Superior discrimination of speech pitch and its relationship to verbal ability in autism spectrum disorders

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Abstract

Whilst hypersensitivity to pitch information appears to be characteristic of many individuals with autism spectrum disorders little is known about the implications of such a tendency for language acquisition and development. Discrimination of systematically varied pitch differences between pairs of words, nonwords, and nonspeech pitch contour analogues was assessed in children with autism spectrum disorders (ASD) and matched controls. The findings revealed superior performance in ASD, although, like controls, discrimination of pitch in speech stimuli was poorer in this group than for nonspeech stimuli. Whilst it was hypothesized that enhanced processing of speech pitch would correlate negatively with receptive language skills in ASD, the findings did not fully support this, and enhanced discrimination skills were observed in individuals without significant language impairment. The implications of these findings for understanding heterogeneity of language ability in ASD are discussed.

Keywords: Autism spectrum disorders, Pitch discrimination, Verbal ability

Autism is diagnosed on the basis of abnormalities in social interaction, communication, and cognitive flexibility that are in evidence before age three (American Psychiatric Association, 1994). Language onset is significantly delayed in autism, and research into language skills shows considerable variability in the extent to which these subsequently develop. Thus, whilst between 25% and 50% of diagnosed individuals never acquire functional language (Gillberg & Coleman, 2000; Klinger, Dawson, & Renner, 2002), relatively well-developed language skills are also observed in some individuals (Boucher, 2003; Kjelgaard & Tager-Flusberg, 2001; Lord & Paul, 1997). Recently, researchers have turned their attention to identifying factors associated with this wide variability in language onset and development in very young children with autism. For example, Luyster, Kadlec, Carter, and Tager-Flusberg (in press) studied a group of 164 toddlers, aged 18–33 months, with autism and found that responsiveness to joint attention cues and nonverbal cognitive ability were important in predicting language development.

Although not currently included as *Diagnostic and Statistical Manual of Mental Disorders–Fourth Edition* (*DSM-IV*) diagnostic criteria for autism (American Psychiatric Association, 1994), processing abnormalities across sensory domains are frequently noted (Leekam, Nieto, Libby, Wing, & Gould, 2006) and are included in the Autism Diagnostic Interview (ADI; Lord, Rutter, & LeCouteur,1994). Recent work into early occurring sensory abnormalities in autism spectrum disorders (ASD) has identified a pattern of sensory abnormalities characterized by underresponsiveness and avoiding behaviours and a low frequency of seeking behaviours in toddlers with ASD (Ben-Sasson et al., 2007). It is interesting, given these sensory difficulties, that superior perceptual discrimination is also characteristic of many individuals with autism (e.g., see Mottron, Dawson, Soulieres, Hubert, & Burack, 2006). For example, enhanced discrimination and memory for complex and simple tones has been shown in a number of experiments (Applebaum, Egel, Koegel, & Imhoff, 1979; Bonnel et al., 2003; Heaton, 2003, 2005; Heaton, Hermelin, & Pring, 1998; Heaton, Pring, & Hermelin, 1999; Mottron, Peretz, & Ménard, 2000).

Theories of enhanced perceptual functioning (EPF; Mottron & Burack, 2001; Mottron et al., 2006) and weak central coherence (WCC; Frith, 1989; Happé, 1999; Happé & Frith, 2006) provide a current theoretical context in which findings of enhanced perceptual discrimination can be interpreted. Both accounts propose that cognition in autism is perceptually and locally biased, although the EPF model does not invoke weak top-down or central processes, but instead outlines an atypical relationship between intact high-level processes and overdeveloped low-level or perceptual processes. WCC also differs from EPF in providing a more constrained account that does not seek to explain communicative and social abnormalities. These are typically interpreted within the context of a "mindblindness" account of autism (Baron-Cohen, 1995). However, findings from a number of studies suggest that pervasive abnormalities in brain development and connectivity are characteristic in autism (Belmonte et al.,2004a; Courchesne & Pierce, 2005a, 2005b; Just, Cherkassy, Keller, & Minshew, 2004), and Herbert (2005) suggests that behavioural features may be consequences of widespread abnormalities that preferentially target mental functions requiring highly coordinated activity. According to Herbert's account, diagnostic features of autism may also be adaptive or compensatory secondary effects of primary sensory and processing abnormalities.

