Autism

http://aut.sagepub.com/

How *central* is central coherence? : Preliminary evidence on the link between conceptual and perceptual processing in children with autism

Beatriz López, Susan R. Leekam and Gerda R . J. Arts

Autism 2008 12: 159

DOI: 10.1177/1362361307086662

autism © 2008
SAGE Publications
and The National
Autistic Society
Vol 12(2) 159–171; 086662
1362-3613(200803)12:2

How *central* is central coherence?

Preliminary evidence on the link between conceptual and perceptual processing in children with autism

BEATRIZ LÓPEZ *University of the West of England, UK*
SUSAN R. LEEKAM *University of Durham, UK*
GERDA R.J. ARTS *University of Durham, UK*

ABSTRACT This study aimed to test the assumption drawn from weak central coherence theory that a central cognitive mechanism is responsible for integrating information at both conceptual and perceptual levels. A visual semantic memory task and a face recognition task measuring use of holistic information were administered to 15 children with autism and 16 typically developing children. If there is a central integration mechanism, performance on the two tasks should be positively associated. No relationship was found, however, between the two abilities in the comparison group and, unexpectedly, a strong significant inverse correlation was found in the autism group. Classification data further confirmed this finding and indicated the possibility of the presence of subgroups in autism. The results add to emerging evidence suggesting that central coherence is not a unitary construct.

KEYWORDS *autism; central coherence theory; face perception; semantic memory*

ADDRESS *Correspondence should be addressed to:* BEATRIZ LÓPEZ, *School of Psychology, University of the West of England, Bristol BS16 1QY, UK. e-mail: beatriz.lopez@uwe.ac.uk*

Introduction

It is over 30 years since Hermelin and O'Connor (1970) made the proposal that children with autism have a cognitive impairment in the ability to integrate information, yet the idea that children with autism have cognitive integration problems continues to influence current thinking. For example, Frith (1989; 2003) claims that children with autism have 'weak central coherence', that is, that the central mechanism responsible for the integration of incoming information is weak in autism and consequently they rely on piecemeal processing.

DOI: 10.1177/1362361307086662

Central coherence may be seen to operate across two different levels. First, central coherence is assumed to be responsible for integrating information at the conceptual level in tasks that involve integration of concepts like semantic memory tasks or sentence processing tasks. Second, central coherence is also assumed to be responsible for integrating information at the perceptual level, in tasks that involve integration of visual information into global patterns like the Navon task (Navon, 1977) or certain face processing tasks. These two types of coherence have been referred to as conceptual and perceptual coherence respectively (Plaisted, 2001).

The assumption that integration of information at conceptual and perceptual levels relies on a general integration mechanism is largely based on the fact that those two abilities are believed to be impaired in autism. As far as conceptual coherence is concerned, evidence from a number of studies shows that individuals with autism have difficulty using semantic information in memory tasks (Hermelin and O'Connor, 1967; Tager-Flusberg, 1991) and in sentence processing tasks that involve using context information (Frith and Snowling, 1983; Happé, 1997; Jolliffe and Baron-Cohen, 1999), although contextual difficulties are not as generalized as first predicted (López and Leekam, 2003; Ramondo and Milech, 1984).

Studies investigating the ability to integrate visual information, in contrast, have provided mixed results. Most of these studies have used the Navon task (Navon, 1977) and whilst some of these studies show abnormalities in the use of global information (Mottron and Belleville, 1993; Plaisted et al., 1998; Rinehart et al., 2000), others show typical global processing in autism (Mottron et al., 2003; Ozonoff et al., 1994; Rinehart et al., 2001). The most likely explanation for this mixed pattern of results is that, as Lamb and Robertson (1989) suggest, the Navon task is not a reliable measure of global processing as minor changes in procedure, stimuli and/or presentation can alter effects. An alternative source of evidence of global processing abilities in autism comes from studies using face perception tasks, as faces are processed largely in terms of holistic information. Although studies have demonstrated the presence of global difficulties in relation to face processing in autism (e.g. Davies et al., 1994; Gepner et al., 1996; Lopez et al., 2004), the evidence is sparse and thus provides less support for the claim of weak perceptual coherence than exists for weak conceptual coherence.

