only does a correlation exist between receptive language skills and detection, discrimination and attention to temporal synchrony, but there is also a positive correlation between receptive language skills and overall looking to linguistic stimuli. This might be the result of better language learning earlier in development due to more accurate multisensory processing. In other words, better multisensory processing related to a more typical temporal binding window has been functioning developmentally to encourage more typical interaction with the environment; however, the exact nature of the relationship is unclear. Better comprehension may be related to more cognitive control, which allows for better endogenous attention to linguistic stimuli and better ability to detect synchrony in linguistic stimuli. Conversely, better endogenous and exogenous attention may be associated with more typical processing of temporal synchrony and both of these features may yield better linguistic comprehension.

Comparison to Existing Research

Other research has demonstrated that children with autism direct more attention toward synchrony than asynchrony given non-linguistic stimuli such as objects banging together (Bebko et al., 2006), but do not demonstrate a preference given linguistic stimuli paired with visually presented talking faces (Bebko et al., 2006; Bahrick, et al., 2010). Results of the present study indicate that temporal synchrony is detected, discriminated and can elicit more attention than asynchrony when modifications are made to the linguistic context. One modification was that the stimuli used in this experiment did not include faces, which was a deliberate design feature for two reasons. First, children with autism have known deficits regarding face processing (e.g. Monk, et al., 2010; Pierce & Redcay, 2008), yet the presence of faces may not be necessary in order to benefit from linguistic information and may even impede the ability of children with autism to process linguistic information. Second, using object play as the visual stimulus, with movements of the dolls in synchrony with the spoken name, was considered ecologically valid compared to the presence of only a talking head. Young children often engage in play in the presence of materials, and eye gaze is often directed toward the referent during play – certainly not always toward the speaker. Typically developing children in the presence of objects and people (when people are not deliberately engaging with the objects or the child) spend more time attending to objects than attending to people (Swettenham et al., 1998). Also, when children engage in joint attention, they are *monitoring* the gaze of their communication partner (as opposed to engaging in dyadic gaze) in order to share attention toward an object or another person (Carpenter et al., 1998). Therefore, having objects rather than a speaker's face as the visual target is more reflective of natural gaze opportunities. Thus, the finding of the present study that children with autism recognize and attend better to temporal synchrony may be explained by the fact that faces were not part of the stimuli.

The Klin et al. (2008) study supports the notion that attention toward synchrony is observed in a linguistic context when faces are not present. In their study, children with autism detected, discriminated and chose to look toward the synchronous condition when linguistic auditory stimuli were paired with point light animations of human movement (either inverted and backward or upright and forward). When the stimulus was the nursery rhyme "pat-a-cake" with the corresponding point-light animation, the context was linguistic, but it was the clap paired with the visual movement that initially drew attention. Post hoc analysis revealed increased visual attention toward other auditory-visual synchrony that was dependent upon the pairing of movement and sound regardless of whether it was intentional or not (i.e. synchrony may occur between the sound and the inverted condition). Therefore, attention toward synchrony was not related to semantic information within the linguistic stimuli, but rather to synchronous pairing of auditory and visual stimuli (e.g. the clap) even when they were unintentional. Nonetheless, the auditory stimulus was still primarily spoken words without the presence of faces.

Similar to the possibility that the presence of faces resulted in avoidance of looking in other studies, the presence of toys as visual stimuli may have resulted in more attention to the monitors. Having only a face as the stimuli in other studies may not necessarily have resulted in avoidance, but perhaps the addition of toys in this experimental paradigm made the video more attractive to some children, and encouraged their visual attention. Also, the play scenarios were all a form of symbolic play, which is developmentally more mature than other types of play. Therefore, the preference for looking at the linguistic video stimuli may be a reflection of the play themes being more familiar to children with higher receptive language.

Studies of typically developing children led to the expectation that children with lower receptive language skills would show a stronger preference for synchrony than children with higher receptive language skills. As children age from five months to 30 months, mothers use less temporal synchrony when communicating with older children (Gogate et al., 2000). This is thought to reflect a decreased need for scaffolding attention to target word referents as young children age, because older children are able to detect referents without additional cues (Werker, Cohen, Lloyd, Casasola, & Stager, 1998). However, in the present study looking to synchrony was positively correlated with better receptive language. This unexpected finding in the present study may indicate that a factor other than receptive language is influencing attention toward synchrony. Based on the conceptual model, if the temporal binding window is particularly large, the children might fail to detect a difference between synchrony and asynchrony. This is a plausible proposition, given the correlations between receptive language, and detection, discrimination and attention to temporal synchrony. Arguably, it may not be language per se, but the size of the temporal binding window that impacts looking behaviors. Similarly, it could be that children with autism benefit from temporal synchrony beyond the stage that the literature on typically developing children would predict, so they seek out temporal synchrony in order to improve processing.

