Impairments in Multisensory Processing are Not Universal to the Autism Spectrum: No Evidence for Crossmodal Priming Deficits in Asperger Syndrome

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Individuals suffering from autism spectrum disorders (ASD) often show a tendency for detail- or feature-based perception (also referred to as ''local processing bias'') instead of more holistic stimulus processing typical for unaffected people. This local processing bias has been demonstrated for the visual and auditory domains and there is evidence that multisensory processing may also be affected in ASD. Most multisensory processing paradigms used social-communicative stimuli, such as human speech or faces, probing the processing of simultaneously occuring sensory signals. Multisensory processing, however, is not limited to simultaneous stimulation. In this study, we investigated whether multisensory processing deficits in ASD persist when semantically complex but nonsocial stimuli are presented in succession. Fifteen adult individuals with Asperger syndrome and 15 control persons participated in a visual-audio priming task, which required the classification of sounds that were either primed by semantically congruent or incongruent preceding pictures of objects. As expected, performance on congruent trials was faster and more accurate compared with incongruent trials (crossmodal priming effect). The Asperger group, however, did not differ significantly from the control group. Our results do not support a general multisensory processing deficit, which is universal to the entire autism spectrum. ***Autism Res*** *2011,4:xxx–xxx*. © 2011 International Society for Autism Research, Wiley Periodicals, Inc.

Keywords: Asperger syndrome; high-functioning autism; multisensory processing; crossmodal priming; local processing

Introduction

According to international classification systems, autism spectrum disorders (ASD) are defined by a triad of symptoms: deficits in social cognition and interaction, impoverished verbal or nonverbal communication and restrictive interests and stereotyped, repetitive behavior. Although not listed by current diagnostic criteria, individuals with ASD also often report a fragmented way of perceiving the world [Grandin, 2009]. Such a local or feature-based perception at the expense of global or holistic perception has frequently been discussed [Dakin & Frith, 2005]. For example, on hierarchical stimuli such as the Navon letters [i.e., for a set of the letter S which are aligned so that their global form takes shape of a letter H; Navon, 1977], typical observers show an advantage for the global level (i.e., H) and are interfered by the global shape when instructed to attend the local level (i.e., S). Individuals with ASD, in contrast, show precedence of the local level [Plaisted, Swettenham, & Rees, 1999]. In concordance with this local attention style, ASD is also associated with deficits in the processing of complex or holistic stimuli such as faces [Behrmann et al., 2006]. The predominant account, the ''weak central coherence theory'', explains such findings by a weak tendency in ASD to combine stimulus details or features into a coherent whole [Happe & Frith, 2006]. Importantly, people with ASD also show abnormalities, or ''sensitivities,'' in other domains than the visual [Blakemore et al., 2006; Foxton et al., 2003]. For example, they also showed less global interference in an auditory Navon-type task, being able to very accurately detect local pitch direction changes embedded in a global auditory structure [Foxton et al., 2003].

Findings that the impaired perceptual integration in ASD is not limited to the visual modality raise questions about a multisensory context. Do people with ASD, like unaffected individuals, profit from multisensory situations, for example, when identifying speech or nonspeech stimuli by both hearing and seeing the originating source [McGurk & MacDonald, 1976; Saldana & Rosenblum, 1993]? The weak central coherence theory would predict no, yet only a few empirical studies have addressed multisensory processing in ASD [de Gelder, Vroomen, & Van der Heide, 1991; Magnee, de Gelder, van Engeland, & Kemner, 2008; Magnee, Oranje, van Engeland, Kahn, & Kemner, 2009;

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Mongillo et al., 2008; Smith & Bennetto, 2007; Taylor, Isaac, & Milne, 2010; van der Smagt, van Engeland, & Kemner, 2007; Williams, Massaro, Peel, Bosseler, & Suddendorf, 2004]. Individuals with ASD indeed often report difficulties or stress in processing unimodal sensory signals (e.g., bright light, touch, noise) or simultaneously occurring signals from different sensory modalities (e.g., during social interaction). Empirically, there is partial support for this anecdotal evidence from studies investigating audiovisual integration [de Gelder et al., 1991; Smith & Bennetto, 2007; Taylor et al., 2010; Williams et al., 2004]. However, most of these studies employed stimuli implying human stimuli such as lips or faces, human speech or voices (within the realms of testing the McGurk effect), which—on their own—can be a problem for individuals with ASD. A closer inspection of multisensory integration studies in ASD (Table I) reveals that deficits are almost exclusively associated with the processing of social-communicative face–speech stimuli [except for Williams et al., 2004], whereas lower level nonsocial audiovisual integration seems unaffected [except for Russo et al., 2010, who reported EEG evidence for disrupted audio-tactile integration]. However, studies did not only differ in social content but also in stimulus complexity (Table I), so that it is unclear whether the social-communicative nature of stimulation (e.g., speech) or stimulus complexity in general modulates audiovisual integration in ASD.