If, as predicted by weak central coherence, abnormalities at the perceptual level and conceptual level stem from impairment of a central mechanism, one can reasonably propose that children who experience difficulty at the perceptual level will also have difficulty at the conceptual level. To date only one study has administered a conceptual and a perceptual task to the same samples of children with autism and typically developing children

(Hoy et al., 2004). Unfortunately the link between the two abilities was not directly tested, and the performance between the autism and comparison groups did not differ once verbal ability was accounted for.

In the present study a conceptual task and two perceptual tasks were administered to a sample of high-functioning children with autism and a matched sample of typically developing children to explore the link between conceptual and perceptual processing. Traditionally, research on central coherence tends to use the block design, the embedded figures test or visual illusions to assess perceptual coherence. These tests measure the extent to which participants can override the Gestalt of a picture and focus on parts of the display. In this study a traditional central coherence test, the block design task (Wechsler, 1974) was used alongside a face recognition task developed specifically to test the ability to *use* rather than ignore holistic information (Donnelly and Davidoff, 1999).

Plaisted (2001) suggests that difficulties in autism at the conceptual level stem from abnormalities at the perceptual level. Specifically, Plaisted (2001) argues that enhanced discrimination of features in autism leads to abnormalities in semantic categorization. A visual semantic memory task was therefore chosen to specifically explore the relationship between potential perceptual and semantic abnormalities in autism. The individual results for the semantic memory task and the face recognition task have been reported elsewhere (López and Leekam, 2003; López et al., 2004). Overall these studies found that children with autism showed difficulty in the face recognition task but not in the semantic memory task. There was, however, a large discrepancy in performance between the children with autism that comprised the sample. This is not surprising since autism is a heterogeneous disorder in terms of symptoms and aetiology (Santangelo and Folstein, 1999; Tager-Flusberg and Joseph, 2003). In the present study we compared performance across tasks in the same individuals. If there is a link between the ability to use holistic and semantic information, as the theory predicts, then we would expect a positive correlation between performance in the two tasks. Also, a negative relationship was predicted between the semantic memory task and performance on the block design test following Plaisted's (2001) suggestion that enhanced discrimination of features lead to semantic impairment.

Method

Participants

Fifteen high-functioning children with autistic spectrum disorder (ASD) were recruited from a range of special schools in England. All had received a diagnosis of autism by experienced clinicians using the guidelines of standard criteria such as DSM-IV (American Psychiatric Association, 1994), DSM-III-R (American Psychiatric Association, 1987), or ICD-10 (World Health Organization, 1990). As in Ozonoff et al. (1994), participants' IQ was measured using four subtests of the WISC–R (Wechsler, 1974): information, vocabulary, block design and object assembly.

The comparison group consisted of a group of 16 typically developing children (TD) matched on chronological age to the autism group. These children were recruited from a range of local schools. The two groups did not significantly differ in chronological age (CA: $t(29) = 0.859$, $p = 0.397$), verbal IQ (VIQ: $t(29) = 1.23$, $p = 0.229$), performance IQ (PIQ: $t(29) = 1.299$, $p = 0.204$) or full-scale IQ (FIQ: $t(29) = 1.548$, $p = 0.132$). Table 1 summarizes the participants' characteristics for both groups of children.

Materials

Face recognition task There were two types of stimuli: complete faces and features. For the complete face trials a set of six target faces was formed in which the features of eyes, nose and mouth were varied, keeping all other aspects of the face constant. Each target face was presented alongside a distractor face that was identical except for the replacement of *one* feature. No distractor face was the same as any other target face. The feature stimuli comprised three examples of eyes, noses and mouths. In feature trials the target feature (e.g. a mouth) was presented alongside a distractor feature (e.g. a different mouth). There were 36 complete face and 36 feature trials (see Figure 1 for example of stimuli).

