J Autism Dev Disord (2007) 37:894–910
DOI 10.1007/s10803-006-0218-7

ORIGINAL PAPER

Describing the Sensory Abnormalities of Children and Adults with Autism

Susan R. Leekam · Carmen Nieto · Sarah J. Libby · Lorna Wing · Judith Gould

Published online: 3 October 2006

Abstract Patterns of sensory abnormalities in children and adults with autism were examined using the Diagnostic Interview for Social and Communication Disorders (DISCO). This interview elicits detailed information about responsiveness to a wide range of sensory stimuli. Study 1 showed that over 90% of children with autism had sensory abnormalities and had sensory symptoms in multiple sensory domains. Group differences between children with autism and clinical comparison children were found in the total number of symptoms and in specific domains of smell/taste and vision. Study 2 confirmed that sensory abnormalities are pervasive and multimodal and persistent across age and ability in children and adults with autism. Age and IQ level affects some sensory symptoms however. Clinical and research implications are discussed.

Keywords Sensory abnormalities · Diagnostic Interview for Social and Communication Disorders (DISCO) · Autism · Language impairment · Learning disability · Typical development

S. R. Leekam (✉)
Department of Psychology, Science Laboratories, University of Durham, South Road, Durham, UKDH1 3LE
e-mail: S.R.Leekam@durham.ac.uk

C. Nieto
Departamento de Psicología Básica, Facultad de Psicología, Universidad Autónoma de Madrid, Madrid, Spain

S. J. Libby
Child and Adolescent Mental Health Service, United Bristol Healthcare Trust, Bristol, UK

L. Wing · J. Gould
Centre for Social and Communication Disorders, National Autistic Society, Bromley, Kent, UK

Introduction

First-person autobiographical accounts often report that people with autism have unusual sensory experiences including insensitivity to pain and atypical responses to auditory, visual, tactile and olfactory stimuli (Bemporad, 1979; Cesaroni & Garber, 1991; Grandin & Scariano, 1986; Gerland, 2003; Williams, 1999). Psychological explanations of autism have also highlighted sensory and perceptual problems, with explanations focusing on impairments in attention and perception and on the integration of perceptual input at a cognitive level (Courchesne, Lincoln, Kilman, & Galambos, 1985; Hermelin & O'Connor, 1965; Frith & Hermelin, 1969; Mottron & Burack, 2001; Ornitz, 1974, 1988; Ornitz, Guthrie, & Farley, 1978; Plaisted, 2001; Shah & Frith, 1993; Wing, 1971). Despite awareness of the importance of this issue however, there is still limited systematic evidence on the patterns of atypical sensory behaviours in autism. The aim of this study was to obtain a more detailed picture of the extent and range of sensory abnormalities found in individuals across the autistic spectrum at different ages.

One of the earliest studies to document the sensory, motor and perceptual problems in autism described patterns of behaviour that were similar to those of deaf-blind children (Wing, 1969). This study found that the behaviours of children with autism differed from children with typical development, Down's syndrome, receptive and executive aphasia. There were similarities however, between children with autism and partial deaf-blind children in their odd reactions to sound and visual stimuli and in their responses to proximal (including tactile and olfactory) stimuli. Since Wing's early study, a growing number of research studies in psychology, neuroscience, occupational therapy, and education have contributed further evidence to the view that sensory disturbances are a common feature in autism (Ayres, 1971; Baranek, Foster, & Berkson, 1997; Ornitz, 1988).

Many of these studies have compared children with autism with children in the normal population. Kientz and Dunn (1996), for example, using an early version of the Sensory Profile, found that children with autism had more sensory symptoms than typical children in specific domains of visual, auditory, taste/smell, movement and touch processing. Sensory symptoms have also been found in children with Asperger syndrome. Dunn, Myles, and Orr (2002) found differences between children diagnosed with Asperger syndrome and typically developing children on 96% of items of the Sensory Profile (Dunn, 1999). Myles et al. (2004) found that children with autism and children with Asperger syndrome did not differ in their sensory symptoms except for auditory processing, a difficulty that was associated with distractibility and inattention. However, children with Asperger syndrome were significantly more affected in their social-emotional coping strategies as assessed by the Sensory Profile.

Fewer studies have investigated the patterns of sensory impairments in children with autism as distinct from children in other clinical groups that have similar IQ levels. A study by Freeman et al. (1981) compared autistic children with comparison groups of sighted and hearing children who had either low ability (mental retardation) or high ability (typical development), as part of a study that aimed to develop an observational scale for autism. This scale included some items related to tactile, auditory and visual responsiveness. Their study showed that when low IQ autistic children were compared with mentally retarded non-autistic children, very few group differences were found, but when high IQ autistic children were compared with typically developing children the differences were quite marked, confirming earlier clinical observations of Bartak and Rutter (1976).

A more recent study using mental-aged matched groups compared very young (2–3 year-old) children with autism with children with Fragile X syndrome and children with developmental delay and typical development (Rogers, Hepburn, & Wehner, 2003). Both groups had been assessed for autism using the ADI-R (Lord, Rutter, & Le Couteur, 1994) and the ADOS (Lord, Rutter, DiLavore, & Risi, 1999) and were also given the Short Sensory Profile (Dunn, 1999). The Short Sensory Profile provides a reduced set of items from the longer Sensory Profile with domains including tactile, taste/smell, visual/auditory sensitivity and auditory filtering, in addition to measures of energy, general responsiveness and movement. Results showed that both children with autism and children with Fragile X syndrome had more sensory symptoms than the developmentally delayed group and typically developing groups. In addition, differences were found for specific domains of tactile sensitivity, taste/smell sensitivity and auditory filtering but not for auditory/visual sensitivity. Although the children with autism and children with Fragile X were similar in their sensory responsiveness, the autism group had more extreme scores for taste/smell sensitivity in particular.

The research studies referred to above make use of postal questionnaires such as the Sensory Profile (Dunn, 1999) in order to study patterns of sensory symptoms in children with autism. Currently, standard clinical interview measures such as the ADI (Le Couteur et al., 1989) and the Autism Diagnostic Interview Revised (ADI-R) (Lord et al., 1994) collect limited information about sensory responding and do not provide a detailed assessment of sensory responsiveness. These clinical instruments have been designed in line with ICD-10 research criteria for childhood autism (World Health Organization, 1993) which itself does not include atypical sensory responding as being a necessary and distinct diagnostic criterion. Instead sensory abnormalities are included within the broad category of repetitive interests and behaviours for both ICD-10 criteria for childhood autism and for DSM IV criteria for autistic disorder (American Psychiatric Association, 1994).

One clinical interview measure that assesses sensory symptoms in detail is the Diagnostic Interview for Social and Communication Disorders (DISCO) (Leekam, Libby, Wing, Gould, & Taylor, 2002; Wing, Leekam, Libby, Gould, & Larcombe, 2002), a clinical interviewer-based schedule designed for use with parents and carers. Its purpose is to elicit information relevant to the broad autistic spectrum in order to assist clinicians in their judgement of an individual's level of development and specific needs. Information elicited from the DISCO can also be applied to a set of algorithms to provide a diagnostic category. In addition to many other items relating to developmental skills and atypical behaviour, the DISCO records in detail the patterns of sensory features seen in children of any age and with any degree of impairment. The sensory items that were originally selected for use within the

DISCO reflect items that are commonly seen in clinical experience when working with children presenting with autistic spectrum disorders. The DISCO uses 21 items related to sensory abnormality that are separated into three groups, proximal (e.g. touch, taste, smell, kin aesthetic) (14 items), auditory (3 items) and visual (4 items). Other items relating to atypical taste/oral, kinaesthetic, and touch responsiveness are also found in other sections of the DISCO.