Thus, to strike a balance between existing studies, we sought to investigate audiovisual interaction effects in ASD using stimuli that were semantically complex and naturalistic, yet did not have a social connotation (e.g., the sound and picture of a coffee machine). We were specifically interested in how vision and audition interact during natural object identification—a novel approach in ASD multisensory research—using crossmodal priming. It is unclear whether multisensory processing deficits in ASD persist independent of general difficulties in processing simultaneously present, interacting features [Minshew et al., 1997]. Only a few studies probed nonsimultaneous multisensory processing in ASD, for example, by crossmodal priming [Magnee et al., 2008, 2009: Table I], in which the visual stimulus precedes the auditory stimulus,

Table I. Overview of Cited Multisensory Processing Studies in ASD

	Participants' age	Diagnosis	Sensory stimulation	Stimulus complexity	Social content	Simultaneous multisensory processing	Results
Williams et al. [2004]	6–13 years	ASD[a]	Audiovisual	High: virtual face with synthesized syllables	Yes	Yes	No deficit[b]
Taylor et al. [2010]	7–16 years	ASD, "mostly HFA"[a]	Audiovisual	High: human face and spoken syllables	Yes	Yes	Pro deficit (not in older age groups)
Smith and Benetto [2007]	12–20 years	ASD/HFA[a]	Audiovisual	High: human face and spoken sentences in noise	Yes	Yes	Pro deficit
Mongillo et al. [2008]	8–19 years	9 = AD, 6 = AS	Audiovisual	1. High: human face and speech 2. Low: bouncing balls	1. Yes 2. No	Yes	1. Pro deficit 2. No deficit
de Gelder et al. [1991]	6–16 years	ASD[a]	Audiovisual	High: human face and spoken syllables	Yes	Yes	Pro deficit
van der Smagt et al. [2007]	Adults (mean age 21 ± 3 years)	ASD/HFA[a]	Audiovisual	Low: sounds and light flashes	No	[c]	No deficit
Magnee et al. [2009]	Adults (mean age 23 ± 2 years)	ASD[a]	Audiovisual	Low: white object (conditioning stimulus) and noise bursts (test stimulus)	No	No	No deficit
Magnee et al. [2008]	Adults (mean age 21 ± 4 years)	ASD/HFA[a]	Audiovisual	High: human face and spoken syllables	Yes	No	Pro deficit (EEG evidence, but not behavior)
Russo et al. [2010]	6–16 years	7 = AD, 8 = AS, 2 = PDD-NOS	Audiotactile	Low: 1,000 Hz tones and vibrotactile stimulation	No	Yes	Pro deficit (only EEG evidence)

HFA, high functioning autism (this may include autistic disorder and Asperger syndrome); AD, autistic disorder; AS, Asperger syndrome; PDD-NOS, pervasive developmental disorder, not otherwise specified.

[a]Not further specified.

[b]After controlling for differences in speech-reading ability, there were no group differences in the McGurk effect.

[c]The authors speak of "concurrent" presentation, although the stimulus onset asynchrony (SOA) of the first beep and flash was 17 ms, a latency possibly too small to be consciously detected.

yielding mixed results. An example for crossmodal priming can be found in real life, in which lightening—the visual stimulus—primes the processing of thunder—the auditory stimulus. Thus, multisensory processing is not limited to simultaneous stimulation. In this study, participants performed a previously established crossmodal priming paradigm [Schneider, Engel, & Debener, 2008], in which they were asked to categorize a naturalistic auditory stimulus that was preceded by a semantically congruent or incongruent visual stimulus. In the congruent condition, the visual stimulus typically facilitates the identification of the auditory target stimulus (i.e., the multisensory interaction effect), suggesting that object identification in one modality is influenced by input from another modality. If audiovisual integration deficits in ASD are not only limited to social-communicative signals such as faces and speech (as previously shown in numerous studies) but also extend to other complex naturalistic stimuli as used in this study, we would expect a weaker visual priming effect for auditory object recognition in ASD due to an inherent difficulty to integrate signals across different sensory modalities. Previous evidence has ruled out lower level audiovisual integration deficits in ASD on the level of abstracts sounds or objects [Magnee et al., 2009; Mongillo et al., 2008; van der Smagt et al., 2007], suggesting abnormalities on higher level processing stages. As we also probed higher level complex processing, while using nonsocial-communicative stimuli, no deficits in our task would rule out a general effect of stimulus complexity on multisensory integration and, instead, suggest selective difficulties in integrating signals related to language, social perception, and interaction.