Visual semantic memory task The materials for this task comprised four sets of pictures, each containing 12 objects. Two sets contained semantically related pictures of either animals or vehicles. The other two sets contained unrelated pictures from different semantic categories. All the pictures were taken from a standardized set of pictures (Snodgrass and Vanderwart,

Table 1 **Mean chronological age (CA), verbal IQ (VIQ), performance IQ (PIQ) and full-score IQ (FIQ) of participants**

n	*Group*		*CA*	*VIQ*	*PIQ*	*FIQ*
16	TD	Mean	14:4	94.13	102.88	98.75
		SD	0:10	19.31	18.25	16.20
15	AD	Mean	13:10	83.53	93.80	87.13
		SD	2:4	28.11	20.64	24.93

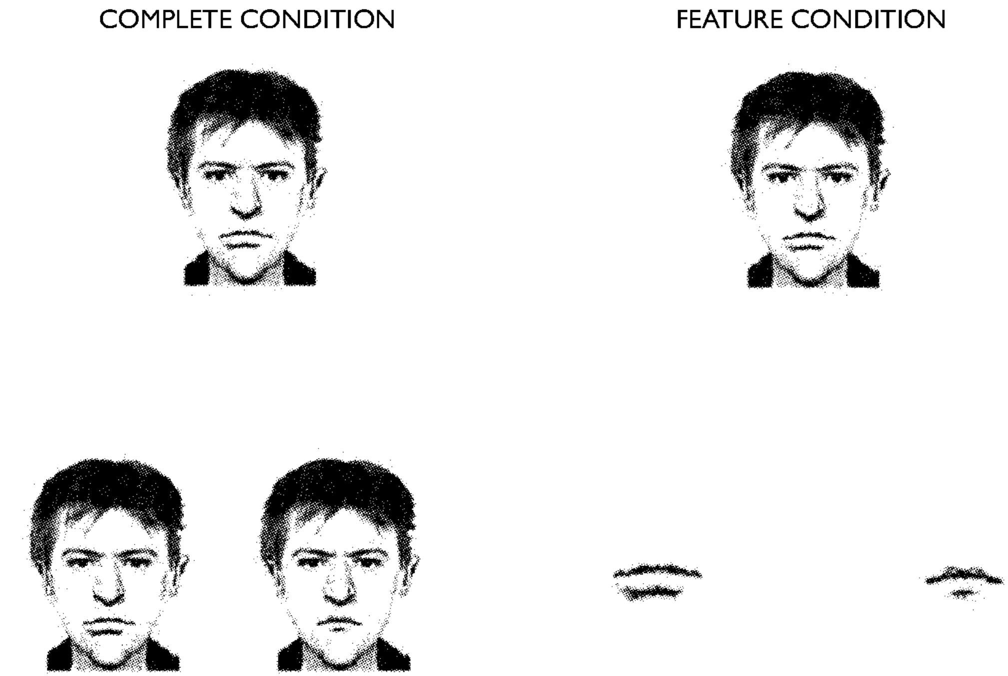

Figure 1 **Examples of stimuli used in the complete face and feature conditions**

1980). The pictures of the unrelated sets were matched individually to the semantically related sets of pictures on the basis of familiarity and complexity. The pictures used in the two conditions did not differ in their verbal properties ($U = 48.5$, $p > 0.40$). All stimuli were presented on a laptop computer using Superlab software.

Procedure

Children were tested individually in a quiet room at either their home or their school. The two tasks were administered as part of a wider study. The global task was administered in an earlier session than the visual semantic task.

Face recognition task Participants were presented with a complete face on the screen (500 ms). After a short delay (500 ms) two items were presented. In complete trials, the two items were two complete faces, one of which matched the previous face. In feature trials, the two items were two features (i.e. two pairs of eyes, two noses, or two mouths), one of which belonged to the face presented before. Participants were told they had to decide which item matched the target face by pressing one of two keys on the keyboard. Targets were equally presented to either the left or right of distractors.

Visual semantic memory task In this task children were told that they would see a series of pictures on the screen of the computer and, once the presentation of pictures was complete, they would be asked to recall as many objects as possible. A practice set of four objects was then presented to familiarize the child with the task. They were then told that in the actual task more objects would be presented. All children understood the aim of the task after the practice trial. Once the practice trial was completed, the child was presented with one test list. The order of the lists was counterbalanced across participants. The items from each list were presented in random order at a rate of one object per second.

