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Interval and Contour Processing in Autism

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High functioning children with autism and age and intelligence matched controls participated in experiments testing perception of pitch intervals and musical contours. The finding from the interval study showed superior detection of pitch direction over small pitch distances in the autism group. On the test of contour discrimination no group differences emerged. These findings confirm earlier studies showing facilitated pitch processing and a preserved ability to represent small-scale musical structures in autism.

KEY WORDS: Autism; pitch processing; global processing; music.

The study of musical cognition in autism is of significance both clinically and theoretically. Although both Kanner (1943) and Asperger (1944) made reference to musical orientation and skills in autism, and music is often included in therapeutic and educational programmes for these children, few well controlled empirical studies into musical cognition have been carried out. More recently however, there has been a surge of interest in this topic amongst researchers and a number of experiments investigating the low level auditory processes that underpin musical perception have been carried out. The findings from these studies have largely been interpreted within the context of non-social theories of autism that have previously been tested within the visual modality.

An aspect of perceptual processing that is of particular relevance to music is pitch processing, and experimental investigations have highlighted exceptional pitch discrimination and memory in autism (Applebaum, Egel, Koegel, & Imhof, 1979; Bonnel *et al*., 2003; Heaton, 2003; Heaton, Hermelin, & Pring, 1998; Heaton, Pring, & Hermelin, 1999). Many of these findings have been interpreted within the context of the Weak Central Coherence (WCC) (Frith, 1989; Happé, 1999) and Enhanced Perceptual Functioning (EPF) (Mottron & Burack, 2001) theories of autism, accounts that predict a bias towards enhanced featural or perceptual processing. A question that is central to attempts to test these theories and to better understand perception of music in autism concerns the extent to which such a bias influences other processes in musical perception.

Several recent studies have addressed the question of whether atypical pitch processing in autism influences musical perception at higher or global levels. In one study, Heaton (2003) looked at whether individuals with autism, who possessed good pitch memory and discrimination, would show abnormalities in processing musical configurations. Working within the framework of WCC (Frith, 1989: Happé, 1999) which predicts a processing bias for parts over wholes, autistic participants and age and intelligence matched controls were presented with two chord disembedding tasks. Outstanding disembedding ability has been noted in autism using visual tasks (Joliffe & Baron-Cohen, 1997; Shah & Frith, 1983, 1993; Mottron, Burack, Iarocci, Belleville, & Enns, 2003) and it was hypothesised that this ability would

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generalise to the auditory domain. However, the findings from the study showed that musical chords tended to be perceived holistically, unless experimental conditions specifically biased those subjects with exceptional pitch memory towards a segmentation strategy. Only then was superior disembedding performance found in the autism group.

In another study, Heaton *et al.* (1999) tested local processing, using a sequential processing paradigm developed by Dowling (see: 1994). The subject of this study was a musically untrained adolescent boy with Asperger's syndrome, who achieved ceiling performance on a battery of tests of music analytic skills. In the study utilising Dowling's paradigm the subject was asked to make same/different judgements about short pairs of melodies which were (1) the same (2) included a one tone, contour violating change, or (3) included a one tone, contour maintaining change. Experimental investigations into the processing of melodies (see: Trehub, Schellenberg, & Hill, 1997) have shown that pairs of different unfamiliar melodies that share Gestalt characteristics tend to be perceived as the same. However, the subject in the case study detected the changes in all of the contour maintaining pairs. Mottron, Peretz, & Ménard, (2000) used this paradigm with a group of high functioning adolescents and adults with autism and matched controls. In their study local processing was operationalised as a one-tone contour preserving alteration in the comparison melody. In two other conditions global processing was operationalised by introducing a single tone contour violating change and presenting melodies in transposition. The findings from this study showed that although the subjects with autism were better able than controls to detect contour maintaining changes in untransposed pairs (termed local condition) they showed no differences in contour violating untransposed melodies (termed global level) and transposed melodies (termed global level). These findings were interpreted as providing support for the enhanced perceptual functioning (EPF) model of autism (Mottron & Burack, 2001), which like WCC predicts good perceptual or local processing, but unlike WCC does not predict abnormalities in global processing. However, a contour study by Foxton *et al.* (2003) included a condition in which untransposed contour maintaining pairs were presented, and here group differences between participants with Autism Spectrum Disorders and typical development failed to emerge. In the present study contour discrimination in autism will be further investigated.

