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# Discrimination of temporal synchrony in intermodal events by children with autism and children with developmental disabilities without autism

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**Background:** This project examined the intermodal perception of temporal synchrony in 16 young children (ages 4 to 6 years) with autism compared to a group of children without impairments matched on adaptive age, and a group of children with other developmental disabilities matched on chronological and adaptive age. **Method:** A preferential looking paradigm was used, where participants viewed non-linguistic, simple linguistic or complex linguistic events on two screens displaying identical video tracks, but one offset from the other by 3 seconds, and with the single audio track matched to only one of the displays. **Results:** As predicted, both comparison groups demonstrated significant non-random preferential looking to violations of temporal synchrony with linguistic and non-linguistic stimuli. However, the group with autism showed an impaired, chance level of responding, except when presented with non-linguistic stimuli. **Conclusions:** Several explanations are offered for this apparently autism-specific, language-specific pattern of responding to temporal synchrony, and potential developmental sequelae are discussed. **Keywords:** Attention, auditory-visual perception, autistic disorder, information processing, intermodal processing, language.

Autism is the most severe of the pervasive developmental disorders and is characterized by deficits in communication and social behaviors, and by the presence of stereotyped, repetitive movements (American Psychiatric Association, 1994). Although these behaviors represent the minimum necessary requirements for a diagnosis of autism, there are other characteristics commonly associated with the disorder such as hyper- and/or hypo-sensitivities to certain sensory stimuli, difficulties with direct eye contact, poor imitation skills, and repetitive self-stimulatory behavior involving the senses (reviewed in Klinger & Dawson, 1996).

These associated impairments are consistent with suggestions of ineffective processing of sensory input in individuals with autism (Grandin, 1996; Waterhouse, Fein, & Modahl, 1996). Moreover, some of the deficits are consistent with impairment in the ability to organize the input received through multiple sensory modalities, a process known as intermodal perception (Walker-Andrews, Haviland, Huffman, & Toci, 1994). However, some of the early research in this area yielded results that were indirect or equivocal in nature (e.g., Kolko, Anderson, & Campbell, 1980; Lovaas, Schreibman, Koegel, & Rehm, 1971). Therefore, there is a strong need for clear and well-conducted examinations into the intermodal processing abilities of young children with autism.

The development of auditory-visual intermodal perception in typically developing children has been extensively researched using the preferential looking technique (Spelke, 1976). This technique involves 2 side-by-side visual displays, with sounds from one centrally located speaker corresponding to only one of the visual displays. The child is placed in front of the apparatus and the degree to which the child observes the sound-matched display versus the non-matched display is recorded. Intermodal perception is considered to be present in the child if there is non-random preferential looking (i.e., greater than chance) towards one of the screens, either sound-matched or not. The underlying assumption of the paradigm is that if participants are able to discriminate the information common to the auditory and visual stimuli, their looking behaviors will be influenced by the auditory stimulus and will be significantly different from the pattern of looking expected if the auditory stimulus was not uniquely linked to either visual stimulus in any way – that is, 50% of looking time given to both displays.

Studies of preferential looking in typically developing infants have shown that 3–4-month-old infants are capable of coordinating auditory-visual intermodal information, particularly when the stimuli involve non-arbitrary, naturally occurring events (Dodd, 1979; Kuhl & Meltzoff, 1982; Spelke, 1976, 1979). Temporal synchrony, the congruence in time of sights and sounds, has been found to be crucial for this unified perception of events (Gibson, 1969; Lewkowicz, 1994).

There have been a number of studies on the relation between temporal synchrony in intermodal processing and factors associated with language development. By 10–16 weeks of age, infants relate


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dynamic faces and voices on the basis of voice-lip temporal synchrony (Dodd, 1979; Spelke & Cortelyou, 1981, Experiment 2), and soon recognize the connection between facial movements and speech sounds (Bahrick, 1983, Experiment 4; Kuhl & Metzoff, 1988). It also appears that 3- to 4-month-old infants use both the sounds and sights of speech to imitate adult speech (Legerstee, 1990). The detection of temporal synchrony by pre-linguistic infants has been shown to be helpful for early lexical development, by uniting spoken labels with visual objects, and has been suggested to provide 'a basis for initially linking words and their referents' (Gogate & Bahrick, 1998, p. 136). It appears clear from these studies, then, that intermodal perception assists infants in the discrimination of segments of the speech signal, which is a necessary step for language acquisition.

In summary, typically developing infants are capable of integrating a wide variety of auditory-visual information. Beginning as young as four months of age, infants have exhibited intermodal perception with both linguistic and non-linguistic stimuli. When processing intermodal information, infants are sensitive to the synchronization of the auditory and visual signals. However, there is equivocal information on how children with autism respond to intermodal sensory information.

In an early study in the field of autism and perceptual dysfunction, C.Q. Bryson (1970) gave 6 children with autism, aged 4 to 8 years, a matching-to-sample task. The children performed better on tasks that required unimodal processing (i.e., visual–visual or auditory–auditory matching) versus those that required the children to use intermodal perception. A second study indicated that intermodal perception deficits were most apparent when stimuli were composed of words (Bryson, 1972). Although these studies are limited due to small sample sizes and lack of comparison groups, they provide a basis to suggest that children with autism have deficits in intermodal perception and that impairments in auditory-visual intermodal perception might be related to difficulties with processing language.