Results

Scoring

Face recognition task Use of holistic information about faces would be demonstrated by enhanced performance in the complete face condition relative to the feature condition. Thus a single difference score was computed by deducting the number of correct responses in the feature condition from the number of correct responses in the complete face condition. Positive scores would indicate good use of holistic information.

Visual semantic memory task The same rationale as for the face recognition task was used in this task. A difference score was computed by deducting the number of correctly recalled items in the two unrelated lists from the number of correctly recalled items from the two related lists. Again, positive scores would indicate successful use of semantic information to facilitate recall.

Comparison across tasks

Table 2 shows raw scores per condition in each task, difference scores and raw and scaled scores obtained in the block design. Difference scores did not differ significantly between the two groups for any of the tasks (face recognition task, $t(29) = 0.894$, $p > 0.05$; visual semantic memory task, $t(29) = 0.628$, $p > 0.05$; block design raw scores, $t(29) = 1.4$, $p > 0.05$; block design scaled scores, $t(29) = 0.023$, $p > 0.05$).

Difference scores for the face recognition task significantly correlated positively with raw scores in the complete face condition ($r = 0.557$, $p < 0.01$) and negatively with raw scores in the feature condition ($r = -0.487$, $p < 0.05$), indicating that large difference scores reflected good use of holistic information and poor recognition of features in isolation and vice versa. The difference scores for the semantic memory task were correlated

Table 2 **Mean accuracy, mean difference between conditions (D) and standard deviations (in brackets) on the face recognition, semantic memory and block design tasks**

	Face recognition			*Semantic memory*			*Block design*	
	Complete	*Part*	*D*	*Related*	*Unrelated*	*D*	*Raw*	*Scaled*
TD	23.31 (3.24)	21.06 (2.83)	2.25 (3.02)	14.37 (1.99)	9.62 (1.89)	4.75 (1.88)	50.87 (9.14)	9.62 (2.44)
ASD	21.80 (3.05)	20.60 (3.31)	1.20 (3.5)	11.8 (4.10)	7.67 (2.16)	4.13 (3.42)	45.47 (12.16)	9.6 (3.54)

only with the related condition ($r = 0.757$, $p < 0.01$), which suggests that difference scores are specifically linked to greater ability to use semantic information to aid recall regardless of ability to recall unrelated pictures.

Spearman's rho correlations between difference scores for the face recognition task, difference scores for the semantic memory task and block design scaled scores were calculated. In the TD sample, no significant correlations were found between difference scores for the face recognition task and difference scores for the semantic memory task ($r = -0.200$, $p > 0.10$), between difference scores for the face recognition task and the block design scaled scores ($r = -0.254$, $p > 0.10$), or for difference scores for the semantic memory task and the block design scaled scores ($r = -0.191$, $p > 0.10$).

Similar correlations were found in the autism group between difference scores for the face recognition task and the block design scaled scores ($r = -0.141$, $p > 0.10$), and difference scores for the semantic memory task and the block design scaled scores ($r = -0.329$, $p > 0.10$). In contrast, however, a significant inverse correlation between the face recognition task and the semantic task was found in the autism group ($r = -0.639$, $p < 0.01$). As differences in age, verbal and non-verbal IQ could account for the relationship between the tasks, partial correlations were calculated controlling for the effect of these three variables. The correlations remained non-significant in the TD group ($r = -0.34$, $p > 0.10$) whilst for the ASD group the correlation between the face recognition task and the semantic task became larger ($r = -0.\ 756$, $p < 0.01$). This correlation suggests that there is a link between perceptual and semantic processing in autism, although in the opposite direction to that predicted by central coherence theory.

A hierarchical regression analysis examined whether the performance of ASD children in the semantic task could be predicted by their performance in the face recognition test. If semantic category knowledge derives from perception (Plaisted, 2001) then the perceptual task and/or the block design scores should predict performance in the semantic task. Thus the sequence of variable entry was as follows: (1) participants' characteristics (PIQ and VIQ) and (2) difference scores in face recognition task and block design scaled scores. The first set of predictors, VIQ and PIQ, did not significantly predict performance in the semantic memory task ($R^2 = 0.030$; $F(2, 12) = 0.120$, $p > 0.05$). The second set of predictors in contrast did account for a significant amount of the variance in the semantic memory task difference scores (R^2 change $= 0.594$; $F(3, 11) = 4.15$, $p < 0.05$). Once all the variables were in the model, only difference scores in the face recognition task emerged as a significant predictor of semantic memory performance ($\beta = -0.843$, $p < 0.05$). This final model accounted for 62 percent of the variance.