One question arising from studies showing increased access to tones within musical contours in autism (Heaton *et al.*, 1999; Mottron *et al.*, 2000) relates to the processing of musical pitch intervals. Substituted tones in contour maintaining melody pairs alter interval patterns within sequences and the good detection of these changes in individuals with autism might reflect atypical representation of melodic information. Melody is believed to be represented in two distinct forms relating to degree of familiarity. Familiar melody representations include information about precise distances between adjacent tones (pitch intervals). Unfamiliar melodies are represented less precisely in rising and falling patterns (Bever & Chiarello, 1974; Dowling, 1978; Edworthy, 1985; Liegeois-Chauvel, Peretz, Babai, Laguitton, & Chauvel, 1998; Peretz, 1990; Peretz & Babaie, 1992; Peretz & Morais, 1987; Peretz, Morais, & Bertelson, 1987). In the previously cited study of an adolescent with Asperger's syndrome (Heaton *et al.*, 1999) who detected all pitch changes in contour maintaining melody pairs, ceiling performance was also observed on a pitch interval discrimination task. Pitch contours consist of sequences of ascending and descending pitch intervals. If outstanding pitch interval discrimination is characteristic in autism this may result in a bias towards interval rather than contour based melody representations.

In the following studies musically untrained children with autism and with normal development will participate in two tasks. In the first, participants will be asked to judge the pitch direction of intervals that vary over pitch distance. The same group of children will also participate in the second study, which will further investigate the question of whether individuals with autism show superior detection of pitch interval changes in contour maintaining untransposed melody pairs.

EXPERIMENT 1

Method

Participants

Thirteen children with autism and two children with Asperger's syndrome participated in the experiment. All were attending a specialist provision for children diagnosed with autistic spectrum disorders (ASD). The children were aged between 7 years, 3 months and 14 years, 9 months (Mean: 10 years). Their scores on the Peabody Picture Vocabulary Test ranged between 56 and 126 (Mean 92) and their scores on the Raven's Matrices ranged between 99 and 147 (Mean 107). The subjects in the two control groups were matched to the autistic children on an individual basis for chronological age, gender, and either performance on the Peabody Picture Vocabulary Test (Group 2) or the Raven's Matrices (Group 3). Two control children attended a specialist school (moderate learning difficulties) and the remaining children attended mainstream schools. None of the subjects included in the studies had undergone extended periods of individual instrumental or singing lessons.

Stimuli

Forty-eight melodic pitch intervals were used in the experiment. They ranged from one semitone apart (minor second) through the whole range up to and including intervals 12 semitones (an octave) apart. There were four of each interval type, two ascending and two descending. The starting notes for the intervals ranged from C3 (one octave below middle C) to A#5 (approaching two octaves above middle C). The intervals were played on a Casiotone 202 electonic keyboard (acoustic piano setting) by the experimenter. The keyboard was out of the child's view.

Procedure

Subjects were shown a picture of a man descending and a woman ascending a staircase and were asked to describe them. A series of pictures depicting objects ascending and descending were then provided for sorting into "up" and "down" categories. After this task was completed the children were told that they were to listen to some musical intervals that would also go up or down. They were told "listen to the two notes and say as quickly as you can whether they go up or down." Four pairs of intervals were played and children were given feedback on the accuracy of their responses. After this the experimental trials began. Presentation of the stimuli was randomised across interval size and movement type. Subjects were awarded one point for each correct identification.

Table I. Means and *SD* for Correctly Identifying Pitch Direction of Small, Medium and Large Intervals

	Small intervals		Medium intervals		Large intervals	
	Mean	*SD*	Mean	*SD*	Mean	*SD*
Autism group (1)	12.07	2.65	12.20	3.80	13.20	3.93
VIQ matched controls (2)	9.13	2.32	11.13	2.67	11.33	3.66
Non-verbal matched controls (3)	9.80	3.03	12.93	2.63	13.80	3.14

*16 Stimuli per condition.