Methods

Participants

We examined 15 adult participants with Asperger syndrome (AS; 6 female; mean age 35 ± 8.3 years; education 18.4 ± 5.1 years; IQ 118 ± 11.1) and 15 age- and IQ-matched control participants (CON; 2 female; age 32.1 ± 8 years; education 19 ± 2.9 years; IQ 117.1 ± 11.7). AS participants were recruited from the autism outpatient clinic at the Department of Psychiatry in Cologne, where data were also collected. Our AS sample consisted of late-diagnosed high-functioning adults, who had voluntarily registered at the outpatient clinic, because they suspected an ASD. Control participants were recruited through on-campus advertisements. Two different physicians (incl. co-author K.V.) explored autistic traits in clinical interviews according to current diagnostic criteria (ICD-10). In addition, all participants were screened for autistic traits using the Autism Quotient [AQ; Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001] and mentalizing ability using the "Reading the mind in the Eyes" test [Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001]. As expected, the AS group scored significantly higher on the AQ (score 43 ± 4.3) compared with the CON group (14.5 ± 6.3; $F(1, 28) = 213.33$, $P < 0.001$). In addition, AS individuals showed significant difficulties in interpreting mental states expressed by eyes (correctly identified 13.5 ± 6.3 of 37 items) compared with CON individuals (correctly identified 18 ± 2.9; $F(1, 25)$[1] $= 5.27$, $P = 0.030$). All participants had normal or corrected-to-normal vision and gave a written consent before participation. The ethics committee of the University Medical Center Hamburg-Eppendorf approved the study.

Stimuli and Task

We employed a crossmodal priming paradigm that used semantically congruent and incongruent stimulus pairs in a S1–S2 paradigm (Fig. 1A). Task-relevant targets (= S2) were auditory stimuli (e.g., the sound of a sheep). Either a semantically congruent (i.e., the prime = S1; e.g., a picture of a sheep) or semantically incongruent picture (e.g., a train) preceded the auditory target. Participants performed an implicit task and judged whether the sound-causing object would fit into a shoebox. Thus, they had to judge only the sound (S2), not the depicted object (S1). More details about stimuli and task can be found in Schneider et al. [2008]. Fifty-two different pictures and sounds were used. Each participant performed 208 trials (50% congruent, 50% incongruent). Stimuli were presented on an ASUS M6000 notebook (15-inch, $1{,}024 \times 978 \times 32$ screen resolution) using the Presentation software (Version 12.0; Neurobehavioral Systems, Albany, CA). Responses were given via the left and right mouse button (left = does fit into shoebox, right = does not). Participants were familiarized with all stimuli (visual and auditory) in a standardized learning session before the start of the actual experiment: the presentation of stimuli was repeated (usually twice) until all objects were identified correctly. Reaction times and responses (i.e., accuracy) were recorded for offline analyses.

Results

Statistics were performed on log-transformed data to meet the parametric test assumption of normality. A crossmodal priming or multisensory interaction effect would be expressed by shorter reaction times (RTs) and increased accuracy for congruent as compared with incongruent stimulus pairs, suggesting that object identification in one modality (i.e., the auditory) is facilitated by input from another modality (i.e., the visual). In this study, both groups showed the expected facilitation

[1]Not assessed in three control participants.