Within the auditory domain, abnormalities in neural processing in autism have been noted (Boddaert et al., 2003; Čeponienė et al., 2003; Gervais et al., 2004; Müller et al., 1999). Behavioural studies have highlighted auditory filtering difficulties (Rogers, Hepburn, & Wehner, 2003) and difficulties in spatially focusing auditory attention (Teder-Sälejärvi, Pierce, Courchesne, & Hillyard,2005) in autism. Underreactivity to speech is frequently observed in young children with this diagnosis (e.g., Klin, 1991), and auditory processing abnormalities identified by Rogers et al. (2003) and Teder-Sälejärvi et al. (2005) may be implicated in this. Research from sources as divergent as tone-language speakers, musically enriched infants, and nonhuman primates provides evidence for learning-induced plasticity in the auditory system (Kraus & Banai, 2007). Considered within the context of these data, atypical auditory development in children with poor orientation to language is unsurprising. Indeed Kuhl, Coffey-Corina, Padden, and Dawson (2005) showed that a subgroup of children with autism who did not preferentially attend to child-directed speech failed to show the neural changes in response to changes in vowel pitch observed in typically developing controls.

An early, but highly significant, body of research, predating the EPF and WCC accounts, tested the hypothesis that, when presented with multiple simultaneous cues, children with autism will focus on a limited number of those available (Koegel & Rincover, 1976; Lovaas & Schreibman, 1971; Reynolds, Newsom, & Lovaas, 1974; Rincover & Koegel, 1975; Schreibman, 1975; Schreibman & Lovaas, 1973). More recently, Samson, Mottron, Jemel, Belin, and Ciocca (2006) have hypothesized that auditory processing in autism is influenced by differences in levels of spectro-temporal complexity in stimuli. In a detailed analysis of the neuropsychological and behavioural literature, they contrasted findings showing an association between superior task performance and typical brain activation with findings showing an association between impoverished task performance and atypical brain activation and concluded that enhanced and impoverished processing across auditory domains reflects levels of stimulus complexity and complexity in patterns of neural processes involved in the processing task.

Speech is a particularly complex auditory stimulus, and Schreibman, Kohlenberg, and Britten (1986) investigated differential responsiveness to different components of the speech signal in autistic participants. Their findings showed that whilst echolalic autistic children selectively responded to intonation in speech, nonverbal autistic children responded to sentence content alone. In contrast, typical controls responded to both intonation and content or to content alone. The finding that a subgroup of children with autism selectively respond to intonation in speech has recently been investigated in samples of verbal children and adolescents with autism. For example, in one study (Järvinen-Pasley, Wallace, Ramus, Happé, & Heaton, 2008) where participants were required to match sentence pitch contours to their visual analogues (rising, falling, and U or inverted U shapes), participants with autism performed at significantly higher levels than did controls. However, when, in a later study, the same participants were asked to categorize a series of short sentences as either questions or statements, they were highly insensitive to the semantic function of the sentence pitch cues. Instead, they relied on a strategy whereby questions without a "W" word (i.e., what, which, where, who, etc.) were categorized as statements (Järvinen-Pasley, Peppé, King-Smith, & Heaton, 2008). As none of the sentences presented did include a "W" word, these verbally able individuals were almost entirely unable to make the question/statement distinction. Taken together these two sets of findings suggest an association between semantic and pragmatic deficits and a bias towards fine-grained processing of the perceptual components of speech-signals.