Recent research has shown that the preferential looking paradigm is a useful method for examining intermodal perception in children with autism (Walker-Andrews et al., 1994). The paradigm requires no or few instructions, and does not entail any kind of newly learned response, reducing the language and cognitive demands placed on participants. It is a non-intrusive method of collecting information about perceptual abilities. Although originally designed for use with infants, the preferential looking paradigm has also been used successfully with older children, to test language comprehension in typical children from 1.4 to 4 years of age (Hirsh-Pasek & Golinkoff, 1996; Golinkoff, Hirsh-Pasek, Cauley, & Gordon, 1987) and in children with motor impairments and intellectual delays up to 6.5 years of age (Cauley, Golinkoff, Hirsh-Pasek, & Gordon, 1989).

In the first study of this kind, Walker-Andrews and colleagues (1994) showed participants taped visual stimuli of 8 pairs of different physical events such as dropping marbles into a cup, or a popping toy lawnmower being pushed across a table surface. There were significant differences in looking time depending on which of the varied visual stimuli was presented. However, for 5 of the 8 events, the participants looked at the sound-matched stimuli significantly longer than chance. While the authors concluded that children with autism have some capacity for intermodal perception, it is difficult to generalize these findings because of a wide participant age range (2–20 years) and the fact that no comparison group was assessed.

Other studies have examined the intermodal capabilities in people with autism with respect to emotion perception. Loveland and colleagues (1995) asked participants with autism or Down syndrome to choose which of two faces affectively matched a soundtrack. Taking chronological age and verbal mental age into account, the authors found that the people with autism had more difficulty than those with Down syndrome, although both groups demonstrated intermodal matching. Another study assessed whether children with autism would show looking preferences when presented with 2 facial expressions, with only one corresponding to the centrally-presented auditory expression (Haviland, Walker-Andrews, Huffman, Toci, & Alton, 1996). People with autism (aged 3 to 20 years) were compared to a small group of 6 typically developing peers matched for mental age. Results indicated that the people with autism demonstrated the same pattern of looking as their peers, although they did spend less time overall looking at the screens. Both groups only demonstrated significant preferential looking toward the sad expression when presented with the sad soundtrack, but did not demonstrate significant intermodal matching with any other expressions. Again, these results must also be interpreted with caution, as the sample with autism spanned a very wide age range, and there were only 6 typically developing children.

As can be inferred from this brief review, there have not been any clearly conclusive explorations into the intermodal perceptual abilities of young children with autism. Previous research has used groups of people with autism from various ages, a range of stimuli, and has failed to include appropriate comparison groups. Research to date has also not examined the role of temporal synchrony in auditory-visual intermodal perception in children with autism, despite the importance attributed to it in normal development. The present study specifically isolated the variable of temporal synchrony. A preferential looking paradigm was utilized and performance by young children with autism (aged 4–6 years) was compared to that of typically developing children and children with other forms of developmental disability, matched on general developmental level.

Using the preferential looking paradigm with 3 types of stimuli (non-linguistic, simple linguistic, complex linguistic), our hypothesis was that children with autism would show a lesser degree of intermodal perception than children with other forms of developmental disability, and non-handicapped peers. It was expected that the participants in the comparison groups would show intermodal perception of auditory-visual temporal synchrony by preferentially looking towards the synchronous display, but not the children with autism. In particular, considering the communication deficits in autism, we expected that children with autism would show less awareness of temporal synchrony during linguistic events compared to non-linguistic events.

## Method

### *Participants*

Three groups of children participated in the study. None of the participants had any known sensory abnormalities in either the visual or auditory modalities, based on parental report. All children were either from homes where English was native or where English was spoken. See Table 1 for a summary of the participants.

The first group contained 16 children with a prior primary diagnosis of autism or PDD, between the ages of 4.6 and 6.1 years ($M = 5.4$ years, $SD = .5$). These participants were recruited through local agencies serving persons with special needs and their families, and had been previously diagnosed according to DSM-IV criteria by a registered psychologist or developmental pediatrician familiar with autism. To verify the diagnosis and quantify the severity of autism, a psychologist, psychology-trained assistant, or developmental pediatrician completed the Childhood Autism Rating Scale as part of this study (CARS; Schopler, Reichler, & Renner, 1992, and described further below). Participants' CARS scores ranged from 30.0 to 56.0 ($M = 41.8$, $SD = 7.5$), indicating that all were in the autism range. Overall adaptive level for each child was determined by calculating the average of age equivalency scores from the Vineland Adaptive Behavior Scales (Sparrow, Balla, & Cicchetti, 1984). Participants' age-equivalent functional levels (hereafter referred to as 'functional level') ranged from 1.1 to 2.9 years of age ($M = 2.3$ years, $SD = .6$), see Table 1. The Vineland Communication Scale age equivalencies were also used separately as an estimate of the children's adaptive language level, and ranged from .8 to 3.1 years ($M = 2.1$ years, $SD = .6$), as indicated in the table.