Classification of ASD children

If central coherence is responsible for integrating visual information both in its context and into global patterns, it would be expected that a child with difficulty using holistic information to facilitate face recognition would also have difficulty using semantic information. With this rationale in mind, ASD children were classified as having either holistic facilitation or not and as having semantic facilitation or not on the basis of their performance in the face recognition task and in the visual semantic memory task.

The classification criterion for each task was obtained by setting a level based on the mean difference score in each task for the TD sample. Children with autism with difference scores above these figures were classified as having holistic and/or semantic facilitation. Two Kendall's tau correlations showed that the new categorical scores and the original difference scores correlated significantly (face recognition, $r = -0.731$, $p < 0.001$; semantic memory, $r = -0.756$, $p < 0.01$).

Figure 2 shows the number of ASD children whose performance was facilitated by the use of holistic information only, semantic information only, both holistic and semantic information, or neither. As can be seen, 74 percent of the children could use either holistic information of faces or semantic information but not both. Of these, 34 percent (five children) could use semantic memory information only and 40 percent (six children) could use holistic information only. Only 13 percent (two children) of the children fitted the expected pattern of weak central coherence across domains. The remaining 13 percent were able to use both types of information.

Discussion

Contrary to the prediction drawn from central coherence theory, this study failed to find a significant positive relationship between holistic and semantic processing in children with autism and TD children. First, performance of

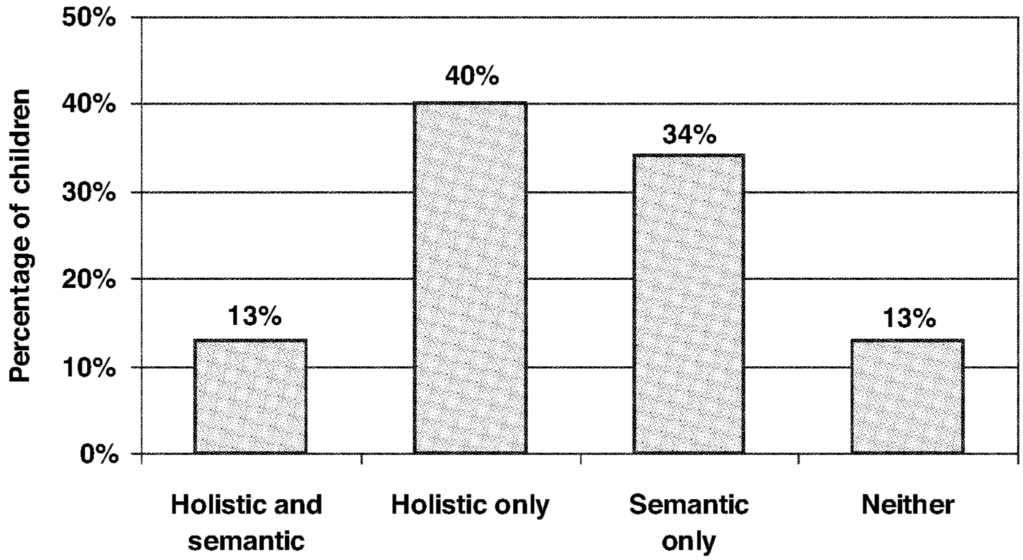

Figure 2 **Percentage of ASD children who were only facilitated by the provision of holistic information, only facilitated by semantic information, facilitated by both types of information or by neither**

TD children in the face recognition task did not correlate significantly with their performance in the semantic memory task. Second, the correlation between the two tasks for the autism group was in the opposite direction to that predicted by weak central coherence theory since increased use of holistic information was associated with reduced ability to use semantic information to enhance recall and vice versa, regardless of verbal and non-verbal IQ. Classification of the ASD children according to their performance on both tasks revealed that the majority of the children had difficulty with either of the tasks rather than with the two tasks or none, as would be expected if weak central coherence operates across domains. The findings from this study therefore fail to confirm the assumption that a central mechanism is responsible for integrating information at both conceptual and perceptual level which, when impaired, results in difficulties at both levels. Instead the results could be taken as evidence for the presence of subgroups in autism, with groups having either weak conceptual or weak perceptual coherence and only in rare cases weak central coherence across domains.