Results

The means and *SD* for the correct identification of small (1–4 semitones), medium (5–8 semitones) and large (9–12 semitones) intervals are show in Table I.

An Analysis of Variance with Interval type (small/medium/large) as the within group factor, and diagnosis (autistic/controls) as the between group factor, was carried out. There was no significant main effect of Diagnosis ($F = 2.29$, n.s.), but the effect of Interval type was highly significant ($F(2) = 17.98$, $p < .001$). There was a significant diagnosis by interval type interaction ($F(4) = 2.88$, $p < .027$) as illustrated in Fig. 1.

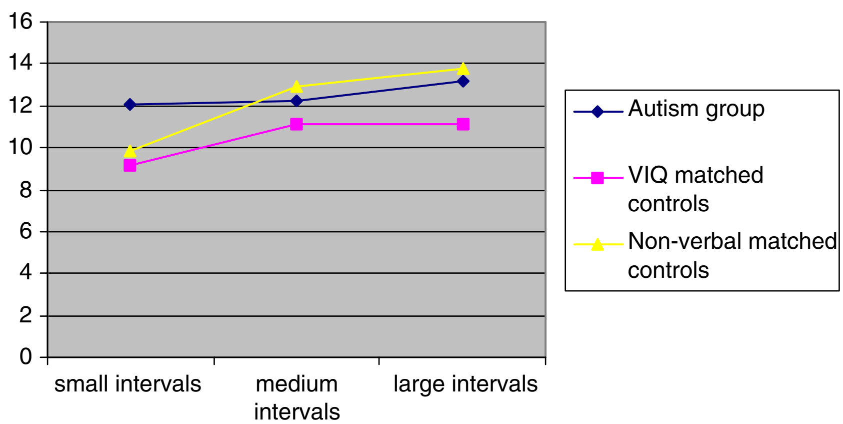

Fig. 1. Group by interval type interaction.

Following the recommendation of Howell (1987), the interaction was subjected to a simple effects procedure. The criterion value for statistical significance was set at .01 in order to control the overall error rate for the set of comparisons. This analysis indicated that the children with autism were significantly better able to correctly identify small intervals than either the verbal IQ matched control group ($F(1, 29) = 10.35$, $p < .003$) or the non-verbal IQ matched control group ($F(1, 29) = 4.92$, $p < .012$). There was no significant difference between groups on the medium and large intervals. Also, for the children with autism there was no significant difference in performance across conditions ($F = 1.45$, n.s.), whereas for both control groups performance on the small interval condition was less good than on the medium and large interval conditions (Group 2 small vs. medium intervals, $F(1, 14) = 5.58$, $p < .023$, small vs. large $F(1, 14) = .53$, $p < .039$: Group 3 small vs. medium $F(1, 14) = 16.8$, $p < .001$, small vs. large $F(1, 14) = 19.63$, $p < .001$).

EXPERIMENT 2: MELODY PROCESSING

Method

Stimuli

Pilot Stimuli: The pilot stimuli were 30 pairs of 10 note melodies. Each melody had a simple tonic-dominant-tonic harmonic structure and was presented at the same moderate tempo (crotchet = 112). The stimuli were randomised across keys and type (same, maintaining, violating) and were presented in the same pitch range (C4 (middle C) to A5). The melody pairs were separated by a four second interval and there was an interval of 8 seconds between pairs. Stimuli were recorded onto DAT 15/20 tapes. The stimuli pairs were of three types: (1) same, (2) different with *maintaining* change (3) different with *violating* change. The altered note in the different pairs occurred around the central point in the melodies. Twelve children with ASD and 12 controls participated in the pilot study. The data from the pilot study showed that overall performance was low, with subjects only able to correctly identify same pairs 53% of the time. Performance on the violating condition was better (64%) but the crucial comparison of conditions has questionable validity when subjects were not reliably able to identify no change pairs.