The assessment of sensory abnormalities within DISCO overlaps with but also differs from the assessment of sensory symptoms within the ADI-R. The ADI collects information on sensory abnormalities in different modalities (visual, auditory, tactile, olfactory) but does so by the use of only two items; ''unusual sensory interests'' and ''abnormal idiosyncratic negative response to specific sensory stimuli''. Although the clinician notes the type of sensory abnormality affected, only a combined rating is recorded for diagnostic purposes. In contrast, the type and degree of every sensory abnormality is explicitly recorded within the DISCO diagnostic profile making it possible to examine the extent to which abnormalities occur in different sensory domains.

The sensory items used in the DISCO also differ from the items within the Sensory Profile. Items selected for the DISCO have been chosen on the basis of many years of clinical observation as being the items that are commonly seen in people with social and communication disorders. For example, 'proximal' (e.g. smell, taste, touch, kin aesthetic and mixed) abnormalities are commonly reported in autism (Ornitz, 1974; Wing, 1969) and it has been suggested that these are particularly impaired in autism relative to distal impairments (vision and hearing) (Goldfarb, 1956). Proximal items are therefore strongly represented amongst the sensory items used in the DISCO. In contrast, items selected for the Sensory Profile represent a more even distribution across different domains of sensory processing. The Sensory Profile questionnaire also includes more items for each domain than are provided in the DISCO. The Sensory Profile questionnaire was initially tested to provide norms from a normal population although it is now widely used with different clinical groups.

There is also substantial overlap between the items used in the DISCO and some of the items in the Sensory Profile. Table 1 summarises the items used in the 9th Edition of the DISCO, the version used for this research, and similar items selected from Kientz and Dunn's (1996) study with autistic children using the Sensory Profile. Although there is overlap in the content of sensory items however, the way that information is collected by the Sensory Profile questionnaire compared with the DISCO interview is very different, including not only the method of data collection but also the scales of measurement for analysis. The Sensory Profile has a scale that differentiates five different levels of sensory responding, enabling a wide range of different levels of responsiveness to be recorded, while the DISCO enables the clinician to differentiate the more extreme problems most associated with autism from milder difficulties or no problems.

The two studies reported below were carried out using the DISCO. Study 1 was a comparative study of children with autism, learning disability, language impairment and typical development. This study allowed us to examine group differences between autism and non-autism populations that were matched on age and IQ and had a wider age and ability range than the children in the Rogers et al study. The aim of the study was to investigate whether children with autism would differ in the overall frequency of sensory symptoms compared with comparison groups and whether they would also differ in specific sensory domains. In addition to examining the overall frequency of sensory symptoms, however we also wanted to examine the pattern of sensory abnormalities in autism, for example whether children with autism have abnormalities within one single sensory domain (e.g. visual or auditory) or atypical sensory responses across multiple sensory domains. Unlike previous studies of sensory processing, the parent interviews were also carried out with the researchers blind to the clinical diagnosis of the groups.

Study 2 was a large study of two hundred individuals, both children and adults, all with autism. This study allowed us to examine in more detail the patterns of sensory abnormalities found within the wider autism population and in particular whether there are differences in the frequency or pattern of abnormalities as a function of age and/or IQ level.

Study 1

Method

Participants

Parents of four different groups of children, aged 34–140 months, were interviewed. The groups comprised 33 children with autistic spectrum disorders (16 low functioning and 17 high functioning), 19 children

Table 1 Sensory items used in the Diagnostic Interview for Social and Communication Disorders (DISCO) and comparative selective items from the Sensory Profile (Kientz & Dunn, 1996)

DISCO category	Sensory items from DISCO (9th Version)	Selected similar items from the Sensory Profile
Auditory		
	1. Distressed by sounds that do not affect others	Responds negatively to unexpected/loud noises Holds hands over ears
	2. Unusual fascination with certain sounds	Enjoys strange noises/makes noise for noise sake
	3. Unusually acute hearing	
Visual		
	1. Unusually interested in bright lights and shiny things	[a]
	2. Gets unusually excited at seeing things spin	
	3. Twists or flicks hands or objects near eyes	
	4. Looks at object from many different angles for no reason	
Proximal		
Touch		
	1. Unusual interest in the feel of certain surfaces	Unusual need for touching certain toys, surfaces, textures Always touching people and objects
	2.Scratches or taps on different surfaces in order to feel sensation	Rubs or scratches out a spot that has been touched
	3. Negative reaction to gentle touch	Reacts emotionally or aggressively to touch
	4. Negative reaction too firm touch	
	5. Aimless manipulation of objects in order to seek sensory stimulation	
	6. Dislikes being washed, having hair washed, nails cut, hair cut, teeth brushed	Expresses discomfort during grooming Expresses discomfort at toothbrushing/dental work
Smell/taste		
	1. Unusual tendency to explore objects or people by smelling them	Deliberately smells object Shows strong preference for certain smells
	2. Has very unusual food fads/ eats a very small range of foods	Shows preference for certain tastes Craves certain foods
Other oral		
	1. Tends to put everything into his/her mouth	Mouths objects frequently[b]
	2. Refuses food that is lumpy or needs chewing	Picky eater, especially regarding textures[b]
Kinaesthetic		
	1. Enjoys being spun round more than age peers	Continually seeks out all kinds of movement (being whirled around by adult, merry-go-rounds)[c]
	2. Spins round or runs round in circles more than age peers	Twirls/spins self frequently throughout the day[c]
Pain		
	1. Indifference to pain, heat and cold	Decreased awareness of pain and temperature[b]
Mixed		
	1. Plays with saliva, urinates to make puddles, smears faeces	
	2. Self-injures if not prevented	
	3. Stimulates self (e.g. taps chin, regurgitates food) without injury	
	4. Destructive activities involving repeated tearing or breaking of things	
	5. Overbreathing	

[a] The most closely worded item from Kientz and Dunn (1996) ''Expresses discomfort or avoids bright lights'' is not equivalent

[b] Items were originally classified as Touch by Kientz and Dunn (1996). Items 'Picky eater' and 'mouths objects', were subsequently classified as Oral Sensitivity in Dunn and Bennett (2002)

[c] Both items classified as Vestibular. 'Twirls/spins self frequently throughout the day' included in Dunn and Bennett (2002)

with developmental disability, 15 with language impairment and 15 typically developing children. Details of the children are shown in Table 2. All children in the autism, developmental disability and language impairment groups were clinically diagnosed before recruitment for the study. None of the children in any of the clinical groups had been diagnosed by any of the authors.