This is not the first study that fails to show universal weak central coherence in autism. A recent study conducted by Loth (2003) also suggests that only about 35 percent of children with autism present weak central coherence across different tasks whilst 48 percent of children present mixed styles, with good performance in conceptual tasks alongside enhanced discrimination of features as measured by the block design and the embedded figures tests. There are two possible explanations for the individual differences in central coherence style in people with autism. The first relates to the heterogeneous nature of the syndrome. As mentioned in the introduction, there is wide variation in the symptoms presented by different individuals with autism, possibly as a result of differences in the aetiology (Santangelo and Folstein, 1999; Tager-Flusberg and Joseph, 2003). The pattern of data reported here supports the view of idiosyncratic cognitive development in children with autism. It is possible that there are subgroups within the autistic spectrum regarding central coherence, and recent research on individuals with different profiles of non-verbal skill relative to verbal skill indicates that particular neurocognitive profiles do exist (Tager-Flusberg and Joseph, 2003). The finding that conceptual and perceptual processing might be inversely, and not positively, related in autism is an unexpected result that might be consistent with the possibility that there are different cognitive outcomes resulting from early visuospatial versus verbal strengths and weaknesses within the autistic spectrum.

Alternatively, inconsistency in performance across tasks might be explained in terms of differences in task demands. It has been assumed that central coherence is a single construct. Evidence, however, is emerging that suggests there are several components related to central coherence. Ropar and Mitchell (2001), for instance, failed to find a relationship between performance of different groups of children, including children with autism, in several 'classic' central coherence tasks such as visual illusions, block design or embedded figures tests. In a recent study, Pellicano et al. (2005) identified two different constructs within perceptual coherence in typical development, one related to visuospatial abilities and a different factor that was more difficult to interpret. The results of the present study seem to add to this emerging evidence that suggests that central coherence is not a unitary concept and thus different aspects might be impaired.

An alternative explanation for the results comes from Plaisted's (2001) proposal that conceptual difficulties in autism stem not from a global impairment but from enhanced discrimination. She argues that because individuals with autism have enhanced discrimination of features they fail to categorize stimuli as being similar, and thus their semantic categorization is more limited, consisting of fewer exemplars in each category and fewer links between categories. The findings of this study, in contrast, failed to find a relation between semantic priming effects and discrimination of features as measured by the block design. These results should be treated with caution since no significant differences were found between the two samples in block design scores. Nevertheless, this proposal has been recently questioned by a wealth of evidence suggesting that individuals with autism are as susceptible to semantic priming effects (e.g. Gardiner et al., 2003; Toichi and Kamio, 2001) and use as much semantic information as non-autistic samples (López and Leekam, 2003), which indicates that enhanced discrimination in autism does not result in semantic categorization impairments.

An alternative explanation of abnormalities in perceptual and conceptual tasks comes from Mottron et al. (2006) who suggest that autism is characterized by enhanced perceptual processing. This is an insightful proposal that is able to account for superior performance in a wide range of perceptual tasks in autism. According to this theory, enhanced perception should be present for all children with autism in the face recognition task, relative to the semantic task, although failure to find enhanced performance in this task could be attributed to a specific face recognition impairment in autism. The theory, however, cannot account for the pattern of results found in this study as it cannot explain the presence of impaired performance in the face task but not in the semantic task in a certain number of children.

The present study has a number of limitations that allow only tentative conclusions to be drawn. First, the individual tasks were not designed to be compared to each other. Second, only three tasks were sampled for this study among many purported to represent weak central coherence, and it is possible that other tasks will show greater consistency, supporting the case for a more general integration difficulty. Third, no group differences were found for any of the tasks, probably due to wide individual differences, especially in the autism sample. Nevertheless, these preliminary findings might still be an initial step towards rethinking the concept of central coherence, by questioning the idea that a general integration mechanism operates at all levels of perceptual and cognitive processing.