These functional-level data were used for matching of the comparison samples based on a fairly broad range of developmental skills. Klin and colleagues (1997) have noted that level of adaptive functioning is sometimes lower than measured intellectual level for children with autism. If that is the case, then matching on functional level could yield an autism sample with somewhat higher intellectual skills than the matched samples, whose adaptive levels would tend to be closer to intellectual level. Although a link with intellectual or mental age level has never been made for this task, since it is also used with infants, if intellectual difference does have any effect, it should work against our hypotheses that children with autism will perform more poorly on this task.

Therefore the children with autism were matched based on average functional level and chronological age to a group of 15 children with developmental disabilities (DD group). Since the etiology of autism is presently unknown, but thought to be heterogeneous or multiply determined (e.g., Waterhouse et al., 1996), an appropriate group of developmentally disabled children was those whose etiologies are due to unknown or a heterogeneous range of causes. This comparison group of children was heterogeneous in terms of diagnoses, with the exclusion of PDD or any known sensory or perceptual abnormalities. The group was composed of one child each with Fragile X Syndrome, Hydrocephalus, and Prader-Willi Syndrome, 6 children with Down Syndrome and 6 of unknown etiology. Since the number of children with Down Syndrome represents a substantial subgroup within the sample, potential differences between their results and the rest of the sample are evaluated in a series of pre-analyses. Families were reached through the aid of Community Living Toronto and the City of Toronto's Children's Services Division. The DD group's chronological ages ranged from 4.1 to 6.5 years ($M = 4.9$ years, $SD = .7$) and their age-equivalent functional ages from 1.1 to 3.3 years ($M = 2.1$ years, $SD = .6$). The DD group did not significantly differ from the group with autism in terms of average functional level or linguistic ability ($p$'s > .05), but did differ in age, $F(1, 29) = 7.53$, $p = .01$, indicating that the DD group was a slightly younger sample, although the difference between the means of the two groups was approximately 7 months.

Because the preferential looking paradigm had not been previously used with typically developing children over one year of age, an additional sample of non-handicapped children was tested to serve as a benchmark for the effectiveness of the paradigm. Sixteen children were recruited from day care centers and a nursery school in Toronto at ages that approximated the

**Table 1** Age and age equivalents data by group

| | Autism group ($n = 16$) | DD group ($n = 15$) | NH group ($n = 16$) |
|---|---|---|---|
| Chronological age | | | |
| M | 5.49 | 4.88 | 2.36 |
| SD | .51 | .72 | .68 |
| Range | 4.6–6.1 | 4.1–6.5 | 1.7–4.2 |
| Vineland Total | | | |
| M | 2.26 | 2.13 | |
| SD | .58 | .64 | |
| Range | 1.1–2.9 | 1.1–3.3 | |
| Vineland Communication | | | |
| M | 2.10 | 2.14 | |
| SD | .62 | .76 | |
| Range | .8–3.1 | .9–3.6 | |

functional levels of the children with autism, to yield a sample of roughly similar developmental level (NH group). It was assumed that normal variability in functional levels approximately above and below the children's ages would offset one another across the sample. The age distribution of the resulting sample was compatible to the functional-level distribution of the children with autism ($M = 2.4$ years, $SD = .7$, ranging from 1.7 to 4.2 years).

### Measures

*Childhood Autism Rating Scale (Schopler et al., 1992).* The CARS is a well-established instrument for identifying the severity of autism. It has 15 symptom subscales on which the child is rated on a 7-point scale, from normal to severely affected, to differentiate autism from other PDD disorders (Sponheim, 1996) and general developmental disability. Several studies have reported good interrater reliability, internal consistency (Perry & Freeman, 1996), and discriminant validity (Garfin, McCallon, & Cox, 1988). The CARS also has excellent concurrent reliability detecting the presence/absence of autism with expert clinical diagnoses (.87 agreement in a sample of 1520 clinic children [Schopler, et al., 1992]).

*Vineland Adaptive Behavior Scales (VABS; Sparrow et al., 1984).* This is a well-known measure of adaptive behavior and is highly correlated with other measures of independent behavior (Middleton, Keene, & Brown, 1990). It has good psychometric validity and is clinically useful for people with autism (e.g., Perry & Factor, 1989). In the present study, the VABS had been completed for all children with autism or other developmental disabilities within the 6 months prior to the experimental testing.

### Apparatus

The design of this experiment was based on the preferential looking paradigm of Spelke (1976). Two 50-cm television monitors were placed side by side on a low table at a distance of one meter from the participants' chair. Each had a split-screen visual display with only the outer half of each screen exposed, ensuring a sufficient distance (60 cm) between the visual stimuli to accurately discriminate eye movements. A black cloth occluded the inner halves of the television monitors, and the rest of the apparatus. The auditory stimulus was presented from a speaker located between the 2 televisions. A video camera was placed between the televisions to enable recording of the children's looking behaviors; only the lens was visible through the black cloth. The camera also captured the reflections of the television monitors from a mirror placed behind the participants' chair. Participants sat behind a low table such that the stimuli were presented at approximately participant eye level.

### Stimuli

An initial 18 sec. master auditory-visual segment was recorded for each of the three stimulus types: (a) non-linguistic event, (b) simple linguistic event, and (c) complex linguistic event. These segments were then used to construct the split-screen images.

