When less is more: poor discrimination but good colour memory in Autism

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Abstract: In two experiments children with autism and two groups of controls matched for either chronological or non-verbal mental age were tested on tasks of colour discrimination and memory. The results from experiment 1 showed significantly poorer colour discrimination in children with autism in comparison to typically developing chronological age matched controls. However, in experiment 2, children with autism, retained unlabelled perceptual colour information to a significantly higher level than either group of controls. The findings suggest that enhanced performance on perceptual tasks relate to a reduced tendency to encode verbal information in memory.

Introduction

Autism is a neurodevelopmental disorder of biological origin that is characterised by deficits in socialisation, communication and imagination (American Psychiatric Association, 1994). In addition to these diagnostic markers, approximately 70% of diagnosed individuals also show corresponding global intellectual impairments (Fombonne, 1999). However, for many of these individuals, specific, circumscribed areas of cognitive functioning are preserved or even enhanced. For example, unusually fine pitch discrimination has been noted in several experimental studies (Bonnel, 2003; Heaton, Hermelin & Pring, 1998; Heaton, Pring & Hermelin, 1999; Heaton, 2003; 2005) and this has lent support to models positing enhanced perceptual functioning (Mottron & Burack, 2001: Mottron, Dawson, Soulières, Hubert & Burack, 2006) or a bias to process and encode local information (Frith, 1989; Happé, 1999) in autism. The studies presented here will extend previous findings of enhanced perceptual processing by testing perception and memory for colour in autism.

An aspect of autism that is likely to have significant implications for perceptual and cognitive information processing and organisation, but is largely unconsidered in current theoretical accounts, relates to the delayed onset and wide variation in language skills in diagnosed individuals (e.g. Kjelgaard & Tager-Flusberg, 2001). Difficulties in generalisation and categorisation in autism have been attributed to perceptual abnormalities, such as an increased tendency to process unique rather than shared features in visual arrays (Plaisted, 2001). But recent studies of face processing in autism (e.g. Deruelle, Ronda, Gepner & Tardif, 2004) show that autistic individuals may use substantially different attentional and processing strategies from typically developing children, at least for visual tasks. Moreover, recent investigations into perceptual categorization (e.g. Roberson, Davidoff, Davies & Shapiro, 2004, 2005: Pilling, Wiggett, Özgen & Davies, 2003; Goldstone, 1998) show that language plays a central role in directing attention to those features of objects relevant for categorization. Findings from the developmental literature show that young children's knowledge of object names results in preferential looking at both objects (Baldwin & Markman, 1989) and pictures of objects (Schafer, Plunket & Harris, 1999). Further, exhaustive sorting of objects into groups occurs within a week of entering the 'naming spurt' at around 18 months (Gopnik & Meltzoff, 1997).

Since Brown and Lenneberg (1954) first proposed a direct relationship between naming and memory for colors, many studies have supported the proposal that coloured stimuli are coded both perceptually and verbally by adults (Kay & Kempton, 1984; Lucy, 1992; Alvarado & Jameson, 2005; Özgen, 2004; Gilbert, Regier, Kay &

Ivry, 2005; Pilling, Wiggett, Özgen & Davies, 2003; Roberson & Davidoff, 2000; Witthoft et al., 2003). Studies of typically developing children's colour naming and memory have shown that discrimination and memory for colours is facilitated by knowing the appropriate label for a colour, relative to colours they cannot name (Sandhoffer & Smith, 2001; Kowalski & Zimiles, 2006; Braisby & Dockrell, 1999), and this is true even when children know only one or two terms (Roberson, Davidoff, Davies & Shapiro, 2004). This evidence suggests that language plays an important role in shaping and modifying cognitive organisation in typical development. However, language onset is significantly delayed in autism, and cognitive theories propose that information processing is perceptually biased. The studies to be described therefore explored the relative influences of verbal and perceptual information on colour processing in autism. In experiment 1 we investigated colour discrimination, and in experiment 2 we examined memory for colours in conditions with and without verbal labels. As intelligence test score means for two of the participants groups (Autism, MLD) were significantly below population norms, a pre-test explored the extent to which each population could comprehend colour terms.

GENERAL METHOD

Participants

Thirteen children and adolescents with autism were recruited from a specialist school, to which entry is dependent upon meeting criteria for autism outlined in DSM 1-V (APA, 1994) or ICD-10 (World Health Organization, 1993). Testing using the Raven's Matrices task (Raven, Court, & Raven, 1992), a test of fluid intelligence, confirmed that for the autism group, standardised scores were within the handicapped range.