Typically Developing Group 15 typically developing children, 9 male, 6 female (IQ range 81–138)

Table 2 Chronological ages, non-verbal IQs and verbal mental ages of children in Study 1

	Low functioning autism	Developmental disability	High functioning autism	Language impairment	Typical
Mean CA in months	86.12	82.05	87.00	89.27	89.40
Standard deviation	33.07	32.70	31.17	28.79	30.66
Range	34–133	40–140	35–131	49–136	51–135
N	16	19	17	15	15
Mean non-verbal IQ	49.38	45.89	102.12	90.21	108.60
Standard deviation	20.69	22.34	20.17	17.85	15.71
Range	12–80	14–95	66–140	58–117	81–138
N	16	18[a]	17	14[b]	15
Mean expressive VMA	24.13	35.33	67.53	77.00	99.73
Standard deviation	17.77	20.23	42.85	32.18	37.84
Range	8–75	8–87	12–186	33–138	42–186
N	15	18[a]	17	15	15
Mean Comprehension VMA	22.07	27.78	64.53	64.00	95.73
Standard deviation	18.91	22.09	38.88	32.42	38.42
Range	8–81	8–87	12–168	17–120	33–156
N	15	18[a]	17	15	15

[a] One child with cerebral palsy could not be tested

[b] One child with (language delay) language impairment was not available for testing

participated. They were recruited from schools and nurseries in the South-east of England.

Autism Group Children with autistic disorders were divided into two groups—high functioning (*n* = 17; 14 male, 3 female) and low functioning (*n* = 16; 15 male, 1 female). This grouping was made on the basis of IQ information available at the time of recruitment. Children were recruited through two main routes. Twenty-two were recruited through the specialised diagnostic centres at Guys hospital, London and the Maudsley hospital, London where the ADI or ADI-R were used for diagnostic assessment. The remaining 11 families were contacted, through local diagnostic centres in Kent, where ICD-10 criteria were used for diagnosing autistic disorders. All 33 children had been fully assessed and diagnosed as having autism or autistic disorders. Four who were high functioning were diagnosed as having Asperger syndrome. None had been diagnosed as having any condition other than the autism.

Language Impairment Group The language impaired group represented the high functioning clinical comparison group. The families of the 15 school children (10 male, 5 female) in this group were contacted through schools in Kent and Sussex for children with specific language disorders and, for the families of pre-school children, through speech and language therapists. Five children had diagnoses in addition to language disorder, as follows: dyspraxia and dyslexia, 1; dyspraxia, 2; severe auditory memory loss, 1; Landau–Kleffner syndrome 1.

Developmental Disability Group The 19 children (11 male, 8 female) in the developmental disability group represented the low functioning comparison group. These children had mental retardation in the moderate to severe range. Eight had no specific aetiology. Eleven had associated diagnosed conditions, as follows; cerebral palsy, 3; microcephaly, 1; calcification in the brain, 1; cerebral haemorrhage in infancy, 1; chromosomal and metabolic disorder, 1: maple syrup urine disease, 1; mucopolysaccharide disease, 1; attention deficit, hyperactivity disorder, 2. The families of the 19 children in this group were contacted through special schools and through voluntary bodies concerned with developmental disability. As with the children with language disorder, the professionals involved were asked to exclude children who had suspected or actual diagnoses of autistic disorders or sensory impairments.

Two years after the parents participated in this study, follow-up enquiries to families involved the study revealed that 3 young children in the study had received a new diagnosis. Two DD children, (one with cerebral haemorrage in infancy and one with chromosomal and metabolic disorder) and one LD child (with dyspraxia) were re-diagnosed with autism on follow-up. For the purpose of this study, the original groups that were used for matching are reported. However all analyses were also subsequently conducted with the revised diagnoses taken into account.

Matching

Age Groups were matched on age. One-third of children in each clinical and comparison group were of preschool age (2 year 10 months to 5 year 7 months), one-third were aged from 6 to 8 years and one third from 9 to 11 years. Children in each of the four clinical groups (high functioning autism, low functioning autism, language impairment, and developmental disability) were individually matched for chronological age within 6 months with a child in each of the other groups. Individual matching was not possible for 7 children but a close group-wise match was achieved with no statistical difference between HFA and LI group ($t = .213$, df = 30, $P = .833$) or between LFA and DD group ($t = .365$, df = 33, $P = .717$). The typically developing group were also matched within 6 months of age with all four of the other groups (HFA, LFA, LI and DD).

Nonverbal IQ Groups were also matched on nonverbal IQ. In order to retain blind rating by the researchers at the interview stage, IQ levels were initially estimated from information available at the recruitment stage. Non-verbal and language tests were then conducted by one of the two researchers a few days after the DISCO interviews were completed. Children were recruited by asking diagnosing professionals to select children who had IQs above 70 (HFA and LI) or below 70 (LFA and LD). Once the results of the psychological tests were known however, the final IQ groupings for each clinical group were above and below 80 with the exceptions of a few children. In the HFA group two children had non-verbal IQs below 80 (66, 74), however they remained in the HFA group as they had a high level of language comprehension and expression (78 months or above). Similarly one autistic child in the LFA group had a non-verbal IQ of 80 but remained in the low IQ group as he had language comprehension below 12 m. Within the non-autism group, one pre-school DD child recruited because of developmental disabilities, had a non-verbal IQ of 95 and four children in the LI group had IQs 58, 64, 72 and 77. These children also remained in the groups to which they were originally assigned. Despite these exceptions, the two high and low functioning autism groups remained group-wise matched to the clinical comparison groups on the basis of IQ.

To calculate non-verbal IQ, the Leiter International Performance Scale (LIPS) (Leiter, 1979) was used for all the children in the HFA, LI and TD groups. Nine children in the DD group and 9 children in the LFA group also had Leiter scores. Some low ability children (9 DD and 7 LFA) could not be tested on the Leiter however and it was necessary to use the Bayley Scales of Infant Development (Bayley, 1993). The Bayley assesses predominantly non-verbal skills, but some items also assess communication skills. Neither Leiter or Bayley scores could be assessed for two children in the comparison group, one with cerebral palsy who was unable to manipulate the materials of the test and one with language impairment who the researchers were unable to visit. The high functioning sub-groups (HFA and LI) did not significantly differ from each other in performance IQ ($t = 1.72$, df = 29, $P = .10$). The low functioning sub-groups (LFA versus DD) also did not differ from each other in performance IQ, either when IQ scores were combined ($t = .47$, df = 32, $P = .64$) or when tested separately (Leiter IQ, $t = .37$, df = 16, $P = .71$, Bayley IQ, $t = .01$, df = 14, $P = .99$). The typically developing group did not differ in performance IQ from the HFA group ($t = 1.00$, df = 30, ns) but did have a higher IQ than the LI group ($t = 2.80$, df = 28, $P < .01$).

Language Testing Mental ages for verbal comprehension and expression were calculated using the Reynell Developmental Language Scale (Reynell & Huntley, 1987) for individuals with a verbal mental age below seven years. The Weschler Objective Language Dimensions (WOLD) (Psychological Corporation, 1996) was used for children with a verbal comprehension mental age over 84 months on the Reynell scale. If a child was unable to score above 12 months on both language comprehension and verbal expression on the Reynell, the MacArthur Communicative Development Inventory: Words and Gestures was used (Fenson et al., 1993). This is a parent questionnaire, which assesses early language comprehension and expression. The scores from a recent Reynell test at the child's school were used for the child with language disorder previously mentioned who could not be visited and the child with severe cerebral palsy was also unable to complete the language test. One child with autism would not comply to complete the language testing. Details of the children's scores on the verbal tests are given in Table 2.