The current experiment extends previous research into the perception of speech-pitch in autism by systematically varying task demands at both semantic and perceptual levels. The task is a paired-stimulus tone discrimination test, comprising pairs of real words, nonsense words, or pitch analogue tone stimuli in which one of the pair is systematically varied in pitch height. Two experimental hypotheses are proposed. The first draws on the EPF theory, predicting that pitch discrimination ability is enhanced in ASD compared to controls. The rationale for the second draws on WCC theory, which states that participants with ASD exhibit weak verbal/semantic coherence. Contrary to controls, who are predicted to show poorer discrimination performance for stimuli with than for those without semantic content (i.e., real-word pairs vs. nonsense word and pitch analogue pairs), children with ASD are predicted to show no such semantic effect.

Finally, in order to explore the relationship between enhanced pitch perception and language, discrimination performance is considered with respect to participant performance on standardized tests of receptive language.

Method

Participants: Recruitment and screening

A total of 20 children with diagnoses along the autistic spectrum (ASD) and 29 children with moderate learning difficulties or typical development (controls) were recruited and completed the experiment. However, of these, 6 children with ASD and 15 control children were unable to consistently discriminate stimuli even in those experimental conditions where differences between comparison pairs were most marked (see section "Fidelity check"), and they were therefore excluded from the principal analysis.

As an aim of the study was to determine whether hypersensitivity to pitch frequency cues in autism might be negatively associated with atypical language, all children completed receptive vocabulary (British Picture Vocabulary Scales; BPVS; Dunn, Whetton, & Pintilie, 1997) and grammar (Test of Reception of Grammar; TROG; Bishop, 1983) tests. For both tests, children are shown groups of four pictures and are asked to indicate those associated with single words (BPVS) or sentences (TROG) read out by the experimenter. As the task procedures are similar and relatively simple they are particularly suitable for sampling vocabulary and syntax together in children with cognitive impairment. Raw scores for both tests can be converted to age-equivalent scores (verbal-mental age) using the norms provided in the manual. As already noted, a large proportion of children tested (48% of controls and 30% of children with ASD) failed to complete the experimental task satisfactorily. Psychometric data for subgroups of children who did and did not understand the task are shown, together, in Table 1.

Comparison of data for groups of participants (ASD and controls) retained in the analysis showed no significant difference between chronological age (CA) scores, $t(27) = -0.306$, *ns*, BPVS Verbal Mental Age-Equivalence (VMA) scores, $t(27) = 0.87$, *ns*, or TROG VMA scores, $t(27) = 0.08$, *ns*. CA and VMA scores for control participants excluded from the analysis were lower than scores for those control participants who were retained, CA, $t(27) = -2.09$, $p < .05$; BPVS, $t(27) = -2.12$, $p < .05$; TROG, $t(27) = -2.07$, $p < .05$, and the same pattern was observed for included and excluded participants with ASD, CA, $t(18) = -2.37$, $p < .05$; BPVS, $t(18) = -2.12$, $p < .05$; TROG, $t(18) = -2.07$, $p < .05$. Comparison of data for excluded children with and without ASD showed no significant difference for CA, $t(19) = -1.04$, *ns*, or TROG VMA scores, $t(19) = -1.63$, *ns*. However, the BPVS VMA scores were significantly lower for excluded ASD children than for excluded controls, $t(19) = -4.95$, $p < .001$. Excluded participants were between 2 and 3 years younger than those who were retained in the analysis, suggesting that the current paradigm is unsuitable for testing children younger than 8 years.

The children with ASD were all male and were recruited through two special educational facilities in the south-eastern UK. In order to verify diagnosis, examination of the children's school records was carried out, confirming that all individuals had been diagnosed with ASD by a paediatrician independent of the study, on the basis of ICD-10 (International Classification of Diseases–10th Revision; World Health Organization, 1992) criteria. Specifically, 11 children were reported to have autistic disorder, 1 child was diagnosed with Asperger syndrome, and the reports of the remaining 2 children indicated unspecified ASD. In 2 children, comorbid presentation of attention deficit/hyperactivity features was noted, with Tourette syndrome also indicated for one child.