The non-linguistic (NL) event was a video recording of the children's game 'Mousetrap', where a ball moves through a series of plastic ramps and cliffs, generating various sounds as the ball rolls, drops, and impacts against other objects along the course. This stimulus type allowed for the opportunity to assess auditory-visual intermodal perception abilities without language. The simple linguistic (SL) event was intended to be a familiar event, with a woman counting forwards from the number 'one' at a rate of approximately one number per 1.5 seconds. For the complex linguistic (CL) task, the same woman told a story (an abridged version of *Kitty's Clothes* by Amye Rosenberg, 1984). In both cases, only the woman's head and shoulders appeared. The CL task represented a more complex and unfamiliar stimulus than the SL event.

A pause segment was also recorded. Visually, it was composed of 3-seconds of black screen and was coupled with three 1-second tones. The pause segment acted as a cue between the stimulus clips to reorient the participants' looking toward the center. During the pause a noise-making toy appeared between the television monitors as a fixation point prior to each new trial.

### Procedure

Two series of stimuli were generated: one familiarization phase and one test phase. During the familiarization period, participants viewed two identical video segments from the same stimulus event with the auditory track in synchrony with both displays. This allowed the participants to become comfortable with the procedure and provided information as to whether any of the children had any inherent looking preference to either side. The participants viewed the complete 18-second master segments for all three stimulus types each separated by a 3-second pause segment. The order of presentation was randomly varied.

During the test phase, two different video segments from the same stimulus event (one segment with the audio and visual synchronized, and one with the same video component either advanced or delayed) were shown on the separate television monitors, with the auditory track matching only one of the visual stimuli. The test phase stimuli differed solely on the basis of temporal synchrony. For each of the three stimulus categories, three shorter clips (12 seconds in length) were edited from the 18-second master segments. Specifically, the first 12 seconds were made into the Advanced (A) out-of-synchrony clip, and the final 12 seconds of the tapes were made into the Delayed (D) out-of-synchrony clip; in both cases, the corresponding auditory track was eliminated. The middle 12 seconds of the tapes comprised the Synchronized (S) clip, accompanied by the matching auditory track. The A and D clips were created in order to counterbalance the direction of asynchronous information viewed by the participants. The visual portion of the resulting asynchronous tracks was offset from the auditory track by three seconds. A viewing sequence was randomly generated with the following constraints: no more than two trials of any one stimulus type were presented consecutively, and each monitor displayed no more than two consecutive synchronous events. A second viewing sequence was created in the inverse order of the first to control for potential order of presentation effects. Half the participants in each sample were given each viewing sequence.

Informed consent from the children's parents was received prior to testing the participants. The experimental session was approximately 10 minutes in length, beginning with a familiarization phase and ending with a test phase. The participants were brought into the room with the apparatus and instructed simply to 'watch TV'. For some children, an experimenter remained behind the children during the testing to ensure that they watched the TVs and to encourage them to remain in the chair. Another experimenter controlled the VCRs, camera, and noise-making toy.

The videotaped recordings of participants' eye movements were coded using the Noldus Observer software. Trained observers coded when participants (a) looked to the left screen, (b) looked to the right screen, or (c) looked to neither screen. Interrater reliability of coding was first established with pilot participants. Coding fidelity was then checked on 10% of participants in the study from each group (i.e., 2 from each group = 6 participants in total) and was calculated by comparing the duration and direction of participants' viewing behaviors, allowing for a deviation of .2 seconds between coders. The coding of eye movements was reliable, with an overall mean agreement of .94 (range .78 to 1.00). The few discrepancies that existed were easily resolved with discussion.

For each stimulus type (NL, SL, CL), consecutive 12-second trials were coded until a total of 15 seconds of looking time to either display was accumulated across trials for each participant. Ensuring that each participant viewed the stimuli for 15 seconds permitted controlled comparisons of the proportion of looking time to the synchronous and asynchronous screens based on exactly the same viewing duration. For example, while one participant may watch the monitors for only 8 out of the 12 seconds (per trial), another child may spend 11 seconds viewing the two screens. Accumulating 15 seconds of viewing time for each subject provided a standard to enable clear comparisons across participants. Therefore, total length of viewing per stimulus type is the sum of the two dependent variables = total looking time at both screens + total looking away time.

## Results

Because a substantial minority of participants in the DD group had the identification of Down Syndrome (6 out of 15), this subgroup was analyzed separately and compared with the remaining DD participants prior to each analysis. Since none of the initial analyses indicated a significant difference or interaction, the data are reported for the combined DD group throughout.

### *Familiarization phase*

*Inherent looking preferences to side.* Possible inherent looking preferences were tested in a two-way repeated measures ANOVA, examining the proportion of total looking time spent looking to the left screen, with stimulus type as a three-level within-subject factor (NL, SL, CL), and group as a three-level between-subject factor (Autism, DD-matched, NH). As expected, neither the stimulus type main effect, group main effect, nor interaction were significant, $F(2, 84) = 2.96$, $F(2, 42) = .44$, and $F(4, 84) = .23$, all $p$'s > .05, respectively.