Measures of receptive vocabulary, using the British Picture Vocabulary Scales (BPVS; Dunn, Whetton & Pintilie, 1997) were consistent with a group mean verbal mental age (VMA) of 5 years. This profile, with non-verbal intelligence scores in the moderate to mild range of handicap, and a large discrepancy between verbal mental age (VMA) and chronological age (CA) is commonly associated with low-functioning autism (LFA). There were two groups of control participants. The first were intellectually unimpaired, were recruited from a mainstream UK state school, and were individually matched to the participants with autism for chronological age (Typically Developing group) (TD). The second group of controls were recruited from a school for pupils with Moderate Learning Disabilities (MLD) and were matched to the children with autism for chronological age and non-verbal IQ. Age and psychometric data for the participant sample are shown in table 1.

(Table 1 about here)

Comparison of the psychometric data for the autism and two control groups revealed no significant difference between chronological age measures ($F(2,36) = .23$). There were significant between-group differences on Ravens Matrices scores ($F(2,36) = 32.24$, $p<.001$) and on verbal mental age measures ($F(2,36) = 17.31$, $p<.001$). Post-hoc Bonferroni tests showed that TD controls had significantly higher Ravens Matrices scores than MLD controls and participants with autism (both $p<.05$). Ravens Matrices scores for MLD controls and participants with autism did not differ significantly. TD participants had higher Verbal Mental Age scores than MLD

controls and participants with autism (both $p<.05$), and MLD controls had higher Verbal Mental Age scores than participants with autism ($p<.05$). Thus whilst participants with autism were chronological age matched to both groups of controls, and were also matched to MLD controls for non-verbal IQ, their language scores (receptive vocabulary) were significantly poorer than those of both control groups.

Pre-test: Color Term Comprehension

Stimuli and Apparatus

11 colour tiles (prototypical examples of red, blue, yellow, orange, brown, pink, purple, grey, black and white) were laid out on a table under natural daylight conditions by a window. The experimenter read out the colour names, one at a time, in random order and children were asked to point to the corresponding tile. Responses were recorded and mean accuracy is shown in table 2.

(Table 2 about here)

A one-way Anova, carried out on the data failed to reveal a significant difference between groups ($F(2,36) = 2.38$, $p>.05$).

Experiment 1: Testing perceptual discrimination.

Colours used in the following studies were glossy Munsell chips (Munsell, 1966). Only the hue value of the colours varied, and chroma (colourfulness) and value (lightness) were kept constant at Munsell levels 6/6. Good examples of the four

primary hues (red, blue, green and yellow) at each of three hue levels were chosen from the Munsell book and converted for the computer into L*u*v* co-ordinates using Munsell conversion software. A full list of stimuli used in all three experiments can be found in Appendix I. The selected coordinates were programmed into bit images using CSS software and the stimuli were presented using e-prime software. A portable spot chroma-meter was used to ensure that colours remained constant across testing conditions.

Training trials: In eight trials (two for each of the four colours) participants saw three colour patches, two of which (distractor patches) differed from the third (target patches) in Munsell hue intervals of 8.5 or 9 steps (e.g. target = 1R6/6, distractors = 9.5R6/6 and 10R6/6). Thus the two distractors were always very similar to each other and quite dissimilar from the target patch. Participants were instructed to point to the most different patch (target) over as many trials as necessary to reach ceiling performance. Verbal feedback was given throughout training trials.

Experimental trials: There were six trials of each colour (red, blue, green and yellow) with the target stimuli differing from the two comparison stimuli by 1, 2 or three Munsell steps. Each target appeared twice with each pair of distractors, making a total of 24 trials, which were presented in random order.

Results.

The means and standard deviations for discrimination scores are shown in table 3.

Place table 3 around here

A 2-tailed binomial test showed that the means for the (lowest scoring) autism group was significantly above chance ($p<.001$). A one-way Anova showed a significant between group effect ($F(2,36) = 7.86$, $p<.001$). Post-hoc Bonferroni tests showed that TD control scores were significantly higher than scores for MLD controls and participants with autism (both, $p<.05$). There was no significant difference between scores for MLD control and autism groups.