Table 1. Descriptive and group matching data for subgroups of children tested

	ASD						Controls					
	Retained (N = 14)			Excluded (N = 14)			Retained (N = 14)			Excluded (N = 14)		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
CA (months)	126	47	12	90	19	41	126	28	109	102	32	117
BPVS VMAa (months)	97	31	112	39	4	10	88	23	85	71	15	60
TROG VMAb (months)	65	24	85	47	0	0	64	21	73	52	8	25

Note: ASD = autism spectrum disorders. CA = chronological age.

a British Picture Vocabulary Scales (BPVS), Verbal Mental Age-Equivalence (VMA) score (Dunn, Whetton, & Pintilie, 1997).

b Test of Reception of Grammar (TROG) VMA score (Bishop, 1983).

As the children with ASD were heterogeneous in terms of level of functioning, and given that the groups were intended to be matched for mean CA and VMA, the control group (14 boys and 1 girl) included children with both typical development (TD, *n* = 2) and moderate learning difficulties (MLD, *n* = 13). The latter group were recruited from the same specialist educational facilities as were the children with ASD, while the former were recruited from a mainstream primary school. Children's school records were again checked to ensure that no child with ASD was included in the control group.

Experimental stimuli

Speech stimuli were generated to cover a range of 10 vowel sounds commonly spoken in British English, with 5 monosyllabic real words (e.g., meat, seat, heat, feet, sweet) and 5 monosyllabic nonsense words (e.g., deat, veat, yeat, geat, leat) generated for each vowel sound. Multiple versions of these word and nonsense word stimuli were recorded by an adult female, and the stimulus set was selected. For each selected word and nonsense word, four pairs were created using PRAAT software (Boersma, 2001;http://www.praat.org/). For the first set of pairs, the original recorded stimulus was repeated. For the second, the overall pitch contour of each original stimulus was shifted a pitch distance equivalent to 1 semitone away from the original, and then paired with the original. For the third and fourth sets, pitch contours were shifted away from the originals by distances equivalent to 3 and 6 semitones, respectively, and again paired with the original recorded stimuli. The pitch contours of the recorded words and nonwords were again traced, and, on the basis of these, nonvocal pitch analogue pairs were created, with the second of the pair again being the same as the original or differing by 2, 3, or 6 semitones.

From the available bank of selected recorded words, a random sample of 40 was selected for the block of trials comprising the real-word pairs. Of these, 10 were "same" stimulus pairs, with the remaining 30 "different" stimuli pairs including 10 with 2-semitone differences, 10 with 3-semitone differences, and 10 with 6-semitone differences. Blocks of 40 nonsense words and 40 tone contour pairs were created and organized in the same way.

Design and procedure

The design was mixed factorial, with group as the between-subject factor (ASD and control) and stimulus type (real words, nonsense words, pitch contours) and interval type (no, small, medium, and large differences) as the within-group factors. As pilot testing had shown that participants became confused when the stimulus types were presented randomly together (e.g., with words, nonwords, and pitch contours all combined within bocks), presentation of the 120 stimuli was blocked by stimulus type. The order of presentation of the three blocks was then counterbalanced across the participants of each group in a Latin square design, while within each block, the ordering of the stimulus pairs was held constant.

The blocks of trials were presented to the children as separate activities, with up to 10 practice trials (with feedback) preceding each. The practice trials were structured in the same way as the main blocks of trials, utilizing stimuli that had been recorded and generated in the same way as the test stimuli, but had not been included in the final stimulus set. Practice and test trials were presented on the computer. An instruction, recorded from the same female voice as the test stimuli, was presented prior to each practice pair—"Listen carefully. Are these two the same?". Following each practice trial response, an automatic feedback recording was presented—"Yes, you got it right", or "No you got it wrong this time. Try again". The experimental blocks also began with the computerized vocal instruction presented once at the start of the block. However, no feedback was provided.