To ensure that no screen side preferences existed for each group, and not merely in difference to each other, proportions of looking time to the left screen across stimulus type were compared to chance in one-sample $t$-tests, between and across groups. Differences between PLT-Left and chance (.5) were not significant for participants across groups: $t(46) = -1.54$, $p = .13$, for the group with autism; $t(15) = -.30$, $p = .77$, for the NH group; $t(15) = -.60$, $p = .56$, for the DD-matched group; $t\ (14) = -1.63$, $p = .13$.

*Looking away behavior.* Total Looking Time Away (TLT-Away) was entered as the dependent variable in a 3 (group) × 3 (stimulus type) repeated measures ANOVA. Results indicated a significant stimulus type main effect, $F(2, 86) = 7.76$, $p = .001$ (see Table 2). There were no significant effects for group, $F(2, 44) = .02$, $p = .99$, or for the Group × Stimulus type interaction, $F(4, 86) = 1.62$, $p = .17$. Post hoc analysis of the stimulus type main effect, using Bonferroni adjustment, revealed that participants looked away significantly more during the CL event compared to the NL event, $M$ Difference ($MD$) = 1.56, $p = .008$ and compared to the SL event, $MD = 1.30$, $p = .009$. There was no significant difference, however, between the NL and SL events, $MD = .27$, $p = 1.00$.

To evaluate whether looking away times for the linguistic stimuli were related to communication skills, two-tailed Pearson product–moment correlations were calculated between the autism group's

**Table 2** Familiarization phase: mean duration looking away (seconds) for the autism, NH, and DD-matched groups by stimulus type

| Stimulus type | Group | | | |
|---|---|---|---|---|
| | Autism ($n = 16$) | NH ($n = 16$) | DD ($n = 15$) | Total |
| Non-linguistic | | | | |
| *M* | 1.22 | 1.79 | 2.63 | 1.86 |
| *SD* | 1.72 | 1.21 | 2.24 | 1.81 |
| Simple linguistic | | | | |
| *M* | 2.38 | 2.13 | 1.96 | 2.16 |
| *SD* | 1.81 | 2.12 | 1.55 | 1.81 |
| Complex linguistic | | | | |
| *M* | 3.97 | 3.63 | 2.77 | 3.46 |
| *SD* | 3.52 | 2.77 | 1.69 | 2.75 |
| Total | | | | |
| *M* | 2.46 | 2.52 | 2.18 | |
| *SD* | 1.71 | 1.42 | .98 | |

age equivalents for the VABS Communication subscale and their TLT-Away values during the SL and CL events. A significant inverse relationship was found for the CL event, $r$ (16) = −.65, $p$ = .009. For the simple linguistic event, the inverse relation was also found, but it was not statistically significant, $r$ (16) = −.32, $p$ = .23. To test whether the significant correlation was related to autism *per se*, or to a general developmental disability, the corresponding correlations between the DD-matched group's looking away times to linguistic events and their VABS Communication scores were calculated. No significant correlations were found for either the SL, $r$ (14) = .03, or CL event, $r$ (14) = .17, both $p$'s > .50. Thus, the relation exists only for children with autism, and most strongly with the more complex linguistic stimuli.

Two-tailed Pearson product–moment correlations between participants' CARS scores and their TLT-Away times during the three events types revealed no significant correlations (all $p$'s > .47), indicating that looking away from the stimuli was not related to the severity of autism. Similarly, age was found to be unrelated to looking away for each event type (all $p$'s > .40).

### Test phase

*Looking away behavior.* The test phase differs from the familiarization phase by the added manipulation of violation of temporal synchrony, where one of the two visual clips is now asynchronous with the audio signal. As in the analyses of familiarization data, looking away time during the test phase was defined as the total duration of looking to neither screen.

Total Looking Time Away (TLT-Away) was examined in a 3 (group) × 3 (stimulus type) repeated measures ANOVA. Results indicated a significant stimulus type main effect, $F(2, 88) = 3.82$, $p = .03$, shown in Table 3. However, there were no significant effects for group, $F(2, 44) = .45$, $p = .64$, or for the Group × Stimulus type interaction, $F(4, 88) = 1.32$, $p = .27$. Post hoc analysis of the stimulus type main effect, using Bonferroni adjustment, revealed that participants looked away significantly more during the SL event compared to the NL event, $MD = 4.06$, $p = .007$. The differences between the SL and the CL events, $MD = 1.47$, $p = 1.00$, and the NL and CL events, $MD = 2.59$, $p = .29$, were not significant.

**Table 3** Test phase: mean duration looking away (seconds) that occurred while accumulating 15 sec of looking time for the autism, NH, and DD-matched groups by stimulus type

| Stimulus type | Group | | | Total |
|---|---|---|---|---|
| | Autism ($n$ = 16) | NH ($n$ = 16) | DD ($n$ = 15) | |
| Non-linguistic | | | | |
| *M* | 1.54 | 2.55 | 5.77 | 3.24 |
| *SD* | 1.53 | 1.80 | 6.26 | 4.13 |
| Simple linguistic | | | | |
| *M* | 8.98 | 6.49 | 6.69 | 7.40 |
| *SD* | 8.97 | 7.08 | 7.01 | 7.67 |
| Complex linguistic | | | | |
| *M* | 8.29 | 4.36 | 3.18 | 5.32 |
| *SD* | 16.59 | 5.29 | 2.95 | 10.31 |
| Total | | | | |
| *M* | 6.27 | 4.47 | 5.21 | |
| *SD* | 7.75 | 3.57 | 3.18 | |

