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REPORT

Embedded figures detection in autism and typical development: preliminary evidence of a double dissociation in relationships with visual search

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Abstract

Individuals with autism show relatively strong performance on tasks that require them to identify the constituent parts of a visual stimulus. This is assumed to be the result of a bias towards processing the local elements in a display that follows from a weakened ability to integrate information at the global level. The results of the current study showed that, among children with autism, ability to locate a figure embedded in a larger stimulus was only related to performance on visual search trials where the target was identified by a unique perceptual feature. In contrast, control children's embedded figures performance was specifically related to their performance on visual search trials where the target was defined by a conjunction of features. This double dissociation suggests that enhanced performance on perceptual tasks by children with autism is not simply a consequence of a quantitative difference in ability to engage in global processing.

Autism is a developmental disorder that is associated with a number of characteristic psychological deficits, most notably in the domains of social interaction, communication and imaginative behaviour (American Psychiatric Association, 1994). However, in contrast to these areas of relative weakness, individuals with autism typically perform well on tasks that require them to focus on the parts, rather than the wholes, of a stimulus. For example, they show superior performance when compared to controls on the 'embedded figures' test (Joliffe & Baron-Cohen, 1997; Shah & Frith, 1983) in which a local element hidden within a larger complex figure has to be identified. This superior performance is assumed to be the result of a bias towards the parts, or local elements, of a stimulus, and has been termed 'weak central coherence' as it contrasts to the typical drive to integrate information in order to create global meaning that is seen in individuals without autism (Frith & Happé, 1994; Happé, 1999). Within this framework, the difference between individuals with and without autism is a quantitative one; individuals with autism are simply less biased towards integrating information at the global level.

Weak central coherence effects are seen among individuals with autism on a range of other tasks, including spatial construction tests such as block design (Shah & Frith, 1993), identification of canonical visual representations (Jarrold & Russell, 1997) and more controversially in perception of visual illusions (Happé, 1996; though see Ropar & Mitchell, 1999, 2001). Individuals with autism also show higher motion coherence thresholds than matched controls (Milne, Swettenham, Hansen, Campbell, Jeffries & Plaisted, 2002; Spencer, O'Brien, Riggs, Braddick, Atkinson & Wattam-Bell, 2000). Although these findings point to a relatively low-level visual basis to weak central coherence, there is at present no generally accepted explanation for this phenomenon. The purpose of our work was to examine the mechanisms that underpin weak central coherence effects in autism.

One way in which one might learn more about these mechanisms is by relating individuals' ability to perform accepted 'weak central coherence tasks', such as the embedded figures test, with their performance in visual search paradigms. As with embedded figures tasks, individuals with autism tend to outperform controls on tests of visual search, showing either generally more rapid search (O'Riordan, 2000), or a faster rate of search for targets among distractors (O'Riordan & Plaisted, 2001; O'Riordan, Plaisted, Driver & Baron-Cohen, 2001; Plaisted, O'Riordan & Baron-Cohen, 1998a). This has led to the

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suggestion (e.g. Plaisted *et al.*, 1998a, 1998b; O'Riordan, 2000) that the same mechanism may underlie this relative superiority on both types of task. However, to our knowledge no previous study has directly related performance on visual search and embedded figures tasks,[1] and this was the aim of the current work.

In visual search tasks, participants search for a prespecified target item, for example a red X, which is presented along with a varying number of distractor items. Traditionally, visual search tasks have been divided into two types. In 'feature search' the target is defined by a unique perceptual feature, such as colour. So, for example, search may be for a red X amongst green X's and green Y's. In contrast, in 'conjunction search' the target is defined by a conjunction of two or more features, such as colour and shape. For example, search may be for a red X presented along with green X's and red Y's. In this case it is neither the colour nor the shape of the target that uniquely identifies it, but rather the conjunction of these two features. Within one class of models of search, target detection in 'feature search' is achieved by monitoring feature maps that independently encode the presence of a specific visual feature in the display. A conjunction search display does not lead to unique feature map activity and so an additional mechanism is required to combine information across the maps, such as visual attention (Treisman, 1988; Wolfe, 1994). Consequently, feature search tends to result in fast, efficient search performance, with search times being unaffected by the number of distractor items present in the display. In contrast, conjunction search tasks tend to produce generally slower and display-size-dependent search times.