Within group correlations were carried out on the discrimination scores, the chronological and verbal mental age scores and the non-verbal IQ scores. Of these, only the discrimination and verbal mental age correlations for the autism group ($r = .66$, $p<.05$) and the TD controls ($r = .72$, $p<.01$) were significant.

Experiment 2: Testing colour memory

In the pre-test familiarisation phase of experiment 2, the same participants were shown one of four animal pictures (taken from Snodgrass & Vanderwart, 1980), paired with one of four different prototypical colour patches (red, green, blue or yellow). The four animal-colour pairings (e.g. dog paired with red, cat paired with blue, pig paired with green and rabbit paired with yellow) were shown four times each, making a total of sixteen familiarisation trials. In the test phase the previously exposed animals (dog, cat, pig and rabbit) were shown individually together with all four of the colour patches (red, green, blue and yellow). Participants were instructed to select, by pointing, the colour that had been associated with the animal in the

familiarisation trials. Each participant had four attempts to match each animal/colour (16 in all). Order of presentation of the trials was randomised. Responses were recorded by the computer.

After a short break, the same familiarisation procedure was repeated for the second phase of the experiment. However, in the test trials for phase 2, the pre-exposed animals, were presented with three colour patches from the same colour category as the patch paired with that animal in familiarisation trials (e.g. cat with three different shades of blue). The position of the pre-exposed and distractor patches was randomised across trials. A full list of stimuli is shown in Appendix I. Participants were again asked to point to the colour patch that had been paired with the animal in the familiarisation trial. Responses were recorded by computer.

Results

Table 4 shows the means and standard deviations from phase 1 and phase 2 of experiment 2.

(Table 4 about here)

In phase 1 there were 4 response options, so the probability of chance performance was 25%. In phase 2 there were 3 response options with a probability of chance performance of 33%. To allow for differences in chance value scores, raw data were converted into *z* scores. *Z* scores for the two phases of experiment 2 are shown in table 5.

(Table 5 about here)

As table 5 shows, all groups scored significantly above chance on phase 1. For phase 2 only autism group scores were significantly above chance.

Analysis of variance with Group (autism/MLDcontrols/TDcontrols) as the between group variable and Condition (phase 1/phase 2) as the within group variable was carried out on the data. This failed to reveal a significant main effect of Group ($F(2,36) = 2.71$, $p>.05$). However, there was a significant main effect of Condition ($F(1,36) = 12.53$, $p<.001$) and a significant group by condition interactions ($F(2,36) = 8.56$, $p<.001$) which is shown in figure 1 below.

Place figure 1 around here.

Correlates of verbal labelling: Although the participants with autism knew colour terms (naming pre-test), and their colour discrimination (experiment 1) was not significantly different to that of controls matched for age and non-verbal intelligence, their performance on experiment 2 suggested that they relied less on verbal labels and encoded more perceptual information. In order to determine which psychometric variables are associated with information encoding strategies, memory scores (phase 1 & phase 2) were correlated with chronological age, verbal mental age, non-verbal IQ

and discrimination ability (scores for experiment 1) for the whole subject sample (n= 39). Scores for phase 1 (where targets could be correctly identified by verbal coding only) correlated with VMA (r=.58, p<.001) and discrimination ability (r = .54, p<.01). For phase 2 scores (where successful performance relied on perceptual encoding) there was a significant negative correlation with VMA (r = -.36, p<.05). No other correlations reached significance. Within group correlations carried out on the control group data (MLD & TD) all failed to reach significance, so the data were then pooled and the correlations were repeated. These showed that for these participants without autism, phase 1 scores correlated with VMA (r = .52, p<.01). No other correlations were significant. Correlations carried out on the autism data were significant for phase 1 and discrimination ability (experiment 1) (r = .62, p<.05). There was also a significant negative correlation between phase 2 scores and VMA (r = -.55, p<.05). These latter findings suggest that a bias to encode perceptual information in autism is associated with low verbal mental age.

Discussion

In the pre-test phase of the experiments, participants were presented with a range of eleven colours for identification. Whilst some individuals with autism and MLD made some errors there was no significant difference between groups and the majority of intellectually impaired participants named all colours correctly. TD children would be expected to know all 11 basic colour terms by five years and the VMA means for all groups were higher than this. The findings from experiment 1 were surprising given that theoretical accounts of autism have proposed that enhanced perceptual

discrimination is characteristic (WCC; EPF) and such abilities have been demonstrated in other domains (e.g. pitch; Heaton, 2003; 2005; visuo-constructional; Caron, Mottron, Berthiaume & Dawson; 2006). However, whilst participants with autism performed at levels that were significantly better than chance, discrimination scores were significantly poorer than those of CA matched typically developing participants and very similar to participants matched for CA and non-verbal intellectual impairment (MLD).