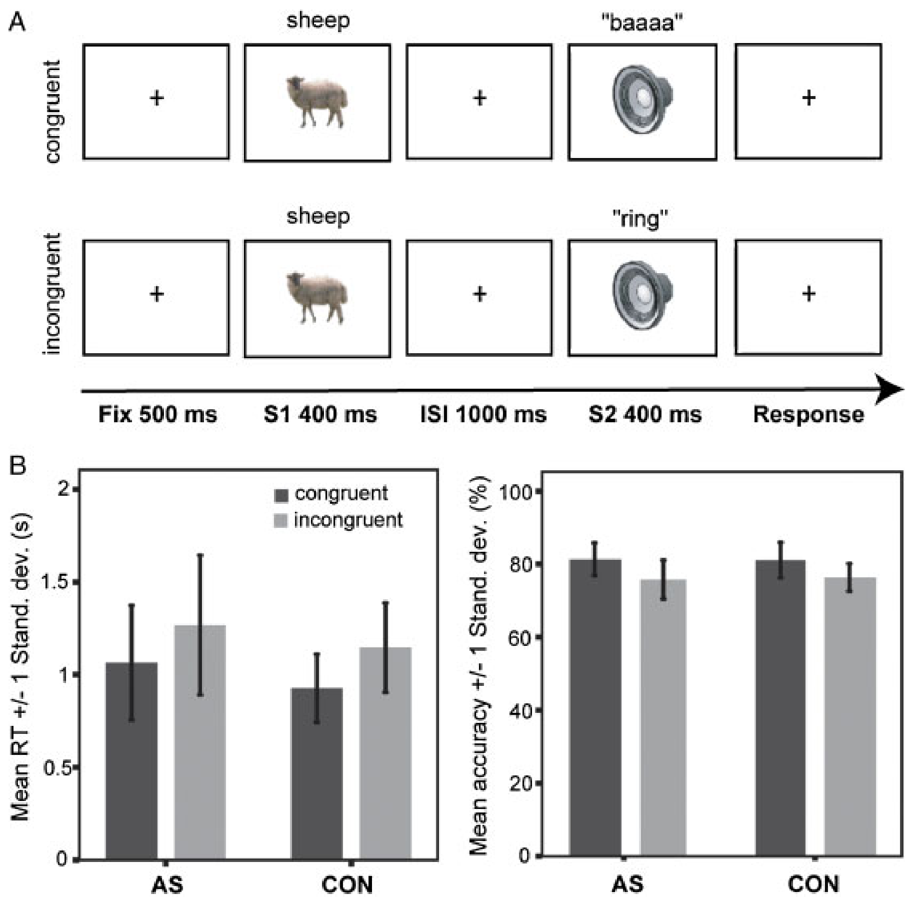

Figure 1. Visual-audio priming task. (**A**) The upper row represents a semantically congruent trial, the lower a semantically incongruent trial. Subjects performed an implicit task and judged whether the sound-causing object would fit into a shoebox. Thus, they judged the sound (i.e., the second stimulus = S2) but not the depicted object (i.e., the prime = S1). (**B**) Both groups showed a significant crossmodal priming effect as indicated by shorter RTs and higher accuracy for semantically congruent vs. incongruent pairs. There were no significant group differences. RT, reaction time.

effect on RTs and accuracy (Fig. 1B). RTs on congruent trials were shorter for the AS (mean ± standard deviation, 1,064 ± 309 ms) and NT group (927 ± 187 ms) compared with RT on incongruent trials (AS: 1,267 ± 377 ms; CON: 1,146 ± 241 ms). In both groups, accuracy was also higher for the semantically congruent (AS: 81.3 ± 4.5% correct; CON: 81.1 ± 4.8%) compared with incongruent condition (AS: 75.8 ± 5.3% correct; CON: 76.3 ± 3.8%). A repeated-measures ANOVA with the within-subject factor "priming" (congruent/ incongruent) and the between-subject factor "group" confirmed a significant effect of priming on RTs ($F(1, 28) = 112.8$, $P < 0.001$, $\eta_p^2 = 0.8$) and accuracy ($F(1, 28) = 50.3$, $P < 0.001$, $\eta_p^2 = 0.64$). The interaction effect "priming × group" did not reach significance, neither for RTs ($F(1, 28) = 0.2$, $P = 0.684$) not for accuracy ($F(1, 28) = 0.3$, $P = 0.579$). There was no main effect of "group" on RT ($F(1,28) = 1.586$, $P = 0.218$) or accuracy ($F(1,28) = 0.013$, $P = 0.910$). Because our samples were not perfectly gender-matched, we performed the same analyses with gender as a nuisance covariate. Gender did not have a significant effect on priming, as indexed by RTs ($F(1, 27) = 0.41$, $P = 0.526$) and accuracy ($F(1, 27) = 0.21$, $P = 0.647$), and the interaction remained insignificant.

Discussion

In contrast to studies showing audiovisual (speech) integration deficits in ASD [de Gelder et al., 1991; Smith & Bennetto, 2007; Taylor et al., 2010], participants with AS in our study did not differ from unaffected control participants in the crossmodal priming of object recognition. These results are in line with other studies, which do not support multisensory processing impairments in ASD [Magnee et al., 2009; Mongillo et al., 2008; Smith & Bennetto, 2007; van der Smagt et al., 2007; Williams et al., 2004; see Table I for conflicting evidence]. Where do discrepant findings on audiovisual integration abilities in ASD arise from?