Alternative models (e.g. Duncan & Humphreys, 1989) have argued that search efficiency is determined by the perceptual discriminability of the target in relation to the distractors. This discriminability decreases when the distractors become more similar to the target and when the distractors become more heterogeneous. As a result, when the difference between the target and distractors decreases in feature search tasks, search can also become effortful and dependent on the number of items in the display (Duncan, 1989; O'Riordan *et al.*, 2001). In the current study we employed such a difficult feature search task alongside a conjunction search task. This allows for a comparison of the importance of the detection processes underlying these tasks that is uncontaminated by large differences in search difficulty.

[1] Plaisted *et al.* (1998a) have previously reported non-significant correlations between search time and block design performance among individuals with autism. However, the measure of block design performance employed was a scaled score standardized for age (essentially an IQ measure) rather than an absolute index of level of ability.

Method

Participants

Eighteen diagnosed children with autism and 18 typically developing control children were recruited to this study with full and informed parental consent. The children with autism were aged between 8 years 4 months and 15 years 0 months (M = 149.0 months, SD = 23.7); control children were aged between 5 years 2 months and 7 years 8 months (M = 77.9 months, SD = 10.9). Controls were matched individually to the children with autism for performance on the Raven's Coloured Progressive Matrices (RCPM; Raven, Court & Raven, 1995).

Procedure

In an initial session, participants were given the British Picture Vocabulary Scale (BPVS; Dunn, Dunn & Whetton, 1982) and the RCPM to assess levels of verbal and non-verbal ability, respectively. Scores on the BPVS were converted to a mental age equivalent score while the dependent measure taken from the RCPM was raw score out of a maximum of 36. Individuals were then presented with two experimental tasks. The embedded figures task employed set A of the Children's Embedded Figures Test (CEFT; Witkin, Oltman, Raskin & Karp, 1971). This consists of 11 embedded figures, each of which contains the same target figure. The time taken by each participant to find the target in each case was recorded using a stopwatch, although if individuals were unable to locate the target within 120 seconds they were credited with a time of 120 seconds in line with the specified test procedure.

The visual search task consisted of two types of trials: feature and conjunction. In each case the participant was instructed to point to the target figure, located on an A4-sized display, with the time taken by the participant to locate the target on each trial recorded by the experimenter. This target was always a red 'jumping' clown in the approximate shape of the letter X, which was approximately 4 cm by 4 cm in size. In feature trials the distractor items were similarly sized 'fat' red clowns in the approximate shape of the letter O, and 'thin' green clowns in the approximate shape of the letter T. In conjunction trials the distractors were jumping green clowns and thin red clowns. Examples of the target and distractor items for each trial type are shown in Figure 1. In previous studies of visual search performance in autism a target was present on only half of the trials and participants were required to make a present–absent response (O'Riordan, 2000; O'Riordan & Plaisted, 2001; O'Riordan