Clinical Implications

Given that children with autism demonstrate increased attention to synchronous presentations of auditory and visually presented stimuli in a linguistic context, such multisensory presentations can easily be integrated into interactions with young children. Based on literature involving typically developing young language learners, temporal synchrony serves to increase attention, clarify the referent of the spoken word, and yield better learning (Gogate & Bahrick, 1998; Gogate et al., 2000; Werker, Cohen, Lloyd, Casasola, & Stager, 1998). Although unstudied in children with autism, it may hold true that such benefits are available for children with autism as well. Recall that mothers of typically developing children naturally provide multisensory presentations and temporal synchrony to their children, but that those characteristics of their communication decrease as the children age and become better at identifying linguistic targets without additional cues (Gogate et al., 2000). Children with autism may benefit from temporal synchrony far beyond the expected developmental periods, based on their chronological or language age, due to their unique features of attention and sensory responsiveness. Perhaps poorer exogenous attention, difficulty with orienting and disengaging attention, and sensory hyporesponsiveness all yield a deficit that would benefit from implementing multisensory cuing strategies aimed at capturing attention within a linguistic context.

Due to the finding that children with lower receptive language demonstrate less detection, discrimination and attention to synchrony, a means of drawing attention to important stimuli needs to be addressed. Other research indicates that if information is presented in a slowed manner, children with autism are able to process multisensory stimulation better. If this is the case, perhaps temporal synchrony delivered in the manner described in this study could be used but slowed to result in attention toward synchrony. If the child demonstrates attention toward synchrony then perhaps benefits of language intervention could be more effective.

Limitations

This research was designed to study attention to temporal synchrony within a linguistic context. In an attempt to be ecologically valid, objects that were the referents of the linguistic stimuli were dynamically displayed on video. In this study, faces were not shown at all to avoid potential confounds of lip and sound synchrony and the additional challenges related to face processing. However, in natural contexts, faces would be present even though visual attention to them would not necessarily add significant value to the linguistic input for children with autism. So, a more ecologically valid representation might have been to display video that included the face of the speaker along with the objects.

The conceptual model presented in this study proposes that detection, discrimination and attention to temporal synchrony lead to better attention and sensory processing of linguistic stimuli and results in better language and communication. However, the direction of this effect is unclear. It may be that better language processing encourages children to seek temporal synchrony. Further research is needed to explore this relationship.

Future Research

Future research pursuant to the outcomes of this study should include basic research to understand the impact of temporal binding as well as applied research addressing external validity. Regarding basic research, the link between attention to temporal synchrony and the temporal binding window within the autism population should be explored. Individual differences in the temporal binding window related to developmental stages should be correlated with factors such as language, severity of autism, and mental age as well as chronological age. Further, those studies should also correlate behavioral measures of attention to synchrony with the size of the temporal binding window. Findings from such investigations together would provide insight into neurophysiological differences that relate to symptoms of autism as well as shed light on developmental processes that result in the phenotypic expression of autism.

Because it appears that children with lower language demonstrate less attention to synchrony and less time looking toward either video presentation, the habituation/test method (e.g. Bahrick & Lickliter, 2000; Gogate & Bahrick, 1998; Gogate, 2010; Lewkowicz, 2003) of assessing the impact of synchrony might be particularly beneficial for lower functioning children with autism including children who are nonverbal. This method requires habituation to either a synchronous, asynchronous or still audio-visual stimulus. Then a mismatch (i.e. a change in the auditory component) is presented and if the amount of looking is similar to a novelty response, then the specific relationship between the first two components is thought to have been encoded. This would allow researchers to assess whether or not any benefit of temporal synchrony exists regardless of whether or not sustained attention is directed toward synchrony. To date, this method has not been attempted with this population.

To address external validity, the nature of linguistic stimuli should be further explored to assess attention in different linguistic contexts such as with and without faces present. Most importantly, the impact of attention to temporal synchrony on learning should be tested to determine if attention to temporal synchrony serves a similar function to children with autism as it does with typically developing younger children. This type of research can also be used to determine the impact of temporal synchrony in a more natural setting on language learning such as fast-mapping in children with very low language including nonverbal children.

Because other researchers have found a different response to temporal synchrony in social versus nonsocial contexts in typically developing children, differences within the population of children with autism should be further explored. It may be the case that children who demonstrate a particular pattern of differential attention given context will have certain language characteristics; if so, these patterns possibly can be used for diagnostic and prognostic purposes. Perhaps strengths in attention can be explored to determine the most effective means of intervention.

In sum, it follows that children with autism whose attention is captured and sustained by linguistic stimuli will more readily acquire language and demonstrate better participation in social and communicative interactions than children who do not attend well to such stimuli. This study demonstrated that auditory-visual temporal synchrony results in detection, discrimination and attention in a linguistic context in young children with autism, and that their attention is related to their receptive language. Further research on this topic could lead to interventions that boost salience of targets in order to address sensory hyporesponsiveness and atypical attention common among children with autism, ultimately improving social and communicative functioning.

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