Design and Procedure

The parent interviews were conducted by two trained researchers (SRL and SJL) using the 9th version of the DISCO. High levels of inter-rater reliability were established for the items of the DISCO by these two interviewers (see Wing et al., 2002). The interviewers were blind to the clinical diagnosis of the children, one blind to the diagnosis of all the children in the study while the other blind to the diagnoses of the school aged children. The procedures for conducting the parent interview and details of the items and coding scheme for the DISCO are described in full in Wing et al. (2002). Items in the DISCO provided the basis for questioning. However the questions were not fixed and adapted according to prior information and cultural background of informant. Informants are encouraged to describe examples of behaviour. The interviewer does not always accept the respondant's answer literally but instead interprets the report of the behaviour when rating it, according to knowledge of severe and mild behaviours.

Materials

Twenty-five sensory items are shown in Table 1. Twenty-one items are found in Part 4, of DISCO 9 sub-sections *ii* Responses to proximal sensory stimuli (includes touch, smell/taste, pain and mixed domains), *iii* Responses to auditory stimuli and *iv* Responses to visual stimuli. Four additional items were taken from other sections to provide a match for similar items reported in previous research studies. These were dislike of being washed, hair cut etc, dislike of lumpy foods, limited food range and self-spinning.

Full details about the rating of items is given in Wing et al. (2002) and Leekam et al. (2002). Training for clinicians includes instruction to rate items by relying not only on information from parent report during the interview but also on observation and information taken from beyond the interview. For the purpose of the current study as the interviewers were blind to the clinical diagnosis and did not see the child, only information from the interview was used.

Scoring

DISCO 9 schedule provides information for 'ever' and 'current' diagnoses. The criteria for 'current' behaviour only were used in the present study. The items were scored following the guidance issued with DISCO. The child's response to sensory stimuli is rated as severe or 'marked abnormality' 'minor abnormality' or 'no problem'. The severe rating was used when a behaviour was observed every day, or whenever a carer's strategy was not in use (e.g. self-injury if no protective clothing worn) or occurred whenever the opportunity arose. For some less frequent behaviours, that were severe when they did occur the severe coding was also used. The minor coding was used if the behaviour occurred sometimes. In line with standard methods of coding diagnostic criteria (e.g. algorithms used by the ADI-R (Lord et al., 1994) and the DISCO (Wing et al., 2002), the 'marked' rating was selected for the data analysis. Therefore, 'minor' and 'no problem' ratings were collapsed together.

Statistical Analysis

A score of 1 was assigned for each item rated as a 'marked' (severe) abnormality, resulting in a total score of 25 comprised of visual (4 items), auditory (3 items), touch (6 items), smell/taste (2 items), other oral (2 items) kinaesthetic (2 items), pain (1 item) and mixed proximal items (5 items) (see Table 1).

Initial analyses of number of sensory items revealed non-normal distribution of scores, preventing parametric analysis. Analyses were conducted for the number of children with sensory items in each of the specific domains as well as the number of items in each domain. Because of the large number of comparisons on the same sample, a significance level of $P < .01$ was used. Results for typically developing children are first reported separately followed by group comparisons for IQ-matched clinical groups.

Results

Typical Development Group

Five children (33%) had sensory symptoms. Total mean score out of 25 items was .47, *SD*, .74. One child had abnormalities in both visual (bright lights and shiny things) and auditory domain (distressed by certain sounds). One had a proximal symptom (eating a small range of foods) and an auditory problem (distressed by sounds) and three others had auditory abnormalities only (1 was upset by certain sounds and 2 had unusually acute hearing).

Autism and Clinical Comparison Groups

Total Scores and Scores for each Sensory Domain

Thirty-one (94%) of 33 children with autism (LFA + HFA) had sensory symptoms compared with

Table 3 Percentage of children with sensory symptoms in each domain and mean number of symptoms in Study 1

DISCO categories	Low functioning autism	High functioning autism	Developmental disability	Language impairment	Typical development	Test value (df = 1)[a]		*P*
N	16	17	19	15	15			
Auditory								
%	44	47	32	13	33	χ^2	3.57	.075
M	.81	.71	.53	.20	.33	U	434.50	.060
SD	1.05	.85	.91	.56	.49			
Visual								
%	56	35	16	7	7	χ^2	9.36	.003
M	.94	.47	.16	.06	.06	U	360.00	.001
SD	1.06	.72	.37	.26	.26			
Proximal								
Touch %	69	47	42	7	0	χ^2	6.66	.014
M	1.56	.94	.74	.13	.00	U	374.00	.008
SD	1.79	1.20	1.15	.52	.00			
Smell/taste %	31	47	5	0	7	χ^2	13.46	.000
M	.37	.47	.05	.00	.06	U	356.0	.000
SD	.62	.51	.23	.00	.26			
Other oral %	31	35	47	27	0	χ^2	.17	.800
M	.44	.35	.53	.33	.00	U	535.5	.704
SD	.73	.49	.61	.62	.00			
Kinaesthetic %	31	41	16	13	0	χ^2	4.15	.053
M	.50	.47	.26	.13	.00	U	441.50	.049
SD	.82	.62	.65	.35	.00			
Pain %	12	6	21	0	0	χ^2	.13	1.000
M	.12	.05	.21	.00	.00	U	546.00	.723
SD	.34	.24	.42	.00	.00			
Mixed %	62	35	21	7	0	χ^2	8.88	.004
M	1.44	.59	.26	.06	.00	U	349.50	.001
SD	1.36	.94	.56	.26	.00			
Total (25 items)								
Total % children	88	100	69	60	33	χ^2	8.66	.006
M	6.19	4.06	2.74	.93	.47	U	262.50	.000
SD	5.06	2.88	2.99	1.03	.74			
Total (20 items)[b]								
Total % children	88	100	69	60	33	χ^2	8.66	.006
M	5.19	3.82	3.00	1.20	.47	U	317.50	.002
SD	5.06	2.50	3.07	1.26	.74			

[a] Group differences calculated between combined HFA + LFA and combined DD + LI groups were tested using Fishers Exact test and Mann–Whitney test (2-tailed)

[b] Total % and mean calculated on marked (severe) symptoms (total 20) from 7 specific sensory domains (auditory, visual, touch, smell/taste, other oral, kinaesthetic and pain). Mixed proximal category excluded

22 (65%) of 34 children in the two clinical comparison groups (LI + DD). Children with autism also had a significantly higher mean total score (out of 25) (5.09, *SD*, 4.16) than children in the comparison groups (1.94, *SD*, 2.47). Chi square analyses for each separate sensory domain showed that significantly more children with autism had sensory symptoms in individual domains of visual, smell/taste and mixed proximal at the $P < .01$ level compared with children in the clinical comparison group. The difference for touch also approached the .01 level (.014). These significant results were supported by analyses of the mean number of items using Mann–Whitney tests. These results and significance levels are summarised in Table 3.