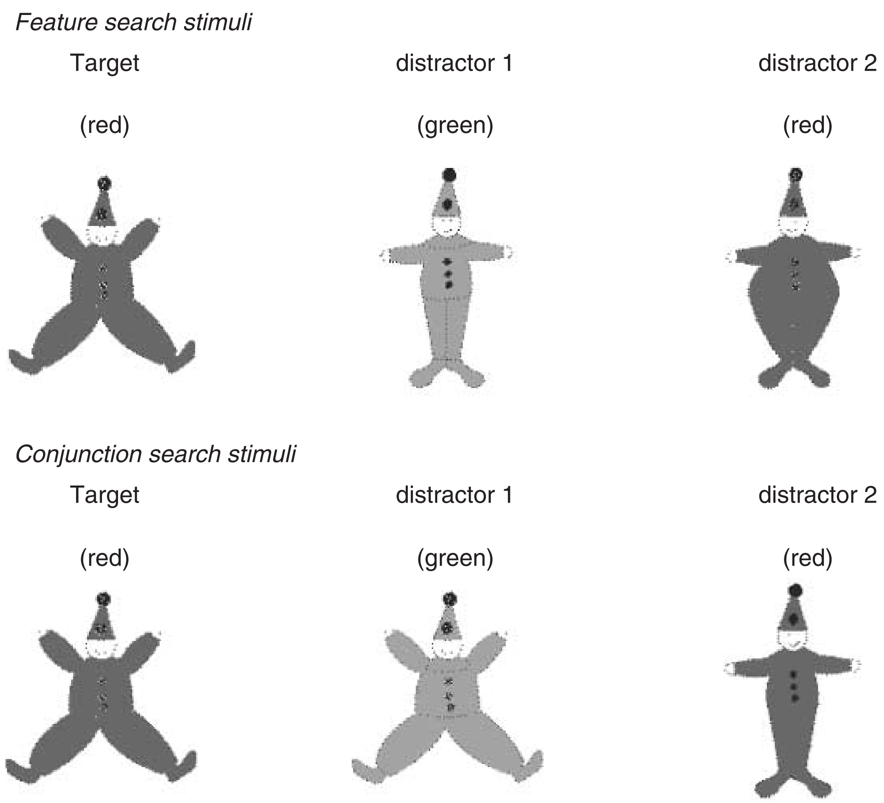


Figure 1 *Examples of target and distractor stimuli employed in feature and conjunction search trials. Note, images were actually presented in colour (as annotated).*

et al., 2001; Plaisted *et al.*, 1998a). In the current study, a target was present on every trial. This not only made the tasks more comprehensible for individuals of the level of ability assessed here, it also reduces the risk of the results being affected by response criterion effects: a potential problem with target absent trials. On any trial the target was presented along with either 3, 6 or 9 of each type of distractor, and the time taken to locate the target was recorded. There were ten trials of each size for each search condition, giving a total of 60 trials, which were presented in a pre-specified pseudo-random order. A regression of response time against number of distractors was conducted for each individual to derive search slope and intercept values for the two types of search trials.

Results

Table 1 presents summary statistics for the performance of each group on the measures of verbal and non-verbal ability and on each experimental task. A comparison of verbal and non-verbal intelligence measures in the two groups confirmed that individuals were satisfactorily matched for RCPM score, $F(1, 34) = .27$, $p = .61$, $\eta^2 < .01$, and also did not differ reliably in BPVS mental age, $F(1, 34) = 1.12$, $p = .30$, $\eta^2 = .03$.

A preliminary analysis of estimates of skewness and kurtosis showed that assumptions of normality were not violated for the experimental measures with the exception of feature and conjunctive slopes among children with autism (zs ≥ 2.35, $p \leq .02$). Slope scores for each individual in each group were therefore subjected to a square root transformation that removed these deviations from normality (subsequent zs for all slope scores $\leq .93$), and these transformed values were employed for all subsequent statistical analyses.

Analysis of average times to locate targets on the embedded figures task showed that individuals with autism were faster at detecting embedded figures than were controls, $F(1, 34) = 11.82$, $p < .01$, $\eta^2 = .26$. Figure 2 plots average untransformed search times for each group and trial type against total number of distractors. A comparison of transformed individual search slopes across groups and tasks revealed a significant difference in average slopes between the two groups, $F(1, 34) = 4.10$,

Table 1 *Summary statistics for group performance*

		Children with autism		Controls	
		M	SD	*M*	SD
RCPM	Score	21.56	7.45	20.56	3.28
BPVS	Mental age (months)	67.78	33.06	76.67	13.25
EFT	RT (s)	14.41	13.04	28.56	11.61
Feature search	Slope (ms/distractor)	60	56	89	42
	Intercept (ms)	153	307	795	554
Conjunction search	Slope (ms/distractor)	54	58	63	34
	Intercept (ms)	186	296	1082	585