Children were tested individually at the schools. No specific order of testing was maintained, with the verbal measures (BPVS and TROG) sometimes presented prior to or following the computerized task, in order to facilitate maintained concentration on all tasks. For some children, the tasks were completed over two sessions on separate days. During the computer task presentation, the experimenter sat with the child, offering encouragement for effort (i.e., not contingent upon their correct responses). Practice trials were curtailed for children who appeared to grasp the task requirements quickly, and in order to avoid fatigue and biased responding, those children who continued to respond with error on the practice trials nonetheless proceeded on to the experimental trials, with fidelity checking later used to screen out any child who had clearly failed to understand the task. Children recorded "same" or "not same" responses by pressing one of two buttons (marked "yes" and "no") on a purpose-built response box. This was connected directly to the computer that recorded the responses.

Results

The response data for each child on the computerized pitch discrimination task were imported into SPSS for fidelity checking and analysis.

Fidelity check

Signal detection analysis (SDA; Green & Swets, 1966/1974) was initially used to confirm the examiner's sense that the data for some children should be discarded due to failure to grasp the task requirements. Children were considered to have understood the task if they responded accurately within the two easiest conditions of the study (i.e., showing ability to distinguish between those pitch analogue pairs in which the stimuli differed greatly—equivalent to 6 semitones—and those pitch analogue pairs in which the stimuli did not differ at all—"same" pairs). For each child, the SDA parameter d-prime (*d′*) was therefore computed on the response data pertaining to these "same" and "large difference" pitch analogue pairs. The parameter *d′* is a measure of the perceived difference between the conditions being compared and is distributed around 0, with a large *d′* parameter indicating that the child understood the task requirements (i.e., was able to correctly respond in such a way that indicated awareness that the "same" pairs were the same, and the "very different" pairs were not the same). By contrast, a small *d′* parameter would indicate that a child was responding as if perceiving no difference between these "same" and "very different" pairs (evidencing lack of understanding of task requirements in this simplest experimental condition).

Such *d′* parameters were calculated for all children assessed and were found to vary between 3.29 (consistently responding correctly) and –2.61 (consistently responding incorrectly). Any child with a *d′* parameter below 0.8 was considered to be a poor discriminator at even this most basic level of the task and was hence considered not to have understood the task requirements. The data for 21 of the children tested ($N = 4$ ASD and 17 control) were therefore omitted from the analysis, resulting in the final sample of 29 children described above and presented in Table 1.

Main analysis

Means, standard deviations, and ranges for correct scores across experimental conditions for the two groups are shown in Table 2.

Table 2. Mean correct scores, standard deviations, and ranges for pitch discrimination task

Group		Real words			Nonsense words			Pitch contours		
		Mean	*SD*	Range	Mean	*SD*	Range	Mean	*SD*	Range
ASD	Same	8.9	1.3	4	8.5	2.3	7	8.9	1.2	4
	Small	6.1	2.9	10	5.8	3.9	10	7.7	0.28	8
	Medium	7.7	2.2	7	7	2.8	10	8.5	0.19	6
	Large	8.5	2.8	10	8.2	2.7	9	8.8	0.17	5
	Total	31.3	7.4	26	29.7	8.9	29	34	0.67	20
Controls	Same	7.9	2.3	7	8.5	1.7	6	8.5	1.8	5
	Small	3.4	2.8	9	3.2	3.1	10	4.3	2.9	9
	Medium	4.3	3.2	10	4	3	10	4.7	2.8	10
	Large	5.2	3.1	10	5.2	2.9	10	7.4	1.8	6
	Total	21	9.1	29	21	8.5	29	24.9	7.2	25