As the mixed sensory domain included non-specific proximal responses that are less comparable with the other sensory domains, further analysis was conducted of the total scores and patterns across the sensory domains with the mixed proximal category omitted. This resulted in a total score based on 20 items across 7 specific sensory domains (vision, hearing, touch, smell/taste, other oral, kinaesthesia and pain). Results (bottom rows of Table 3) remained unchanged. Significantly more children with autism than comparison children had at least one symptom and children with autism also had a higher mean score (out of 20) than children in the comparison group.

Table 4 shows the extent to which sensory abnormalities were found across multiple rather than single

Table 4 Study 1: Percentage of children with sensory symptoms in multiple sensory domains[a]

Number of sensory domains in which symptoms appear	Low functioning autism	High functioning autism	Developmental disability	Language impairment	Typical development	Test value df = 1[b]		P
None	12	0	32	40	67	χ^2	20.22	.000
One	19	29	16	53	20	χ^2	7.49	.112
Multiple	69	71	52	7	13	χ^2	23.65	.000
Mean number of domains	2.75	2.59	1.79	.67	.47	U	284.50	.000
Standard deviation	1.88	1.28	1.65	.62	.74			

[a] Seven sensory domains included: auditory, visual, touch, smell/taste, other oral, kinaesthetic, pain (mixed proximal category excluded)

[b] Group differences calculated between combined HFA + LFA and combined DD + LI groups were tested using Fishers Exact Test and Mann–Whitney Test (2 tailed)

sensory domains using the 7 specific sensory domains (mixed proximal category excluded). A significantly higher percentage of children with autism than comparison children had symptoms across multiple domains. This result was also supported by Mann–Whitney tests when the mean total of domains in each group (out of 7) was analysed.

Scores for each Individual Sensory Feature

The absolute number of children showing each individual sensory item (see Table 1 for descriptions of each item) was small and these low frequencies prevented meaningful statistical comparisons for many items. However, significant group differences at .01 levels were found between autism and comparison children for three items. The first, 'stimulates self without injury' (χ^2 = 12.11, df = 1, $P < .001$) was found in 10 (30%) children with autism compared with 0 comparison children. The second, 'smelling objects and people' was found in 6 (18%) children with autism compared with 0 comparison children (χ^2 = 6.79, df = 1, $P < .01$) and the third,'smears, plays with saliva etc' was found in 7 children with autism (21%) compared with 0 comparison children (χ^2 = 8.05, df = 1, $P < .005$). Another feature, 'twisting hands or object near eyes' was never found in either marked or in minor form in any of the developmental disability or language impaired children but found in 5 children with autism.

Comparisons between Clinical Subgroups

Separate comparisons for each clinical subgroup were also conducted using Fishers test. First the HFA and LI groups were compared. With all symptoms taken together, more children in HFA than the LI group had at least one symptom (χ^2 = 8.36, df = 1, $P < .006$). The result was the same whether or not the mixed proximal symptoms category was included in the analysis. The difference in multiple sensory domains was also significant between HFA and LI subgroups. Only 1 LI child (7%) compared with 12 HFA children (71%) had symptoms in more than one domain (χ^2 = 13.50, df = 1, $P < .001$) (see row 3 of Table 4). When each of the specific sensory domains were examined separately, differences at the .01 level were found for the smell/taste sub-domain (smell + food fads) (χ^2 = 9.41, df = 1, $P < .003$). Second, LFA/DD groups were compared. Taking all symptoms together, no differences were found at the .01 level for the presence of any symptoms, nor for presence of multiple domains. In addition, no differences were found for any of the specific domains though the difference for the mixed proximal category and the visual category approached this (χ^2 = 6.22, df = 1, $P < .018$; χ^2 = 6.31, df = 1, $P = .03$, respectively). When the 5 mixed proximal items were omitted (20 total items) no significant differences for total scores or multiple domains were found at the .01 level.

Finally, subgroup comparisons within the autism group were tested to examine whether HFA children would show fewer sensory abnormalities than LFA children. No significant differences were found for any of the domains singly or for total symptoms or total domains. Likewise, comparison between the two clinical comparison groups (LI versus DD) also revealed no significant difference for either the presence of multiple features or for separate sensory domains.

Reanalysis for Revised Groupings

All the analyses above were carried out again using the revised diagnostic groupings that resulted from 2 DD children and 1 LI child in the HFA group changing their diagnosis to autism some years after the study (see Method section). All the results remained the same as for the original groupings with no change. For the LFA/DD comparison however, the mixed proximal category now reached significance, (χ^2 = 10.98, df = 1, $P < .002$). while for the HFA/LI groups the results were identical. The HFA/LFA and the LI/DD comparison also remained identical.

Discussion

Children with autism were more affected by sensory abnormalities than were children with language impairment and developmental disability. In fact only 2 out of 33 children with autism (6%) were *not* affected by a sensory symptom compared with 12 of 34 (35%) of clinical comparison children. Children with autism differed from comparison children in both the frequency and pattern of abnormalities. Unlike the comparison group, the children with autism were more likely to have abnormalities across multiple sensory domains whereas most comparison children had features in one, if in any, domain.

These results support earlier studies using the Sensory Profile showing that sensory symptoms are common in children with autism (Kientz & Dunn, 1996). Unlike the Sensory Profile which uses a wider scale for scoring, the DISCO measure used here included only the most severe extremes of atypical sensory responding. Therefore the absolute numbers of individual sensory features were fewer in this study than in previous research. However, the patterns are similar across studies. The results replicated the finding of Roger et al. (2003) by showing significant group differences at the $P = .01$ level for total sensory symptoms and for specific domains of smell/taste and a group difference at the $P = .014$ level for touch. We also found significant differences for the mixed proximal domain in our study but even when these symptoms were excluded from the analysis due to their non-specific status, significant differences for total symptoms, multiple domains and specific domains remained. In addition, results for the specific symptoms suggest that there may be features, especially those involving the seeking of stimulation, that are found relatively rarely in children without autism and more frequently in children who have autism.

Some differences were found between our study and other studies regarding the visual and auditory domain. As Table 1 shows, the visual and auditory items selected for the DISCO are not the same as the Sensory Profile. The current study found significant differences in visual symptoms between children with autism and comparison children while Rogers et al. did not. However, the measure used in Rogers et al.'s study was a mixed visual/auditory domain. Kientz and Dunn (1996) using the complete Sensory Profile, did find differences between autism and typical samples for visual and for auditory symptoms and found several symptoms in both the visual and in the auditory domains that appeared in 50% or more of the autism population. Dahlgren and Gillberg (1989) also found abnormal auditory reactions. Therefore it would be expected that both visual and auditory symptoms should be more common in autism than in non-autism groups. Although we found a significant effect for vision however, the lack of difference for auditory symptoms in our study was an unexpected result. Five typical children had unusual responses to sound, indicating that these items are less sensitive for discriminating typical and atypical responding. On the other hand, while these five children may have differed from other typical children, it remains possible that the magnitude of their auditory sensitivity and its impact on the child's everyday life was less extensive than that seen in children with autism. For example, acute hearing may be found in typical children but unusual acuteness specific to particular sounds (e.g. for keys or crisp wrappers) is more unusual. Thus the limited range of scoring criteria in the DISCO compared with other instruments may help to explain these results. The DISCO also used fewer examples of similar sensory items compared with other measures and did not provide multiple items representing both undersensitivity and oversensitivity to auditory stimuli.