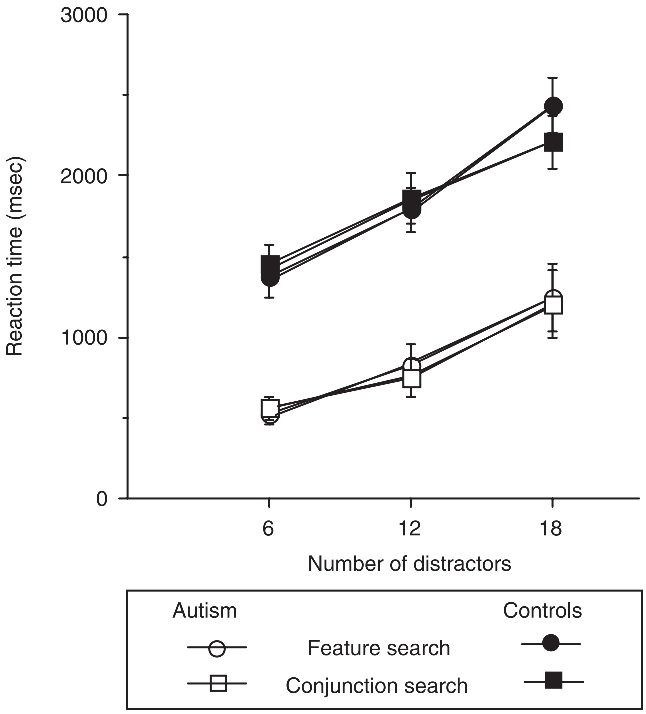
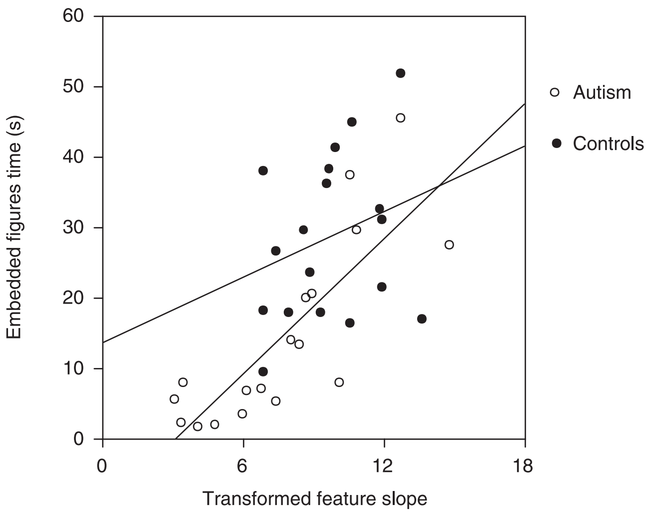


Figure 2 *Average reaction time to detect target among displays of 6, 12 or 18 distractors by group and type of search trial (error bars are +/– 1* SE*).*

p = .05, η^2 = .11; individuals with autism produced shallower slopes. Search slopes for conjunction search trials and feature search trials did not differ significantly; though if anything search slopes were steeper for feature than for conjunction trials, $F(1, 34) = 3.36$, $p = .08$, $\eta^2 = .09$. The interaction between group and search type was also non-significant, $F(1, 34) = .74$, $p = .40$, $\eta^2 = .02$. A similar analysis was performed on intercept data. This revealed a reliable difference between average intercepts for the two groups, $F(1, 34) = 33.74$, $p < .001$, $\eta^2 = .50$, with generally faster performance among individuals with autism. Intercepts for feature search trials were reliably lower than for conjunction search trials, $F(1, 34) = 4.53$, $p = .04$, $\eta^2 = .12$, and the interaction between group and search type was non-significant, $F(1, 34) = 2.88$, $p = .10$, $\eta^2 = .08$.