Table II. Means and *SD* for Correct Identification of Melodies Across Three Experimental Conditions

	Same		Maintaining		Violating	
	Mean	*SD*	Mean	*SD*	Mean	*SD*
Autism group (1)	7.60	1.80	5.07	2.58	6.33	2.35
VIQ matched controls (2)	7.40	1.92	4.53	1.64	6.33	1.80
Non-verbal matched controls (3)	7.27	2.19	4.40	1.76	6.60	1.76

*10 Stimuli per condition.

Experimental Stimuli: These differed from those used in the pilot study in two ways. Firstly the sequences were of six rather than 10 note duration; secondly, the altered note in the different pairs was randomised across positions over the sequence.

Procedure

The experiment was carried out at the various participating schools. All attempts were made to ensure the minimum of distracting noise. The children were seated in front of the DAT player and speakers and told that they would hear pairs of melodies and should decide whether they thought the melodies were the same or different to each other. The children's responses were recorded by the experimenter.

Results

The means and *SD* for the three experimental conditions are shown in Table II.

An analysis of variance with stimulus type (same/maintaining/violating) as the within group factor and Diagnosis (children with autism and control subjects) as the between group factor was carried out on the data. The analysis failed to reveal a significant effect of Diagnosis ($F(2, 42) = .221$, n.s.), but did reveal a highly significant effect of Condition ($F(1) = 22.02$, $p < .001$). There was no Diagnosis by Condition interaction ($F(2) = .22$, n.s.). Pairwise comparisons were carried out on the three experimental conditions with a Bonferonni adjustment whereby the criterion value for statistical significance was set at $p < .017$. These showed that performance was significantly better on the same than on the maintaining condition ($t(44) = 5.817$, $p < .001$) and at a level approaching significance on the violating condition ($t(44) = 2.413$, $p < .02$). Performance on the violating condition was superior to performance on the maintaining condition ($t(44) = -5.170$, $p < .001$).

As findings of enhanced contour discrimination had been previously found in an adult autistic sample, age and contour correlations were carried out on the data. This was statistically significant for both the autism group ($r = .559$, $p < .05$) and for the control groups ($r = .365$, $p < .05$).

Correlations were carried out between total scores for experiments one and the three experimental conditions in experiment two. None of these were significant for either the autism group (interval×same $r = .266$, ns; interval×contour maintaining $r = .361$, n.s.; interval×contour violating $r = .234$, n.s.) or controls (interval×same $r = -.291$, n.s.; interval× contour maintaining $r = .360$, n.s., or interval× contour violating $r = .155$, n.s.).

DISCUSSION

In Experiment 1, children with autism showed significantly better discrimination of small pitch intervals than controls. When intervals were medium (5–8 semitones) or large (9–12 semitones), all subjects showed good levels of performance and no group differences emerged. On the small interval condition (1–4 semitones) normally developing controls showed poorer levels of correct discrimination and this was statistically significant. No such differences were found in the autism group and they were as able to discriminate pitch direction with small intervals as medium and large ones.

The finding of enhanced sensitivity to pitch direction is consistent with previous findings of superior pitch processing in participants with autism (Heaton *et al.*, 1998, 1999; Heaton, 2003). However, there are important differences between these earlier studies and experiment 1 presented here. The research question for the earlier studies concerned the extent that absolute pitch ability, as seen in musical savants with autism, might also be found in autistic subjects without savant talent. The experimental findings did indeed show that pitch information is more accessible and stable in autism than in normal development, and this was interpreted as indicating superior utilisation of long-term memory processes for this type of stimuli (Heaton, 2003). However, in experiment 1 presented here, task performance required subjects to judge the relative position (higher/lower) of tones to each other. It would not appear that superior long-term pitch memory for individual tones would facilitate performance. Indeed studies have shown that the perception of pitch patterns and the perception of isolated pitches are subserved by different neural mechanisms (Johnsrude, Penhune, & Zatorre, 2000; Patterson, Upperkamp, Johnsrude, & Griffiths, 2002). In the present study normal controls showed generally good levels of performance and group differences only emerged on the small interval condition where pitch distance discriminations required finer grained levels of analysis.