Although there was no main effect for group, the children with autism looked away more from the two linguistic stimuli than the other groups. We evaluated the possibility that for the children with autism, asynchrony in a linguistic display might in some way be an aversive stimulus, versus simply a non-preferred stimulus, leading to more looking away behavior. If this was the case, more aversive reactions (looking away occurrences) should be observed after participants with autism looked at the asynchronous displays (which were different from the familiarization phase) than the synchronous displays (similar to the familiarization phase). The frequency of looking away behavior after looking at the asynchronous vs. synchronous displays was coded for each participant, and paired samples $t$-tests were calculated for each stimulus type. Results revealed no significant difference between the frequency of looking away after looking at the synchronous versus asynchronous displays for the NL, SL, or CL events, $t$ (15) = .32, $t$ (15) = .00, $t$ (15) = −.98, respectively, all $p$'s > .10.

*Response to temporal asynchrony.* Because participants' looking times to the two screens are standardized out of 15 seconds, Total Looking Time toward the synchronous screen (TLT-Synch) is by definition the proportional inverse of Total Looking Time toward the asynchronous screen (TLT-Asynch). Therefore, any significant differences found using one dependent variable also reflect a significant difference in the other.

To examine whether children with autism are impaired in their discrimination of temporal synchrony compared to peers, TLT-Synch values were analyzed in a two-way (group by stimulus type) repeated measures ANOVA. To also provide a test of preferential looking compared to chance, an additional virtual group of participants was added, representing a sample of participants whose TLT-Synch performance was at chance level, or 7.5 sec. (i.e., the 50% chance level of 15 seconds of total looking time). Thus, group was a four-level between-subject factor (Autism, NH, DD-matched, Chance groups) and stimulus type was a three-level within-subject factor (NL, SL, CL). Tests of the homogeneity of variance and covariance were not significant ($p$'s > .10), so no epsilon adjustments were required.

Results of the ANOVA showed a significant main effect for stimulus type, $F(2, 88) = 6.92$, $p = .002$, and for group, $F(2, 44) = 6.04$, $p = .005$, and a nonsignificant Group × Stimulus type interaction,

**Table 4** Participants' looking durations to synchronous displays in seconds (and percent of 15 seconds) by group and stimulus type, with one-sample *t*-scores comparing response duration to chance

| | Group | | | |
|---|---|---|---|---|
| Stimulus type | Autism ($n = 16$) | NH ($n = 16$) | DD ($n = 15$) | Mean across groups |
| Non-linguistic | | | | |
| *M* | 9.04 (60%) | 9.67 (65%) | 10.76 (72%) | 9.80 (65%) |
| *SD* | 2.70 | 3.54 | 3.02 | 3.03 |
| *t* | 2.28* | 2.45* | 4.71** | |
| Simple linguistic | | | | |
| *M* | 7.56 (50%) | 8.59 (57%) | 9.41 (63%) | 8.50 (57%) |
| *SD* | 2.69 | 2.71 | 2.64 | 2.73 |
| *t* | .09 | 1.61$^{+}$ | 2.81* | |
| Complex linguistic | | | | |
| *M* | 7.29 (49%) | 8.61 (57%) | 8.3 (56%) | 8.08 (54%) |
| *SD* | 1.88 | 1.72 | 2.14 | 1.96 |
| *t* | −.45 | 2.58* | 1.55$^{+}$ | |
| Mean across stimuli | | | | |
| *M* | 7.96 (53%) | 8.96 (60%) | 9.51 (63%) | |
| *SD* | 1.54 | 1.42 | 2.14 | |
| *t* | 1.13 | 4.09** | 3.87** | |

$^{+}p < .10$; $*p < .05$; $**p < .01$.

$F(4, 88) = 1.09$, $p = .37$.[1] Table 4 reports each group's mean duration spent looking to the synchronous screen by stimulus type and overall. Values more than 7.5 sec indicate a preference for the synchronous auditory-visual displays, and less than 7.5 sec a preference for the asynchronous displays.

Post hoc analyses with Bonferroni adjustment found that the DD group and the NH group differed significantly from the virtual sample (i.e., chance value of 7.5 sec.), with mean differences of 2.01 sec. ($p = .002$) and 1.46 sec. ($p = .04$), respectively. In contrast, the Autism group did not show a significant difference from chance, $MD = .47$, $p = 1.00$. The Autism sample showed less preference than the DD group, $MD = -1.54$, $p = .03$, and the NH group, although the latter difference approached significance only with the Fisher's LSD, $p = .10$, but was not significant with the Bonferroni adjustment, $MD = -.99$, $p = .34$ . The NH and DD groups did not differ from each other, $MD = .55$, $p = 1.00$. Post hoc analysis of the Stimulus type main effect with Bonferroni adjustment found that participants showed the strongest preference for synchrony during the Non-linguistic event compared to both the Simple and Complex Linguistic events, $MD = .98$, $p = .04$, and $MD = 1.31$, $p = .004$, respectively. The two linguistic events did not differ from each other, $MD = .33$, $p = .93$.