Preliminary correlational analyses were performed to examine whether embedded figures detection times were related to individuals' visual search rates. Scatterplots for the association between embedded figures detection times and either feature or conjunction search slopes are shown for the two groups in Figure 3; analysis of the residuals for each of these associations revealed no outliers whose data warranted removal ($z < 2.3$, Tabachnick & Fidell, 2001, p. 122). Embedded figures times were reliably related to feature search slopes among children with autism, $r(16) = .81$, $p < .001$, but not among controls, $r(16) = .28$, $p = .26$. In addition, these two correlations differed reliably in strength, $z = 2.31$, $p = .02$ (Howell, 1997, pp. 261–262). In contrast, embedded figures times were not significantly related to conjunction search slopes among individuals with autism, $r(16) = .29$, $p = .24$, but were reliably related to conjunction search slopes among controls, $r(16) = .50$, $p = .03$. However, in this instance the difference in strength of these two correlations was not significant, $z = .70$, $p = .48$.

These results suggest a group difference in the associations between embedded figures detection and feature search only. However, although a distinction has been made between the two types of search tested here, both share a number of common processes including feature extraction, target encoding and decision criterion (Duncan & Humphreys, 1989). It is therefore possible that these shared factors contribute to the correlations between embedded figures detection and each visual search slope measure. To determine the extent to which either search measure accounted for unique variance in embedded figures time, simultaneous regressions were conducted in which feature and conjunction search slopes were entered as predictors of embedded figures time in each



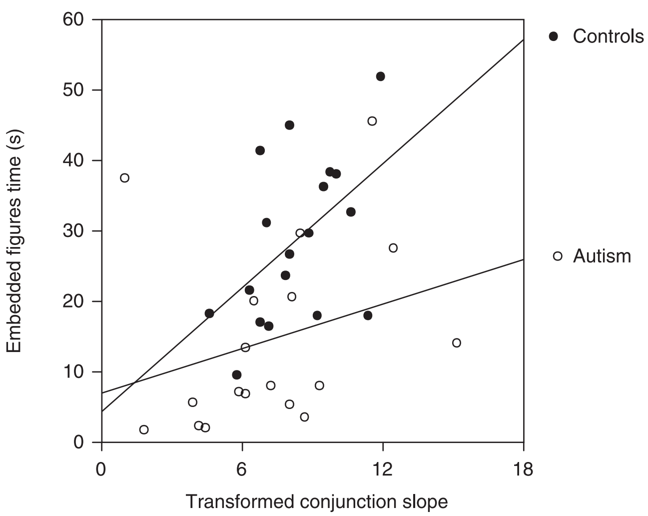


Figure 3 *Scatterplots of the relationships between embedded figures detection and search slopes.*

Table 2 *Predictors of embedded figures detection time in each group*

	Children with autism			Controls		
	Beta	*F*	*p*	Beta	*F*	*p*
Feature slope	.85	15.41	< .01	.24	1.22	.29
Conjunction slope	–.13	0.43	.52	.52	5.50	.04
BPVS mental age	–.06	0.09	.77	–.23	1.12	.31

group. BPVS mental age was also included as a potential predictor in order to control for the effects of individual variation in developmental level not already accounted for by Ravens matching. The results of these analyses are shown in Table 2, which provides standardized regression coefficients for each independent variable, as well as a test of the significance of the unique contribution of that variable to the prediction of embedded figures detection. Estimates of tolerance and collinearity diagnostics for each model were acceptable. These results show that among children with autism embedded figures performance was uniquely related only to feature slope, but that among controls only conjunction slope was a reliable predictor. A formal test (Chow, 1960) showed that these patterns of regression weights differed significantly across the two groups, $F(4, 28) = 3.70$, $p = .02$.

To confirm that this group difference in patterns of association with embedded figures time was really mediated by differences in relations with the two search measures, a final analysis compared partial correlations between embedded figures detection time and each search slope that controlled for search rate on the other visual search task. The partial correlation between embedded figures time and feature search slope, controlling for conjunction search slope, was significant among individuals with autism, $r(15) = .80$, $p < .001$, but not among controls, $r(15) = .26$, $p = .32$. These two partial correlations differed significantly in strength, $z = 2.28$, $p < .05$.[2] The partial correlation between embedded figures time and conjunction search slope, controlling for feature search slope, was not reliable among individuals with autism, $r(15) = -.18$, $p = .50$, but was significant among controls, $r(15) = .49$, $p = .04$. Again, these two partial correlations differed significantly in strength, $z = 1.97$, $p < .05$.