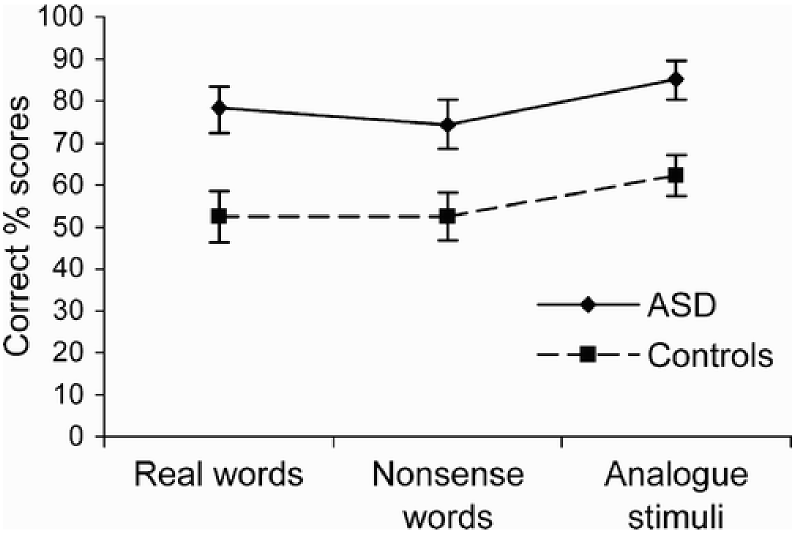
N*ote:* Mean correct scores (out of maximum of 10). ASD = autism spectrum disorders.

It was predicted that enhanced pitch discrimination would be observed in the children with ASD in comparison with controls and that the presence of semantic meaning within the stimuli would hamper pitch discrimination for controls, but not for children with ASD.

The data were analysed using a mixed factorial analysis of variance (ANOVA) with the between-subjects factor of group (2 levels; ASD and control) and within-subjects factors of stimulus type (3 levels; real words, nonsense words, and pitch analogues) and interval (4 levels; same, and small, medium, and large differences). The dependent variable was the number of correct responses across the 10 trials at each level of stimulus type by interval, and given that a priori hypotheses had been specified, these were tested directly with no adjustment made to the significance level for multiple testing.

The analysis revealed a significant main effect of group, $F(1, 26) = 11.38$, $p < .01$) with children with ASD making more correct pitch discriminations than controls ($M = 9.51$, $SD = 2.81$ for ASD group, and $M = 6.69$, $SD = 2.32$ for control group). There was a highly significant main effect of stimulus type, $F(2) = 8.47$, $p = .001$, with no significant stimulus type by group interaction, $F(2) = 0.32$. This is shown in Figure 1.

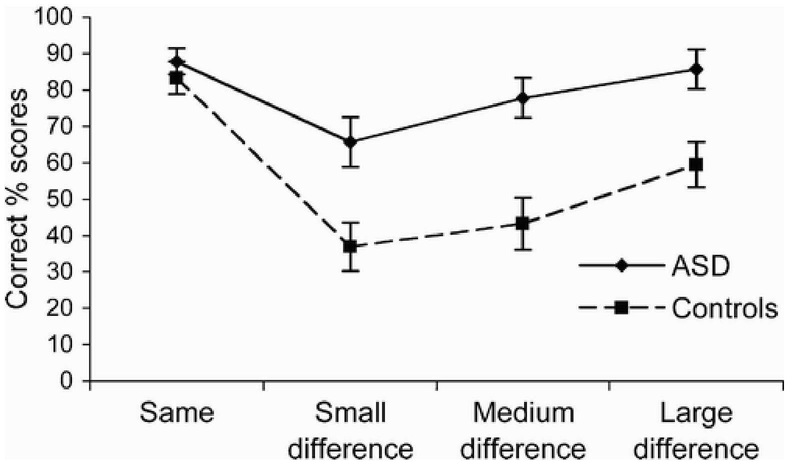
Figure 1. Main effect of group.



Across both groups, correct discrimination scores for the real and nonsense words did not differ, $t(28) = 0.57$, *ns*, $M = 0.65$, $SD = 0.23$, and were lower than pitch analogue scores, $t(28) = -4.02$, $p < .001$; $M = 0.74$, $SD = 0.20$. Thus, participants from both groups showed poorer discrimination performance when the stimuli included linguistic content.