In summary, the results from this study question the assumption that there is a central mechanism responsible for integrating information at perceptual and conceptual levels and add to the mixed evidence already found for the presence of weak central coherence problems in autism. However, while the results may raise questions about the *central* nature of a high-level cognitive mechanism that works simultaneously at perceptual and conceptual levels, they do not undermine the idea that children with autism present anomalies across either perceptual or conceptual tasks.

References

AMERICAN PSYCHIATRIC ASSOCIATION (1987) *Diagnostic and Statistical Manual of Mental Disorders*, 3rd edn rev. (DSM-III-R). Washington, DC: APA.

AMERICAN PSYCHIATRIC ASSOCIATION (1994) *Diagnostic and Statistical Manual of Mental Disorders*, 4th edn (DSM-IV). Washington, DC: APA.

DAVIES, S., BISHOP, D., MANSTEAD, A. & TANTAM, D. (1994) 'Face Perception in Children with Autism and Asperger's Syndrome', *Journal of Child Psychology and Psychiatry* 35: 1033–57.

DONNELLY, N. & DAVIDOFF, J. (1999) 'The Mental Representations of Faces and Houses: Issues Concerning Parts and Wholes', *Visual Cognition* 6: 319–43.

FRITH, U. (1989) *Autism: Explaining the Enigma*. Oxford: Basil Blackwell.

FRITH, U. (2003) *Autism: Explaining the Enigma*, 2nd edn. Oxford: Blackwell.

FRITH, U. & SNOWLING, M. (1983) 'Reading for Meaning and Reading for Sound in Autistic and Dyslexic Children', *Journal of Developmental Psychology* 1: 329–42.

GARDINER, J.M., BOWLER, D.M. & GRICE, S.J. (2003) 'Further Evidence of Preserved Priming and Impaired Recall in Adults with Asperger's Syndrome', *Journal of Autism and Developmental Disorders* 33: 259–69.

GEPNER, B., DE GELDER, B. & SCHONEN, S. (1996) 'Face Processing in Autistics: Evidence for a Generalised Deficit?', *Child Neuropsychology* 2: 123–39.

HAPPÉ, F. (1997) 'Central Coherence and Theory of Mind: Reading Homographs in Context', *British Journal of Developmental Psychology* 15: 1–12.

HERMELIN, B. & O'CONNOR, N. (1967) 'Remembering of Words by Psychotic and Subnormal Children', *British Journal of Psychology* 58: 213–18.

HERMELIN, B. & O'CONNOR, N. (1970) *Psychological Experiments with Autistic Children*. Oxford: Pergamon.

HOY, J.A., HATTON, C. & HARE, D. (2004) 'Weak Central Coherence: A Cross Domain Phenomenon Specific to Autism?', *Autism* 8: 267–81.

JOLLIFFE, T. & BARON-COHEN, S. (1999) 'A Test of Central Coherence Theory. Linguistic Processing in High-Functioning Adults with Autism or Asperger Syndrome: Is Local Coherence Impaired?', *Cognition* 71: 149–85.

LAMB, M.R. & ROBERTSON, L.C. (1989) 'Do Response Time Advantage and Interference Reflect the Order of Processing of Global- and Local-Level Information?', *Perception and Psychophysics* 46: 254–8.

LÓPEZ, B. & LEEKAM, S. (2003) 'Do Children with Autism Fail to Process Information in Context?', *Journal of Child Psychology and Psychiatry* 44: 285–300.

LÓPEZ, B., DONNELLY, N., HADWIN, J. & LEEKAM, S. (2004) 'Face Processing in High-Functioning Children with Autism: Evidence for Weak Central Coherence', *Visual Cognition* 11: 673–88.

LOTH, E. (2003) 'Social, Cultural and Cognitive Aspects of Theory of Mind in Practice', unpublished PhD thesis, University of St Andrews.

MOTTRON, L. & BELLEVILLE, S. (1993) 'A Study of Perceptual Analysis in a High-Level Autistic Subject with Exceptional Graphic Abilities', *Brain and Cognition* 23 (279): 351–67.