The primary hypothesis for the study was that the preferential looking for the group with autism would likely be at random levels (i.e., no preference for the synchronous or asynchronous screen) for each stimulus type, but with the strongest effect for the linguistic stimuli, while the comparison groups' preferential looking would be different from chance, and directed toward the synchronous display. To examine these specific *a priori* hypotheses more directly, one-sample *t*-tests were calculated to determine if participants' preference for the synchronous information was significantly different from chance within each group. As shown in Table 4, the group with autism showed essentially random looking during the two linguistic events ($p$'s > .10) but showed significant preferential looking during the non-linguistic event ($p = .02$). In contrast, the NH group displayed preferences for the synchronous displays for each individual stimulus type (NL and CL $p$'s = .01, SL $p = .06$). The DD-matched group also displayed significant non-random looking for the NL ($p < .001$) and SL ($p = .005$) events, and the CL event approached significance ($p = .07$). The borderline nature of the DD group's CL finding and NH group's SL finding may simply be due to the sample size not providing sufficient statistical power.

Pearson product–moment correlations were calculated between the Autism group's VABS age equivalents, CARS scores, chronological age, and the duration looking to the Synchronous screens (TLT-synch) for each stimulus type. Results showed no significant associations between any of the individual characteristics and looking time ($p$'s > .17), indicating that degree of autism, functional level, and age did not mediate children's preference. Similar patterns were found for the NH children for age (all $p$'s > .44) and for the DD children for age and VABS scores (all $p$'s > .14).

## Discussion

This study was the first to systematically investigate the discrimination of temporal synchrony in a group of young children with autism compared to their

[1] In order to avoid artificially inflating the possibility of significance due to the insertion of the virtual (chance) group, critical *F*'s were found using the degrees of freedom without the virtual group.

typically developing peers and a group of children with other forms of developmental disability but no autism. We found that with a limited age range of participants, well-matched comparison groups, and a focus on temporal synchrony discrimination, the children with autism did have a deficit in intermodal perception specific to the processing of linguistic stimuli.

This research also confirmed that the preferential looking paradigm is a useful technique for assessing intermodal perception in children beyond infancy with and without disabilities. The procedure was very simple, required no conscious communicative responses from participants, and the children seemed to enjoy the experience. As in the Walker-Andrews and colleagues (1994) study with children with autism, neither chronological age nor functional level was correlated with performance during the experimental sessions, and all participants were able to complete the procedure. Furthermore, the results from this study are similar in form to findings from research using the preferential looking paradigm with typically developing infants, thus showing developmental continuity across ages. As with other children, our NH and DD-matched groups spent approximately 61% of their overall total looking time across stimulus types attending to the temporally synchronous displays.

For these two groups, both the direction of participants' preference and the proportion of preferential looking were similar to the typical sound-matched preferences found in infant studies. The consistent finding in the literature is that infants show small, yet significant, preferences on sound-matching tasks. For example, Spelke (1976) found that 4-month-old infants spent 64% of their total looking time to synchronous and sound-matched auditory-visual events. Likewise, when 6-month-old infants were presented with male and female faces and voices, they looked 58% and 54% of the time to the appropriately matching pairs (Walker-Andrews, Bahrick, Raglioni, & Diaz, 1991). When compared to previous research that manipulated temporal synchrony only (Bahrick, 1983, Experiment 4), the comparison groups' degree of preference is strikingly similar, showing a 60% preferential looking rate. Thus, we are confident that the preferential looking paradigm provided accurate information about intermodal perception in the three groups of children who participated in this study.

The typically developing children in the NH group showed significant preferential looking when presented with all three stimulus types: non-linguistic, simple linguistic and complex linguistic. This indicates that a typical child of about 2 to 4 years of age prefers to look at a synchronous auditory-visual display, regardless of the content.

For children with autism, the same thing occurs for non-linguistic stimuli, albeit somewhat less strongly. The children with autism looked at the non-linguistic synchronous display for 60% of the time vs. 65% and 72% for the other groups. However, for linguistic stimuli, the children with autism responded with no clear screen preference, much as in the familiarization phase, when no temporal asynchrony was present. There are several possibilities to account for this response pattern. One possibility is that the children with autism do not detect the violation of synchrony in the test phase for linguistic stimuli. A less extreme version of this interpretation is that they are slow to detect violations, and the trials were not of sufficient duration to enable them to do so. For example, the nature of the language impairment in autism may be such that the importance or saliency of temporal synchrony is not recognized. Therefore, violations are not detected, or at least require a longer exposure than for children without autism to detect them. Another possibility is that no expectations have been built about what is typical in linguistic events with regards to synchrony. Without additional data, no differentiation can be made among these explanations. However, any of these accounts is consistent with an intermodal processing deficit in autism that is mediated by or specific to language.

In comparison, children with heterogeneous forms of developmental disabilities (other than autism) showed significant preferential looking during both the non-linguistic and simple linguistic stimuli, and a borderline preference for the complex linguistic event, a pattern much like the NH comparison group. The borderline finding for the complex stimuli is likely a result of the sample size somewhat limiting statistical power. If it is not a power issue, an alternative interpretation may be that when viewing stimuli with higher affective content and more linguistic variation, some of the children with DD may need to focus on the asynchronous display for part of the time in order to interpret the event better, or they may look more randomly simply because they could not detect the differential temporal synchrony during an event with an increased cognitive component. On further examination of the data, however, 67% of the children in the DD-matched group did prefer the synchronous screens to some degree during the complex linguistic event. This observation implies a pattern of results consistent with the non-handicapped group's results (70%), supporting the power interpretation.