The main effect of interval size was significant, $F(3) = 32.71$, $p < .001$, with correct discrimination scores improving with increases in interval sizes (all comparisons $p < .01$). There was a significant interval size by group interaction, $F(1.77, 47.74) = 6.25$, $p < .01$, with participants with ASD making more correct decisions than controls on all “different” pair conditions, $t(27) = 33$, $p = .033$; ASD, $M = 0.76$, $SD = 0.21$; control $M = 0.48$, $SD = 0.24$, but not on “same” pair conditions, $t(27) = 0.64$, *ns;* ASD, $M = 0.88$, $SD = 0.13$; control $M = 0.84$, $SD = 0.17$. It is unlikely that a participant, even with low discrimination ability, would falsely identify “same” pairs as “different”. Therefore the “same” condition is likely to elicit fewer errors, and the interaction, shown in Figure 2, may be an artefact of a ceiling effect on this condition.

Figure 2. Group × Condition interaction.



These results clearly show that sensitivity to pitch cues in speech is heightened in ASD, although semantic content was found to hamper this ability in a similar way to that seen for controls. In order to explore the relationship between pitch discrimination and language levels, CA and VMA measures were correlated with scores for separate conditions and total test scores (summed across all three conditions). Discrimination scores for each of the stimulus types (real words, nonwords, and pitch analogues) were found to be highly related, with coefficients varying between .67 and .87 for ASD and between .71 and .86 for controls (all $p < .01$), and this justified the summing of conditions.

For the ASD group BPVS VMA scores correlated with total discrimination scores ($r = .61$, $p < .05$) and with nonword scores ($r = .66$, $p < .01$). The BPVS VMA pitch analogue and real-word correlations approached significance (pitch analogue, $r = .5$, $p = .06$; real words, $r = .48$, $p < .07$). Neither CA nor TROG VMA scores correlated with any of the discrimination scores for the ASD group. For controls, TROG VMA scores correlated with scores on nonwords ($r = .57$, $p < .05$), and the TROG VMA correlations approached significance for real words ($r = .48$, $p = .07$) and total discrimination scores ($r = .52$, $p = .052$). Neither CA nor BPVS VMA scores correlated with any of the discrimination scores for controls. This differential pattern of correlations across groups is somewhat difficult to interpret. For controls, the correlation between BPVS and TROG VMA scores was significant ($r = .74$, $p < .01$) although VMA scores derived from the TROG were significantly lower than those derived from the BPVS ($p < .05$). The correlations showing that control children with higher TROG VMA scores also achieved higher discrimination scores may therefore reflect the role of intelligence in task performance. Whilst there was a similar discrepancy between VMA scores derived from the

TROG and BPVS ($p < .05$) for the children with ASD, the correlation between the two measures appeared to be weaker than that for controls ($r = .43$, *ns*) suggesting greater heterogeneity in the relationship between receptive vocabulary and syntax in this group. Whilst no clear conclusions can be drawn from the differential pattern of correlations observed for the ASD group, it is plausible to suggest that pitch discrimination is under the influence of different mechanisms in this group.

Discussion

The current results showed that children with ASD were exceptionally sensitive to changes in pitch contours across different types of auditory stimuli. The group mean discrimination scores were uniformly higher for participants with ASD than for controls, and whilst only 3 of the 15 controls achieved discrimination scores above 62%, only 2 participants from the ASD group scored below 64%. The findings therefore support the EPF theory and replicate previous studies showing enhanced discrimination of musical (Applebaum et al., 1979; Bonnel et al., 2003; Heaton, 2003, 2005; Heaton et al., 1998, 1999; Mottron et al.,2000) and linguistic (Heaton, Davies, & Happé, 2008; Järvinen-Pasley & Heaton, 2007; Järvinen-Pasley et al., 2008) pitch.