Existing studies differ in social-communicative content, stimulus complexity (high-level vs. low-level processing), and stimulus synchrony (Table I). All investigations that reported behavioral audiovisual integration deficits in ASD, exclusively examined the McGurk effect using faces and speech. In contrast, simple sounds and visual stimuli were perfectly integrated on the behavioral level (Table I). Thus, previously reported impairments in audiovisual integration might be limited to the processing of socially relevant auditory and visual information. Mongillo et al. [2008] directly tested this hypothesis, indeed showing that children with ASD were impaired in the integration of human faces and voices but not on tasks involving nonhuman stimuli (i.e., bouncing balls). Despite Mongillo and colleagues' important contribution, it remained unclear how multisensory processing abilities in ASD look like when complex nonsocial stimuli are used, beyond the level of too simplistic beeps and flashes or bouncing balls. The integration of complex sounds and pictures without social content has not been investigated. We employed semantically complex, naturalistic stimuli, the multisensory understanding of which was relevant for daily functioning (e.g., a car and a horn), without bearing social content. In contrast to the face–speech literature [de Gelder et al., 1991; Smith & Bennetto, 2007; Taylor et al., 2010], our participants with ASD were able to audiovisually integrate at a higher level processing stage, suggesting selective integration deficits regarding social-communicative signals such as human faces/language as previously shown by, for example Mongillo et al. [2008].

Our task also differed from other multisensory integration tasks in the sense that participants did not need to process stimuli from different sensory domains at the same time, but successively, as multisensory processing is not limited to simultaneous stimulation [Schneider et al., 2008; Stein et al., 2010]. It has been hypothesized that the rapid (i.e., simultaneous) and integrative processing or binding of information from multiple inputs characterizes many cognitive deficits in ASD [Brock, Brown, Boucher, & Rippon, 2002; Minshew et al., 1997]. Anecdotal evidence indeed suggests that individuals with ASD are easily overwhelmed by information overload or many simultaneously occurring sensory events. Social interaction—the key area of disturbance—requires the simultaneous integration of many different signals; what is more complicated than the mother's face leaning over the autistic child, talking, smiling, and expecting a reaction? Only few studies examined whether multisensory processing deficits in ASD also occur under nonconcurrent stimulation (Table I), as in a crossmodal priming paradigm [Magnee et al., 2008, 2009]. Magnee and colleagues investigated low- and high-level crossmodal priming in adults with ASD, finding intact multisensory processing at the behavioral level. Unfortunately, to date there is only little direct evidence how concurrent compares with nonsimultaneous multisensory processing in ASD.

Only four (including our own) investigations of audiovisual integration included adults participants with ASD [Magnee et al., 2008, 2009; van der Smagt et al., 2007; Table I], and did not find evidence for disrupted multisensory processing. In this study, we did not include younger participants, thus we cannot rule out that younger individuals with ASD might have shown difficulties with our task. Indeed, evidence from typically developing children demonstrated a significant effect of age on audiovisual integration [Tremblay et al., 2007], especially when the McGurk effect was probed (involving human faces and speech). In fact, when accounting for age or the degree of developmental delay, difficulties with audiovisual integration in ASD seem to diminish [Taylor et al., 2010]. Taylor et al. [2010] suggested that, as age increases (i.e., up to 16 years), individuals with ASD may "catch-up" with unaffected peers in multisensory processing, while social deficits persist. It is possible that early ASD-related deficits in sensory processing and selective attention lead to persisting higher level social deficits, while the more fundamental deficits disappear in development. In contrast, Dawson et al. [2004] would argue for a primary deficit in social interest and joint attention. Longitudinal studies are necessary in order to track developmental trajectories as well as interactions between (multi)sensory and social abnormalities in ASD.

In this study, we investigated multisensory processing with semantically complex stimulus material—not involving faces, bodies or language—in adult participants with AS. Our ASD participants showed normal performance in our crossmodal priming task, ruling out general difficulties at higher processing stages. Multisensory processing deficits in ASD might be limited to the integration of signals related to language, social perception, and interaction, irrespective of stimulus complexity, to concurrent stimulation or to younger ages. Our results are not in favor of a general or universal multisensory processing deficit as a common denominator for ASD. Future studies of multisensory processing in ASD should directly compare concurrent and nonconcurrent multisensory-social stimulation, while considering developmental trajectories and the possibility of different sensory phenotypes in ASD [Lane, Dennis, & Geraghty, 2010].

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