Discussion

In common with previous reports, the individuals with autism assessed in this study out-performed controls equated for general level of non-verbal ability on the detection of embedded figures and of targets in visual search displays. However, the key finding of this study is that the two groups also differed reliably in the pattern of associations shown between embedded figures detection and visual search. Children with autism showed a relationship between embedded figures task performance and feature, but not conjunction, search rate. Typically developing individuals showed the opposite pattern. In addition, when partial correlations were examined in order to explore the specific links between embedded figures detection and each measure of search slope, the

[2] This comparison employs the same basic formula as that used for comparing two independent correlations, but takes into account the fact that the standard error for a Fisher transformed partial correlation is $1/\sqrt{(N-2-k)}$, where k is the number of partialled variables.

relationship with feature search slope was significantly stronger among individuals with autism than controls, and the opposite pattern was observed for conjunction search.

These findings therefore suggest that a double dissociation exists in the relationships between embedded figures detection and feature versus conjunction search in autism and typical development. However, this evidence should be viewed as preliminary for three main reasons. First, in order to adapt the visual search methodology for use with young individuals with autism with a degree of developmental delay, a non-standard testing procedure was used. The task was still clearly visual search; however, targets were presented on relatively large displays that would have required participants to scan over a larger visual angle than is common in computer-based tasks, and 'target-absent' trials were not employed. Indeed, these manipulations may have contributed to the unusual finding that search rates on the feature and conjunction conditions did not differ significantly. Of course, the strength of this matching is that the difference in relationships between search performance and embedded figures detection observed in these two groups cannot be attributed to quantitative differences in search difficulty. Nevertheless, a replication using more standard visual search paradigms would allow a more direct comparison with previously published data.

Second, because the individuals with autism assessed here were not particularly high-functioning, they were matched to typically developing controls who were necessarily younger in age. We would argue that matching for level of intellectual functioning captures the fact that mental age is a much better predictor of cognitive performance in individuals with any developmental delay than is chronological age (cf. Weiss, Weisz & Bromfield, 1986), and that any additional age-based maturation in search performance is unlikely. However, it is conceptually possible that the difference in patterns of association observed here is driven by maturational differences in search behaviour. This could be tested in studies of high-functioning individuals with autism matched to controls for both age and ability, though clearly the generalizability of such work would be limited by the need to select a non-representative sample.

A third concern follows from the fact that our key analyses are correlational in nature, and the sample sizes employed here are small for this form of approach. This clearly limits the power of these analyses to detect associations between measures, and increases the likelihood that results may be erroneously affected by atypical cases or differences in the range or reliability of a measure across groups. Having said this, it is the case that clearly significant differences in patterns of association across groups are seen even in samples of this size, and consequently the effects observed here appear to be reasonably large in magnitude.

Consequently, despite these important caveats, the current findings do have implications for our understanding of autism, and the processes involved in visual search and embedded figures detection. They obviously suggest that embedded figures detection relies primarily on those processes unique to feature search among individuals with autism, and on processes unique to conjunction search among controls. However, what is less clear is exactly what differentiates feature and conjunctive search, particularly when the two tasks are matched for overall difficulty as is the case here, and given the considerable evidence that they share a number of common processes (Duncan & Humphreys, 1989).

Within models like Treisman's Feature Integration Theory (FIT; Treisman, 1988), the critical difference between the feature and conjunction tasks is the extent to which target detection can be achieved by detection of the presence of unique feature map activity. In the feature task used here, this unique feature map activity is a difficult signal to detect and so search is at least as hard as the conjunction task. In contrast, for the conjunction search task, target detection is not possible by monitoring the activity in a single feature map, but instead must rely on a representation in which both target features are combined. This representation, or the master map of locations in FIT, is by definition a higher-level representation as it is constructed from the output of the relevant feature maps. Under this account, the fact that performance on the embedded figures task is correlated to conjunction search performance among controls suggests that these participants rely on information encoded in a higher-level representation, in which basic visual features are combined, to detect the presence of the embedded figure. In contrast, the correlation with feature search performance in autism suggests that the participants with autism are more dependent on information in the basic feature maps to detect the embedded figure. This potential difference between the two groups in the type of representation that supports performance in the embedded figures task may also go some way to explain the enhanced discrimination of targets in the embedded figures test among individuals with autism; individuals with autism may be able to use a more basic low-level representation to detect the embedded figure which in turn would be available to drive detection processes more quickly and so lead to faster responding in this group.