One of the most striking results of the study was the frequency of sensory symptoms in the high functioning autism group compared with the matched comparison group. Like Freeman (1981), therefore we found that when high functioning autistic children were compared with an IQ-matched comparison group the difference was greater than when low functioning children with autism were compared with developmentally disabled children. In the current study, the high functioning autism group had more sensory symptoms overall and were more affected by multiple sensory domains than the language impairment comparison group. In contrast the low functioning autism group did not differ from the developmental delayed group.

Surprisingly, high functioning children with autism also showed a high frequency of proximal abnormalities. Proximal abnormalities are associated with low developmental immaturity, yet over 35% of HFA children had abnormalities in virtually all of the proximal categories and did not differ from low functioning autism group in the frequency of these features.

It is notable that within the autism group, the low and high functioning subgroups did not differ significantly from each other either in the frequency of total sensory symptoms or in any of the separate sensory domains. While differences in sensory responding was not seen as a function of IQ however, it is possible that both IQ and age differences might be seen in a larger sample of individuals. Research on repetitive behaviours in autism does show differences in the severity of repetitive behaviours found in low and high IQ individuals (Turner, 1999). Turner found that low-level repetitive behaviours such as stereotyped movements were seen in high ability individuals but these low-level behaviours tend to reduce in frequency and intensity in older and high IQ children, The sensory abnormalities studied here could all be classified as low-level behaviours that might be found in young typical infants. The question then, is whether the frequency and/or pattern of these behaviours change with age and ability level. This question was investigated in Study 2.

Study 2

Method

Participants

Participants were seen at the Centre for Social and Communication Disorders, a specialist tertiary referral centre for diagnosis and assessment. Almost all of the referrals to this centre have disorders in the autistic spectrum. The DISCO is used as part of the assessment process to obtain information from parents or other carers on developmental history and present clinical picture.

The sample comprised 200 children and adults aged 32 months to 38 years (mean 12 years 7 months, standard deviation 8 years 1 month), seen at the centre. The DISCO interview was completed by either L. Wing or J. Gould during the period 1994–1997. The participants were those for whom all the information elicited by the DISCO interview was complete and coded for computer entry. Individuals were seen at Elliot House in chronological order according to the date when referral was confirmed. They were assigned to the clinicians who were working at Elliot House on the days of the appointments. There was no process of selection that would introduce bias in the clinical pictures of those included versus those excluded. A different data set using the DISCO has previously been reported for this group (Leekam, Libby, Wing, Gould, & Gillberg, 2000).

Age and Ability Level Ages and ability levels are shown in Table 5. Because of the wide range of ages and abilities, a number of different types of formal assessment were used. These included the Wechsler Intelligence Scale for Children (WISC-III-UK), the Wechsler Preschool and Prima Scale of Intelligence (WPSSI), the Wechsler Adult Intelligence Scale (WAIS), the Leiter International performance Scale or Merill Palmer were used as appropriate. Language was assessed from the verbal scale of the Wechsler tests, the British Picture Vocabulary Scale or the Reynell Language Development scales. Forty-seven of the 200 participants did not have IQ test because they were too low in ability or, in a very few cases, were too uncooperative to be tested. For these individuals, their behaviour was observed by the psychologist in structured and unstructured situations. This information, together with the developmental information from the DISCO, was used to make an estimate of the level of ability. The group were divided in low and high ability if they had an IQ or estimated IQ above or below 70. A

Table 5 Chronological ages, and non-verbal IQ ranges of children in Study 2

	Low functioning young	Low functioning old	High functioning young	High functioning old
CA in months	68.63	206.26	83.00	233.92
Standard deviation	23.34	80.88	30.26	87.67
Range	32–118	123–420	19–120	123–456
N	35	35	65	65
IQ[a] range				
Profound 0–19	0	3	0	0
Severe 20–34	3	6	0	0
Moderate 35–49	17	7	0	0
Mild 50–69	15	19	0	0
Borderline 70–89	0	0	26	32
Average 90–119	0	0	35	28
Superior 120+	0	0	4	5

[a] One hundred and fifty three participants were tested on the following IQ tests: The Weschler Intelligence Scale for Children (WISC-III-UK), the Weschler Preschool and Prima Scale of Intelligence (WPSSI), the Weschler Adult Intelligence Scale (WAIS), the Leiter Intenational Performance Scale. Forty-seven participants were not given formal IQ tests due to poor ability or lack of cooperation. IQ estimates were taken by clinicians from informal testing and DISCO information

median age split was taken. Participants were above or below 10 years 3 months.

Results

Comparisons were made between four groups of participants; young low IQ ($N = 35$) young high IQ ($N = 65$) old low IQ ($N = 35$) and old high IQ ($n = 65$). As with Study 1, data were not normally distributed and non-parametric statistics (Kruskall Wallis and Chi Square Tests) were used with significance levels set at .01.

Total Scores

A very large number of individuals, regardless of age or IQ had sensory symptoms. In all, 185 of 200 (92.5%) had at least one sensory abnormality. Analysis of the total number of participants with sensory symptoms showed no difference in the number of individuals who had symptoms in each age and IQ group. Younger and lower IQ individuals had more total symptoms (out of 25) but the group difference for the mean number of total symptoms did not quite reach the .01 level. Analysis using 20 items (excluding non-specific symptoms in the 'mixed proximal' category) showed the same results. One hundred and eighty three of 200 individuals had sensory symptoms when the 'mixed proximal' category was excluded and the difference in total scores across the 4 subgroups did not reach the .01 level.

Table 6 shows that there was no difference in the number of participants with sensory abnormalities in more than one domain. However, the mean number of domains affected was significantly higher for participants who were younger and who had low IQ.

Scores for each Sensory Domain

Table 7 shows the percentage of individuals with symptoms in each domain (including the 'mixed proximal' domain). No age or IQ differences were found for the domains of touch, smell/taste, pain or auditory. Significant differences between these subgroups were found at the .01 level for visual and other oral domains for both the number of participants and the number of symptoms. The mixed proximal category and the kinaesthetic category also approached significance at the .01 level. To investigate the significant effects for visual and other oral domains, separate analyses were conducted, examining the effects of age and of IQ. Analyses for age showed that more individuals had visual and other oral symptoms in the younger than in the older age group ($\chi^2 = 8.49$, df = 1, $P < .005$, visual, $\chi^2 = 10.15$, df = 1, $P < .002$ other oral). Analyses for IQ revealed no further effects for visual and other oral symptoms. The significant differences for age and IQ were the same when analyses were conducted of the mean number of features rather than percentage of individuals.