In experiment 2, animals and colour patches were presented for paired learning. In phase 1 of the experiment, the colours with which the animals were associated were both widely separated in perceptual space and were also from different name categories. Therefore either attention to perceptual features or a naming strategy should yield correct performance. In phase 2 of the experiment however, all three choice alternatives received the same name, so a memory strategy based on naming would not result in successful identification. Only by attending to the perceptual qualities and ignoring the name classification of the presented stimuli would above-chance performance be achieved. Children with autism performed above chance on this condition (although controls did not) indicating that they remembered the exact shades of the paired colours, rather than relying on the category name. Whilst all of these participants knew the relevant colour names, these appeared to influence their colour perception to a far lesser degree than that of children with similar levels of non-verbal intelligence, but without autism.

The correlations carried out on the data from the experiments revealed interesting differences in patterns of performance between groups and across the different conditions. Within the typically developing group, the most verbally able children showed the highest levels of discrimination on experiment 1 and phase 1 of experiment 2. Whilst discrimination in experiment 1 did not correlate with VMA for the MLD controls, the phase 1 scores and VMA correlation approached significance. Whilst MLD scores were poorer than those of TD participants, they resembled them in showing a primary reliance on verbal labels in memory and chance level performance when recognition depended on encoded perceptual information.

The low levels of performance, observed in participants without autism in phase 2 of experiment 2, are surprising given empirical findings showing that colour stimuli are encoded both perceptually and verbally by adults (e.g. Robeson & Davidoff, 2000; Pilling et al., 2003). However, in experiment 2, attention was directed to both colours and animals, and this may have reduced perceptual encoding of colour information. Further, familarisation trials and test trials for phase 1 may have served to reinforce the use of a verbal labelling strategy, which resulted in chance performance on phase two.

The correlations carried out on the autism data showed that like TD participants, discrimination performance on experiment 1 correlated with VMA. This finding is interesting in that much of the empirical work that has supported enhanced perception theories has been carried out with intellectually able individuals with autism. However, in experiment 1, the upper range for discrimination scores was still lower

than for the MLD group (19 MLD; 17 LFA). As was the case for the participants without autism, there was a positive and significant correlation between VMA and scores for phase 1 of experiment 2. However for phase 2, where performance was not at chance, performance scores and VMA correlations were significant and negative, showing that children with autism *and* low VMA retained unusually high levels of perceptual information. This finding is important in providing evidence for a direct link between perception and deficits in language in autism.

At the early, pre-linguistic stages of typical development, information processing appears to be characterised by attention to perceptual features. For example, French, Mareschal, Mermillod & Quinn (2004) were able to manipulate categorisation performance in 3- 4 month old infants by making small changes to specific visual features. However, whilst these changes influenced category re-allocation (e.g. cat to dog category) in infants, such effects were not seen in adults (Rakison, 2000). The probability that such a developmental shift in attentional processing is linked to the onset of language is supported by evidence showing increased attention to objects and pictures of objects for which verbal labels are available (Baldwin & Markham, 1989; Schafer et al., 1999), and the close link between the onset of spontaneous exhaustive sorting of object into groups and the naming spurt at 18 months (Gopnik & Meltzoff, 1997). If, as this evidence suggests, an early interplay between perceptual and linguistic processes is an important characteristic of typical developmental trajectories for the development of concepts and categories, then this raises important questions about qualitatively atypical information processing in children for whom language has been markedly delayed. Whilst most of the autistic participants knew colour names,

these influenced information processing to a much smaller degree than children without autism. For children with autism, the increased salience of perceptual information reflects the impoverished role that language plays in cognitive development. Late language competence may force autistic individuals to adopt novel strategies in a wide range of perceptual categorisation tasks.