However, in the models of visual search developed by Duncan and Humphreys (1989) there is no such mechanistic difference between the process deployed in feature and conjunction search; instead search performance is simply determined be the relative balances of target–distractor similarity and distractor–distractor heterogeneity. Two search tasks can be equally difficult but have different balances of these two factors. For example, low target–distractor similarity and high distractor–distractor heterogeneity (a difficult feature task) could lead to similar overall search difficulty as high target–distractor similarity and low distractor–distractor heterogeneity (a conjunction task). Under these conditions variation in feature search rate will be driven by variation in individuals' ability to discriminate targets and distractors, and variation in conjunction search rate will depend primarily on variation in the ability to group distractors. Consequently, the current data suggest that embedded figures performance relates to the processes that allow the target to be differentiated from the background among individuals with autism and to the processes that group non-target items together among controls. If this reasoning is correct then the embedded figures task involves an interplay between global grouping processes and the local differentiation of the target. Indeed in the CEFT all of the displays have a global identity and the difficultly for controls might be in overriding this. In contrast, superior embedded figures detection in autism could, in principle, result from either a weakening of global grouping processes (cf. Jarrold & Russell, 1997; Shah & Frith, 1993) or superior target discrimination (O'Riordan & Plaisted, 2001; Plaisted *et al.*, 1998a, 1998b; Plaisted, Saksida, Alcántara & Weisblatt, 2003). The fact that detection in this group relates to feature search, which we argue relies more on target detection than grouping, suggests that it may be enhanced discrimination of target features that underlies superior embedded figures performance in autism.

Whichever of these two classes of explanation of the current data is correct, these results still suggest that rapid embedded figures detection in autism may involve more than a simple perceptual *bias* driven by *weak* central coherence. If feature map activity (cf. Treisman, 1988) underlies embedded figure detection in this group, then this would represent a qualitative difference relative to controls, rather than a bias per se. Alternatively, if the balance of grouping versus differentiation (cf. Duncan & Humphreys, 1989) is atypical in autism, then it may be too simplistic to ascribe this to a simple weakening of coherence, as enhanced target detection may also affect performance. Indeed the importance of the current results is that they expose the perceptual complexity of the apparently simple embedded figurers test and key differences between perceptual processing in autism and typical development.

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References

American Psychiatric Association (1994). *Diagnostic and statistical manual of mental disorders*, 4th edition. Washington, DC: American Psychiatric Association.

Chow, G.C. (1960). Tests of equality between sets of coefficients in two linear regressions. *Econometrica*, **28**, 591–605.

Duncan, J. (1989). Boundary-conditions on parallel processing in human-vision. *Perception*, **18**, 457–469.

Duncan, J., & Humphreys, G.W. (1989). Visual-search and stimulus similarity. *Psychological Review*, **96**, 433–458.

Dunn, L.M., Dunn, L.M., & Whetton, C. (1982). *British Picture Vocabulary Scale*. Windsor, UK: NFER-Nelson.

Frith, U., & Happé, F. (1994). Autism: beyond 'theory of mind'. *Cognition*, **50**, 115–132.

Happé, F.G.E. (1996). Studying weak central coherence at low levels: children with autism do not succumb to visual illusions. A research note. *Journal of Child Psychology and Psychiatry*, **37**, 873–877.

Happé, F. (1999). Autism: cognitive deficit or cognitive style? *Trends in Cognitive Sciences*, **3**, 216–222.