Scores for Individual Sensory Features

As in Study 1, the absolute numbers of participants with each feature was small. Analyses of group differences for each individual feature revealed one proximal feature, 'gentle touch' that was significantly affected by age. Thirty-one percent of high IQ older participants and 23% of low IQ older participants disliked gentle touch compared with 4.6% of participants in the high IQ young group and 14.3% in the low IQ young group ($\chi^2 = 15.96$, df = 3, $P < .001$). Four other significant group effects were found for individual visual features that improved rather than worsened with age and IQ. 'Interest in bright lights and shiny things', ($\chi^2 = 11.69$, df = 3, $P < .009$). 'Twisting hands and objects near eyes' ($\chi^2 = 14.23$, df = 3, $P < .003$). 'Gets unusually excited at seeing things spin' ($\chi^2 = 14.47$, df = 3, $P < .002$). 'Looks at objects from many different angles' ($\chi^2 = 14.42$, df = 3, $P < .002$). Two other non-visual symptoms were also affected by age and IQ 'Spinning round in circles'

Table 6 Study 2: Percentage of children with sensory symptoms in multiple sensory domains[a]

Number of sensory domains in which symptoms appear	Low functioning group		High functioning group		Test value df = 3[b]		P
	Younger	Older	Younger	Older			
None	6	6	9	11	χ^2	1.173	.759
One	11	14	22	25	χ^2	3.314	.346
Multiple	83	80	69	64	χ^2	5.163	.160
Mean no. domains	3.45	2.85	2.74	2.15	KW	13.06	.005
Standard deviation	1.82	1.68	1.89	1.50			

[a] Seven specific sensory domains included: auditory, visual, touch, smell/taste, other oral, kinaesthetic, pain (mixed proximal category excluded)

[b] Group differences between 4 groups tested using χ^2 and Kruskal–Wallis tests

Table 7 Percentage of children with sensory symptoms in each domain and mean number of symptoms in Study 2

DISCO categories	Low functioning group		High functioning group		Test value χ^2 df = 3[a]		P
	Younger	Older	Younger	Older			
N	35	35	65	65			
Auditory							
%	54	57	49	43	χ^2	2.21	.529
M	.77	.91	.75	.54	KW	4.32	.229
SD	.88	.89	.92	.69			
Visual							
%	63	37	40	23	χ^2	15.44	.001
M	1.4	.63	.66	.33	KW	20.67	.000
SD	1.31	1.00	.97	.69			
Proximal							
Touch %	63	63	55	63	χ^2	1.05	.788
M	1.11	1.31	.88	1.31	KW	3.95	.267
SD	1.08	1.28	.99	1.33			
Smell/taste %	51	57	43	37	χ^2	2.32	.508
M	.51	.40	.54	.41	KW	1.99	.570
SD	.51	.55	.69	.58			
Other oral %	46	26	32	12	χ^2	14.30	.003
M	.48	.29	.35	.123	KW	14.30	.002
SD	.56	.52	.54	.33			
Kinaesthetic %	34	23	31	11	χ^2	10.04	.018
M	.43	.26	.38	.123	KW	10.32	.016
SD	.65	.50	.63	.37			
Pain %	34	43	23	26	χ^2	5.03	.170
M	.34	.43	.23	.26	KW	5.00	.172
SD	.48	.50	.42	.44			
Mixed %	51	51	34	26	χ^2	9.73	.021
M	.51	.71	.28	.25	KW	11.65	.009
SD	.89	.89	.65	.47			
Total (25 items)							
Total % children	94	94	91	92	χ^2	0.61	.895
M	5.57	4.94	4.08	3.35	KW	10.10	.017
SD	3.81	3.37	3.47	2.43			
Total (20 items)[b]							
Total % children	94	94	91	89	χ^2	1.17	.759
M	5.06	4.23	3.80	3.11	KW	8.39	.039
SD	3.39	3.01	3.13	2.34			

[a] Group differences between 4 groups tested using χ^2 and Kruskal–Wallis tests

[b] Total % and mean calculated on marked symptoms (total 20) from 7 specific sensory domains (auditory, visual, touch, smell/taste, other oral, kinaesthetic, and pain). Mixed proximal category excluded

(χ^2 = 13.88, df = 3, P < .003) 'mouthing objects' (χ^2 = 13.39, df = 3, P < .004).

Discussion

Study 2 extended the results found in Study 1 by showing that more than 90% of autistic individuals in this sample of 200 had sensory abnormalities and that these abnormalities were found across multiple modalities. In particular the proximal domains of touch and smell/taste that distinguished autism and non-autism groups in Study 1 did not change with age or IQ in Study 2. As found in Study 1, these low-level responses were found even in the highest functioning individuals. On the other hand, not all proximal domains remained constant across age and IQ. For example, other oral symptoms were found significantly less frequently in older participants and the effect of age and IQ approached the .01 level of significance for the proximal domains of kinaesthetic and mixed proximal symptoms.. Of the distal domains, auditory symptoms remained constant across age and IQ while visual symptoms appeared to show most difference with both age and IQ. In fact, each of the four individual visual features showed significant differences across the 4 IQ and age groups.

Difference in sensory abnormalities between age and IQ groups were also found in the overall pattern of sensory responsiveness across domains. For example, while the great majority of individuals with autism had symptoms in more than one sensory domain, the younger low-functioning group had a higher mean domain score showing that they are affected by more domains than the other groups.

It is difficult to draw firm conclusions about the differences found for age and IQ. The results reported here may give a conservative view of the extent to which changes occur given that this study included a wide range of ages with many older individuals included. Other age and IQ differences may be found in even younger children and infancy. It is premature therefore to make any strong claims about which particular sensory domains change with age or IQ. Nevertheless this study shows two main findings. First that sensory abnormalities continue to affect the very great majority of individuals with autism even into adolescence and adulthood and second that some sensory symptoms change with age and IQ. For some symptoms this involves a reduction of symptoms with age and IQ but for others such as sensitivity to gentle touch, there may be an increase in symptoms as awareness increases with age.

General Discussion

The results of these studies show that sensory abnormalities are a pronounced problem in individuals with autism. At least 90% of the individuals in both Study 1 and in Study 2 had sensory abnormalities, a striking finding given that sensory problems are not an essential diagnostic criterion for autism. Study 1 showed that children with autism differ from clinical comparison children not only in their overall sensory scores but in the specific domains of vision and smell/taste, with differences for touch approaching significance at the .01 level. Our results also show that individuals with autism tend to have sensory abnormalities, not only in one sensory domain but in two or three. Study 2 supported these results, showing that sensory abnormalities persist across age and IQ in people with autism. Despite the persistence of sensory abnormalities across age and IQ groups however, some difference in age and IQ can be seen.

To summarise, while sensory abnormalities are not unique to autism, they are more prevalent in children with autism than in children with other developmental delays. They also persist across age and IQ although age and IQ differences can be seen for some symptoms. These findings support earlier research studies that have used a narrower definition of autism and show that sensory abnormalities are common even when the broader concept of autistic spectrum is applied. The findings from these studies may therefore have implications for clinical assessment and for research.