The second aim of the study was to test the effect of semantic content on information processing in autism. WCC theory (Happé,1999) proposes that coherence at verbal/semantic levels is weak, and experiments supporting this hypothesis have typically observed a reduced tendency to process language for meaning in autism. For example, several studies have shown that participants with autism are less likely to capitalize on available semantic information when required to disambiguate homographs (Frith & Snowling, 1983; Happé, 1997; Jolliffe & Baron-Cohen, 1999; López & Leekam, 2003). However, these studies have also shown that when participants are specifically instructed to "read for meaning", increased attention to semantic content is observed (Happé, 1994; Jolliffe & Baron-Cohen, 1999; Snowling & Frith, 1986). In the current study understanding of the test words was not directly tested but it was assumed that controls (but not participants with ASD), would be captured by meaning and perform at lower levels on the word than on the nonword and pitch contour conditions. The findings did not show a difference between real words and nonsense words for either group, and it appeared that speech, rather than speech content, was the important factor in predicting poorer pitch discrimination. Whilst differences in psychoacoustic complexity between speech and nonspeech stimuli are likely to have influenced performance, highly significant correlations between speech and nonspeech discrimination scores were observed for both groups of participants, and this suggested that similar cognitive processes were recruited for the different conditions. Although it was predicted, based on WCC theory, that discrimination performance would be less disrupted by semantic content for participants with ASD, this was not the case, and group differences on the task resulted from difference in perceptual discrimination thresholds only.

The final aim of the study addressed developmental issues by attempting to determine whether increased sensitivity to nonsemantic information in speech stimuli might contribute to the undercutting of language development in ASD. In the study by Schreibman et al. (1986), echolalic autistic children selectively attended to intonation, and it is indeed difficult to understand how such a tendency would not result in constrained language development. However, the findings from the current study failed to reveal a simple negative relationship between attention to pitch information and language skills in ASD. A total of 4 individuals with ASD obtained discrimination scores that were higher than 90% on the most difficult discrimination condition (i.e., comparing real words with only very small interval differences), and for 2 of these receptive language scores were very low. However, language scores for the other 2 high-scoring individuals were within the normal range, and correlations carried out on the discrimination and receptive vocabulary scores (VMA) for the whole group were positive and significant. This suggests that whilst enhanced perception of pitch information in speech may contribute to the undercutting of language for some individuals, language impairment is not a necessary outcome of this tendency. Previously cited research into early precursors of language in autism (Luyster et al., in press) have highlighted the importance of joint attention and nonverbal intelligence, and these factors may serve to limit any negative effects resulting from sensory abnormalities. However, it may also be the case that sensory difficulties are less marked in children with relatively unimpaired joint attention and nonverbal intelligence.

The nature of the relationship between enhanced perceptual discrimination shown on experimental tasks and the sensory abnormalities noted in clinical settings in ASD is little understood. Sensory abnormalities are not confined to ASD although low perceptual discrimination thresholds do not appear to be characteristic in other neurodevelopmental disorders associated with sensory abnormalities. In the study by Ben-Sasson et al. (2007), toddlers with ASD showed increased sensory abnormalities compared to chronological- or mental-age-matched controls, with avoiding behaviours and low awareness of sensations being most marked. However, as the authors noted, these items on the test scales involved social components, and this may have biased and increased underresponsiveness scores. The results from the diagnostic tests revealed high rates of unusual sensory interests in these toddlers, and the authors concluded that sensory seeking in ASD may not differ from sensory seeking in typical development in terms of frequency but in quality. An important question is whether differences in perceptual discrimination thresholds, as noted in the current study, may be downstream effects of these early and highly atypical sensory interests and preoccupations. Current influential accounts of autism, for example the WCC theory and theory of mind deficit hypothesis, explain social and nonsocial abnormalities within different theoretical frameworks. However, interrelationships between assets in nonsocial and deficits in social domains are currently not well understood. If enhanced perception results from a disruption in the early occurring bias to process social stimuli, a more holistic approach to studying development in autism would then be justified.

Summary

The present findings confirm that discrimination of pitch information across speech and nonspeech auditory domains is enhanced in ASD. Task difficulty resulted in the exclusion of ASD and control participants with low CA and VMA scores. As outstanding questions about the genesis of enhanced perceptual discrimination and the implications of sensory abnormalities for language development may be better addressed in studies of younger children, a future goal will be to develop a paradigm suitable for testing pitch discrimination in younger and less able children with autism. The inclusion of such a task in a battery of language, intelligence, and sensory processing tests may enable researchers to identify interrelationships between sensory abnormalities, low perceptual thresholds, and language skills.

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