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Appendix 1
Stimuli used in Experiment 1

Discrimination Task
Practice Trials

1R6/6, 9.5R6/6, 10R6/6
1B6/6, 9.5B6/6, 10B6/6
1G6/6, 9.5G6/6, 10G6/6
1Y6/6, 9.5Y6/6, 10Y6/6

Test Trials
2.5B6/6, 5B6/6, 7.5B6/6, 10B6/6
2.5Y6/6, 5Y6/6, 7.5Y6/6, 10Y6/6
2.5R6/6, 5R6/6, 7.5R6/6, 10R6/6
2.5G6/6, 5G6/6, 7.5G6/6, 10G6/6

Memory Task
Part One

5R6/6, 5B6/6, 5G6/6. 5Y6/6

Part Two
5R6/6, 1R6/6, 9R6/6
5B6/6, 1B6/6, 9B6/6
5G6/6, 1G6/6, 9G6/6
5Y6/6, 1Y6/6, 9G6/6

Table 1: Psychometric data for participants with autism and their controls.

Group	**Chron. Age**		**Ravens Matrices**		**Verb. Ment. Age**	
	Mean	**sd**	**Mean**	**sd**	**Mean**	**sd**
Autism (n=13)	11.4	2.46	62.15	6.82	5.38	.97
MLD Controls (n=13)	11.5	2.07	65.54	7.73	7.06	.97
TD Controls (n=13)	11.0	2.44	89.15	14.42	8.76	3.11

Table 2. Mean number of colours correctly identified in response to the appropriate colour term at pre-test.

Group	Mean (max=11)	s.d.
Autism	10.23	1.48
MLD Controls	10.77	.59
TD Controls	11.00	.0

Table 3. Mean number of correct colour discriminations in experiment 2.

Group	**Total correct discrimination scores (max = 24)**	
	Mean	**s.d.**
Autism	**.53**	**3.23**
MLD Controls	**13.84**	**4.41**
TD Controls	**18.23**	**3.76**

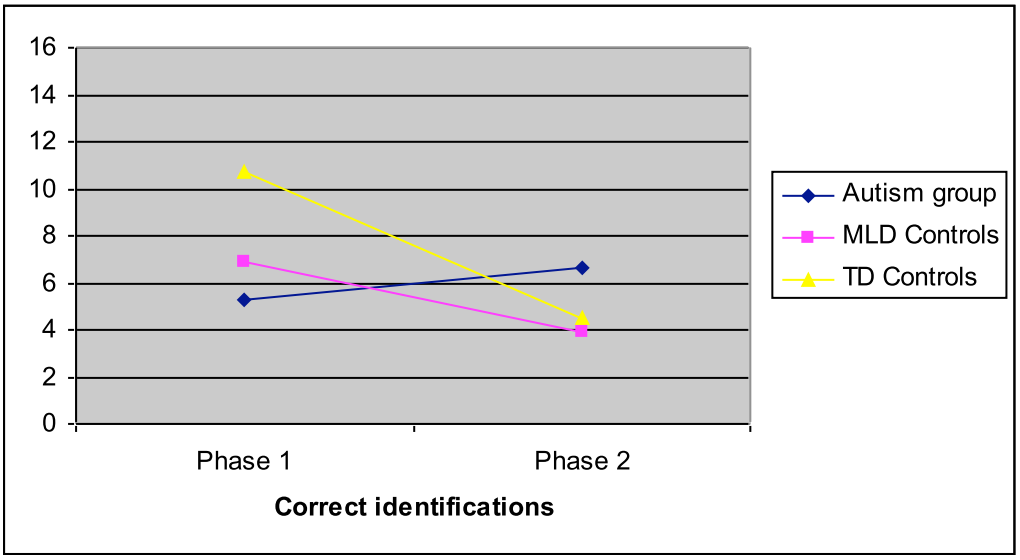
Table 4: Mean memory accuracy and standard deviations for the participants with Autism and their controls on phase 1 and phase 2 of experiment 2.

Group	**Phase 1** (max = 16)		**Phase 2** (max = 16)	
	mean	sd	mean	sd
Autism	5.31	3.2	6.62	1.85
MLD Controls	6.92	4.59	3.92	1.44
TD Controls	10.69	5.2	4.54	2.36

Table 5: Z scores for phase 1 and 2 of experiment 2.

Group	Phase 1 Z scores	Phase 2 Z scores
LFA	.92	2.47
MLD Controls	.62	-1.87
TD Controls	13.9	-1.52

Figure 1. Interaction in experiment 2.


16
14
12
10
8
6
4
2
0
Phase 1
Phase 2
Correct identifications
Autism group
MLD Controls
TD Controls