Howell, D.C. (1997). *Statistical methods for psychology*, 4th edition. Belmont, CA: Duxbury Press.

Jarrold, C., & Russell, J. (1997). Counting abilities in autism: possible implications for central coherence theory. *Journal of Autism and Developmental Disorders*, **27**, 25–37.

Jolliffe, T., & Baron-Cohen, S. (1997). Are people with autism and Asperger syndrome faster than normal on the Embedded Figures Test? *Journal of Child Psychology and Psychiatry*, **38**, 527–534.

Milne, E., Swettenham, J., Hansen, P., Campbell, R., Jeffries, H., & Plaisted, K. (2002). High motion coherence thresholds in children with autism. *Journal of Child Psychology and Psychiatry*, **43**, 255–263.

O'Riordan, M. (2000). Superior modulation of activation levels of stimulus representations does not underlie superior discrimination in autism. *Cognition*, **77**, 81–96.

O'Riordan, M., & Plaisted, K. (2001). Enhanced discrimination in autism. *The Quarterly Journal of Experimental Psychology*, **54A**, 961–979.

O'Riordan, M.A., Plaisted, K.C., Driver, J., & Baron-Cohen, S. (2001). Superior visual search in autism. *Journal of Experimental Psychology: Human Perception and Performance*, **27**, 719–730.

Plaisted, K., O'Riordan, M., & Baron-Cohen, S. (1998a). Enhanced visual search for a conjunctive target in autism: a research note. *Journal of Child Psychology and Psychiatry*, **39**, 777–783.

Plaisted, K., O'Riordan, M., & Baron-Cohen, S. (1998b). Enhanced discrimination of novel, highly similar stimuli by adults with autism during a perceptual learning task. *Journal of Child Psychology and Psychiatry*, **39**, 765–775.

Plaisted, K., Saksida, L., Alcántara, J., & Weisblatt, E. (2003). Towards an understanding of the mechanisms of weak central coherence effects: experiments in configural learning and auditory perception. *Philosophical Transactions of the Royal Society of London B*, **358**, 375–386.

Raven, J.C., Court, J.H., & Raven, J. (1995). *Coloured Progressive Matrices*. Oxford: Psychologists Press.

Ropar, D., & Mitchell, P. (1999). Are individuals with autism and Asperger's syndrome susceptible to visual illusions? *Journal of Child Psychology and Psychiatry*, **40**, 1283–1293.

Ropar, D., & Mitchell, P. (2001). Susceptibility to illusions and performance on visuo-spatial tasks in individuals with autism. *Journal of Child Psychology and Psychiatry*, **42**, 539–549.

Shah, A., & Frith, U. (1983). An islet of ability in autistic children: a research note. *Journal of Child Psychology and Psychiatry*, **24**, 613–620.

Shah, A., & Frith, U. (1993). Why do autistic individuals show superior performance on the block design task? *Journal of Child Psychology and Psychiatry*, **34**, 1351–1364.

Spencer, J., O'Brien, J., Riggs, K., Braddick, O., Atkinson, J., & Wattam-Bell, J. (2000). Motion processing in autism: evidence for a dorsal stream deficiency. *Neuroreport*, **11**, 2765–2767.

Tabachnick, B.G., & Fidell, L.S. (2001). *Using multivariate statistics* (4th edn.). Boston, MA: Allyn & Bacon.

Treisman, A. (1988). Features and objects: the 14th Bartlett memorial lecture. *The Quarterly Journal of Experimental Psychology*, **40A**, 201–237.

Weiss, B., Weisz, J.R., & Bromfield, R. (1986). Performance of retarded and nonretarded persons on information-processing tasks: further tests of the similar structure hypothesis. *Psychological Bulletin*, **100**, 157–175.

Witkin, H.A., Oltman, P.K., Raskin, E., & Karp, S.A. (1971). *A manual for the Embedded Figures Tests*. Palo Alto, CA: Consulting Psychologists Press.

Wolfe, J.M. (1994). Guided search 2.0 – a revised model of visual-search. *Psychonomic Bulletin & Review*, **1**, 202–238.

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