MOTTRON, L., BURACK, J., IAROCCI, G., BELLEVILLE, S. & ENNS, J.T. (2003) 'Locally Oriented Perception with Intact Global Processing among Adolescents with High-Functioning Autism: Evidence from Multiple Paradigms', *Journal of Child Psychology and Psychiatry* 44: 904–13.

MOTTRON, L., DAWSON, D., SOULIÈRES, P., HUBERT, I. & BURACK, J. (2006) 'Enhanced Perceptual Functioning in Autism: An Update, and Eight Principles of Autistic Perception', *Journal of Autism and Developmental Disorders* 36: 27–43.

NAVON, D. (1977) 'Forest before Trees: The Precedence of Global Features in Visual Perception', *Cognitive Psychology* 9: 353–83.

OZONOFF, S., STRAYER, D.L., MCMAHON, W.M. & FILLOUX, F. (1994) 'Executive Function Abilities in Autism and Tourette's Syndrome: An Information Processing Approach', *Journal of Child Psychology and Psychiatry* 35: 1015–32.

PELLICANO, E., MAYBERY, M. & DURKIN, K. (2005) 'Central Coherence in Typically

Developing Preschoolers: Does It Cohere and Is It Related to Mindreading and Executive Control?', *Journal of Child Psychology and Psychiatry* 46: 533–47.

PLAISTED, K. (2001) 'Reduced Generalization in Autism: An Alternative to Weak Central Coherence', in J. BURACK, T. CHARMAN, N. YIRMIYA & P. ZELAZO (eds) *The Development of Autism: Perspectives from Theory and Research*. Mahwah, NJ: Erlbaum.

PLAISTED, K., O'RIORDAN, M. & BARON-COHEN, S. (1998) 'Enhanced Discrimination of Novel, Highly Similar Stimuli by Adults with Autism during a Perceptual Learning Task', *Journal of Child Psychology and Psychiatry* 39: 765–75.

RAMONDO, N. & MILECH, D. (1984) 'The Nature and Specificity of the Language Encoding Deficit in Autistic Children', *British Journal of Psychology* 75: 95–103.

RINEHART, N.J., BRADSHAW, J.L., MOSS, S.A., BRERETON, A. & TONGE, B.J. (2000) 'Atypical Interference of Local Detail on Global Processing in High-Functioning Autism and Asperger's Syndrome', *Journal of Child Psychology and Psychiatry* 41: 769–78.

RINEHART, N.J., BRADSHAW, J.L., MOSS, S.A., BRERETON, A. & TONGE, B.J. (2001) 'A Deficit in Shifting Attention Present in High-Functioning Autism but Not Asperger's Syndrome', *Autism* 5 (1): 67–80.

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: 539–49.

SANTANGELO, S.L. & FOLSTEIN, S.E. (1999) 'Autism: A Genetic Perspective', in H. TAGER-FLUSBER (ed.) *Neurodevelopmental Disorders*. Cambridge, MA: MIT Press.

SNODGRASS, J. & VANDERWART, M. (1980) 'A Standardized Set of 60 Pictures: Norms of Name Agreement, Image Agreement, Familiarity and Visual Complexity', *Journal of Experimental Psychology: Human Learning and Memory* 6: 174–215.

TAGER-FLUSBERG, H. (1991) 'Semantic Processing in the Free Recall of Autistic Children: Further Evidence for a Cognitive Deficit', *British Journal of Developmental Psychology* 9: 417–30.

TAGER-FLUSBERG, H. & JOSEPH, R.M. (2003) 'Identifying Neurocognitive Phenotypes in Autism', *Philosophical Transactions of the Royal Society of London, Series B* 358: 303–14.

TOICHI, M. & KAMIO, Y. (2001) 'Verbal Association for Simple Common Words in High-Functioning Autism', *Journal of Autism and Developmental Disorders* 31: 483–90.

WECHSLER, D. (1974) *Weschler Intelligence Scale for Children–Revised*. New York: Psychological Corporation.

WORLD HEALTH ORGANIZATION (1990) *ICD-10 Classification of Mental and Behavioural Disorders*. Geneva: WHO.