Enhanced pitch interval discrimination found in the autism group did not result in superior detection of pitch changes in untransposed melody pairs in experiment 2. The data analysis failed to show positive significant correlations between total scores on the interval task and under the different conditions of the contour task for children with autism or controls. In the contour study participants correctly identified 74% of same pairs; poorer performance was found on violating melodies and here only 64% were correctly labelled as different. Lowest levels of performance were seen with untransposed contour maintaining melodies where subjects correctly made a different response only 46% of the time. Indeed only 7 of the 45 participants performed at levels that were significantly above chance. It is clear from the data that neither a local (changes detected) nor a global (changes undetected) processing strategy dominated here and this was true across subject groups. Thus these data, like those obtained by Foxton *et al.* (2003) do not support previous findings showing increased detection of changed tones in contour maintaining untransposed melody pairs in autism (Heaton *et al.*, 1999; Mottron *et al.*, 2000). This non-replication of previous findings does not result from methodological differences between studies, as the stimuli and procedures used in Experiment 2 were the same as those used in the previously cited single case study (Heaton *et al.*, 1999) where superior contour discrimination in autism was found. A significant correlation between age and performance on the contour task was found in Experiment 2 and this raises the possibility that developmental differences between the child participants tested here and the older participants tested in the Mottron *et al.* study influenced the experimental findings. However, the participants in Foxton *et al.*'s study were also adults and did not demonstrate superior discrimination of contour maintaining stimuli. The question of why there should be such variability between different groups of participants with autism clearly merits further investigation.

It was earlier suggested that the study of cognitive mechanisms underpinning music cognition serves to provide insights into the extent that musical skills are spared in autism and also allows cognitive theories to be tested within the auditory domain. Important to the question of preserved musical skills in neurodevelopmental disorders are studies carried out with individuals who show abnormalities in such skills (congenital amusia). These studies have identified deficits in pitch discrimination (Ayotte, Peretz, & Hyde, 2002; Peretz *et al.*, 2002) and pitch pattern perception (Foxton, Dean, Gee, Peretz, & Griffiths, 2004) and have greatly informed our understanding of the conditions under which musical information processing becomes compromised. These findings contrast sharply with those obtained from studies of autistic participants with enhanced or intact processing at these levels. Further, studies showing enhanced pitch memory and discrimination (Bonnel *et al.*, 2003; Heaton, 2003; Heaton *et al.*, 1998, 1999; Mottron *et al.*, 2000), and preserved chord (Heaton, 2003) and contour processing (Foxton *et al.*, 2003; Heaton *et al.*, 1999; Mottron *et al.*, 2000) are consistent with findings showing enhanced feature processing and unimpaired configural processing in the visual domain in autism (Plaisted, Saksida, Alcantara, & Weisblatt, 2003). Whilst these findings provide much support for cognitive models proposing enhanced featural (WCC) or perceptual (EPF) processing in autism, limitations in experimental paradigms leave the question of corresponding deficits in global processing (WCC) largely unexplored. Whilst global processing is difficult to define and operationalise, it is clear that stimuli used in experimental investigations into such processes should reflect the demands of the domains under investigation. Accordingly, global musical stimuli should require the integration of various musical components, including for example, tempo, rhythm, pitch, timbre etc. In the study by Foxton *et al.* (2003) "global" processing involved the integration of absolute pitches, pitch direction and time value changes, and participants were required to match pitch direction change under experimental conditions that included local pitch interference or local pitch and timing interference. The findings from the study showed an additive effect of interference for control participants, with discrimination performance being highest without interference and poorest when two interfering features (pitch and timing) were introduced. In contrast, the performance of the participants with ASD showed no significant decreases in the interference conditions. The authors concluded that their participants with ASD were not susceptible to interference from an auditory coherent whole. Future studies might adapt this approach, by excluding interfering features and manipulating the numbers and types of musical components to be integrated. Such studies will be important in determining whether or not insensitivity to interference effects generalises to difficulties in integrating musical elements in on-line music listening and will also provide a valid test of global processing in autism.

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