Recent fMRI, ERP and EEG work (reviewed in Calvert, 2001) implicates specific brain structures involved in the synthesis of information coming from multiple sensory modalities. Different structures appear to be involved in the integration of auditory and visual information deriving from linguistic vs. non-linguistic stimuli. The superior temporal sulcus (STS) appears to play a key role in the synthesis of audio-visual linguistic signals. A less clear network seems involved in non-linguistic signals, but likely involves the sensory cortices and fronto-temporal sites (Calvert, 2001). An additional network involving the superior colliculus and insula is sensitive to the temporal correspondence of intermodal cues. If the behavioral results in our study are replicated, then differences such as those found when the temporal correspondence of the linguistic versus non-linguistic information is violated may be reflected in differential levels of activity of these underlying brain structures in children with autism. In addition, the STS has been linked to the processing of mouth movements (Fadiga, Craighero, Buccino, & Rizzolatti, 2002) and other biological movements (Rizzolatti et al., 1996). While there have been fMRI findings of deficits in STS-related activities (Pierce, Muller, Ambrose, Allen, & Courchesne, 2001) in autism, these suggestions are speculative at the present time. This link with underlying brain structures provides an interesting direction for additional research.

The lack of significant group main effects and group × stimulus interactions in looking away times, in both the familiarization and test phases, is an important finding. Initially it appears to contrast with Klin (1991), who found that children with autism actively preferred non-speech sounds or at least showed a lack of preference for their mother's speech over noise, while DD-matched and typically developing comparison groups had strong preferences for speech. A vital difference from the Klin (1991) study, where only auditory stimuli were used, is the inclusion of concomitant visual stimuli in the present study, which may have contributed to the similar group preferences. At the very least, these results' absence of group differences in looking away behavior in the present study eliminate one potential confound: that differences in response to violations of temporal synchrony may be related to basic differences between the groups in terms of inherent preferences to particular stimuli.

Interestingly, a language effect was nonetheless found *within* the autism group in the familiarization phase. While as a group they did not differ in the amount of time they looked away from the linguistic stimuli compared to the other groups, there was a significant positive correlation within the autism group between the children's linguistic ability, as measured by their VABS Communication scores, and their time spent looking at the complex linguistic stimuli. The lower their language skill, the more there was an apparent disinterest in the stimuli. The fact that this relationship failed to exist in the children with other forms of developmental disability precludes the possibility that it was merely mediated by participants' developmental impairments. Rather, the relation appears to be unique to the autistic disorder, at least for the children in this study.

There are some caveats in the interpretation of the present findings. First, the linguistic stimuli differed from the non-linguistic event not only by linguistic content, but also in terms of social content, since a face was visible. However, it is unlikely that the social component of the stimuli was a major contributor to the present findings, since there was a significant difference in the amount of time the children looked away from the complex vs. the simple linguistic stimuli in the familiarization phase and a similar but nonsignificant trend for the test phase of the study, even though the same person's face was present in both sets of stimuli. Therefore, the language variable was at least contributing additional effects over and above any social effect.

Second, the disparity between the auditory and visual portions of the asynchronous displays in this study was quite large (3 seconds). A smaller offset may yield an even greater effect, if it further enhances the experience that the auditory and visual components are the same event. It would be useful to examine further the impact of varied delays, as well as to determine whether children with autism require different degrees of asynchrony compared to peers before noticing that the audio and visual aspects are out of phase with each other.

The lack of preferential looking during the linguistic events by the children with autism has important potential theoretical and clinical implications. The importance of awareness of temporal synchrony for typical language development has been clearly established. Typically developing infants use temporal synchrony to associate arbitrary audio and visual stimuli, such as to establish word–object associations (Gogate & Bahrick, 1998; Morrongiello, Fenwick, & Nutley, 1998; Slater, Brown, & Badenoch, 1997). Discrimination of temporal synchrony may be the first step in developing a capacity to discriminate more complex and specific forms of language or other information that is invariant across sensory modalities (Lewkowicz, 1999). Bahrick and Pickens (1994) stress the importance of temporal synchrony awareness for overall child development:

> Initial sensitivity to temporal relations can selectively focus infant attention on meaningful, unitary events and serve as a buffer against learning the numerous wrong or meaningless relations one might detect. We believe that there is now sufficient evidence to conclude that young infants are at first selectively tuned to detect certain amodal relations. This initially substitutes for the prior knowledge that adult perceivers find so critical for directing meaningful perception, learning, and memory. (p. 206)

Therefore, the developmental sequelae of an atypical response to temporal synchrony, or a diminished response to violations of temporal synchrony in the linguistic domain, such as we found here, would be significant.

Further refinement of the preferential looking paradigm should enable us to understand more fully the nature of the language-specific difficulty children with autism exhibit with intermodal processing. If successful, early detection and intervention methods may improve the children's attention to linguistic stimuli and enhance the coordinated perception of visual and auditory stimuli to hopefully help ameliorate some of the difficulties these children face.

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