The results of this study suggest that as sensory symptoms are so prevalent in autism that more fine-grained documentation of sensory problems may be helpful in the assessment and management of children with autism. Currently, the ADI-R (Lord et al., 1994), which follows ICD-10 criteria, records information that combines responses to different sensory domains. More detailed assessment of sensory problems may enable clinicians to identify and assist with the distress that many people with autism experience. The distress caused by particular sensory inputs can cause severely disturbed and aggressive behaviour in low functioning people with autism who cannot explain their distress. Identifying the specific sensory input causing the problem is essential in order to organise the environment and daily routine that will minimise the chances of such distress. A programme of desensitisation may prove helpful. Dislike of being touched increases the social problems and is distressing to parents who want to show their love through touching. Parents therefore need to have an explanation of the way the child experiences the world.

Some high functioning people with autism are able to explain the difficulties caused by sensory input and some have suggested techniques for helping (Grandin & Scariano, 1986). Some people with autism have found that sessions in 'sensory rooms', areas that provide soft cushions for sitting or lying on, pleasant displays of coloured lights, soft sounds or music have a calming effect and are much enjoyed. However, this is not true of all people with autistic spectrum disorders and it is important to adapt the programme to the individual sensory preferences and difficulties of the person concerned.

The findings from this research also raise theoretical questions about how low-level sensory difficulties may be involved in the higher level perceptual integration problems that have been proposed in autism (Frith, 2003; Mottron & Burack, 2001; O'Connor & Hermelin, 1978; Plaisted, 2001). It might be argued that the extreme developmental immaturity in tactile and olfactory responding in autism shown by even high functioning people with autism has implications for research that attempts to understand perceptual difficulties in autism.

For example, the findings may help to throw light on how multisensory links between visual, auditory and tactile processing may be crucial in explaining visual perceptual impairments in autism. Recent research with blind people has shown that absence of vision during early development can result in qualitative changes in tactile and auditory perception (Röder, Rösler, & Spence, 2004). If early visual experience shapes the development of tactile and auditory perception, then impairments in tactile or auditory experience may equally affect visual perception. Our findings indicate that children with autism have multi-modal sensory difficulties. One proposal is that this difficulty may create limitations for the capacity for sensory/perceptual integration (Leekam & Wyver, 2005). Future research may also help to establish whether the developmental process of multi-sensory integration is affected in autism.

This research also raises questions for perceptual accounts that are heavily dominated by a focus on vision. This is even more relevant given that our findings suggest that visual features may be the least stable of the domains, changing significantly with age and IQ. Therefore it may be relevant for theories of visual processing deficits to take account of developmental changes in visual symptoms when considering whether higher level perceptual processing is also subject to improvements across age and ability levels.

This research supports previous research findings in showing a high frequency of sensory symptoms in individuals with autism. Differences with previous studies were also found however, especially with respect to visual and auditory symptoms. Differences across studies are not surprising given the differences in samples and methods used. The DISCO is a clinical tool designed to collect information about a wide range of behaviours and developmental skills and is not a specialised instrument for investigating sensory symptoms. The scoring system used for the study therefore may have had limitations in representing the degrees of sensory symptoms found across different populations in comparison with a standardised measure such as the Sensory Profile. The conclusions about group differences in Study 1 must also be constrained by the limitations of small sample size and within-group variability. It is also difficult to draw firm conclusions about the age and IQ differences found in Study 2 without further research. While it was possible to document age and IQ differences in this study, the age groupings were not ideal for studying changes that might be seen much earlier in development, for example between the ages of 2 and 5 years. Therefore it might be expected that other sensory domains are also affected by age but this study did not capture these changes because comparisons were needed between children at younger ranges.

Despite the limitations of this study, these research findings help to build a more consistent picture of the sensory abnormalities in autism, confirming their prevalence, their multimodal nature and their potential for developmental change. New research is needed in order to establish more clearly the precise developmental changes that occur from infancy to adulthood. New research requires new methodologies to test whether parental report of children's sensory functioning is consistent with observational, experimental or physiological measures. Such methods may substantiate these results and give further insight into the nature of these difficulties. If these findings can be confirmed across different measures, other questions lie ahead for future research.

One question is whether and how sensory abnormalities in children with autism are connected to the development of social and communication impairments. Rogers et al. (2003) did not find significant associations between sensory scores on the Short Sensory Profile and scores on the social and communicative scales of the ADI for their group of children with autism. However, when they assessed children with Fragile X syndrome a group that had a mixed range of both poor and good performance on the social communication scale, they did find an association between social communication behaviour and sensory symptoms. Therefore, more research is needed to explore the links between sensory abnormalities and social communication skills in other groups who, like the Fragile X group have a wider range of good and poor social interaction abilities.

New research with typically developing infants as well as with children with autism may be needed if we are to answer questions about how sensory and social experience are connected. Longitudinal studies involving both typically developing and developmentally delayed children may also help to answer questions about the effect of early atypical sensory development on perceptual, cognitive and social functioning in later childhood. Meanwhile, the studies presented here provide a description of the sensory abnormalities of children and adults with autism from which new hypotheses can be generated.

Acknowledgments We gratefully acknowledge the help of the children, parents and teachers who contributed to this research. This research was supported by funding from the NHS Executive (SPGS262) and by a Research Training Grant to Carmen Nieto from the Autonomous Community of Madrid (Spain), co-financed by the European Social Fund.

References

American Psychiatric Association (1994). *Diagnostic and statistical manual of mental disorders. Fourth Edition*. Washington, DC: American Psychiatric Association.

Ayres, A. J. (1971). Characteristics of types of sensory integrative dysfunction. *The American Journal of Occupational Therapy, XXV*(7), 329–334.

Baranek, G. T., Foster, L. G., & Berkson, G. (1997). Tactile defensiveness and stereotyped behaviors. *American Journal of Occupational Therapy, 51*(2), 91–95.

Bartak, L., & Rutter, M. (1976). Differences between mentally retarded and normally intelligent autistic children. *Journal of Autism and Childhood Schizophrenia, 6*, 109–120.

Bayley, N. (1993). *Bayley Scales of infant development* (2nd Ed.). San Antonio, TX: The Psychological Corporation.

Bemporad, J. B. (1979). Adult recollections of a formerly autistic child. *Journal of Autism and Developmental Disorders, 9*(2), 179–197.

Cesaroni, L., & Garber, M. (1991). Exploring the experience of autism through first hand Accounts. *Journal of Autism and Developmental Disorders, 21*(3), 303–313.

Courchesne, E., Lincoln, A. J., Kilman, B. A., & Galambos, R. (1985). Event-related brain potential correlates of the processing of novel visual and auditory information in autism. *Journal of Autism and Developmental Disorders, 15*, 5–76.

Dahlgren, S. O., & Gillberg, C. (1989). Symptoms in the first two years of life: A preliminary population study of infantile autism. *European Archives of Psychiatry and Clinical Neurosciences, 238*, 169–174.

Dunn, W. (1999). *Sensory profile*. San Antonio, TX: The Psychological Corporation.

Dunn, W., & Bennett, D. (2002). Patterns of sensory processing in children with attention deficit hyperactivity disorder. *Occupational Therapy Journal of Research, 22*(1), 4–15.

Dunn, W., Myles, B. S., & Orr, S. (2002). Sensory processing issues associated with Asperger's syndrome: A preliminary investigation. *The American Journal of Occupational Therapy, 56*, 97–102.

Fenson, L., Dale, P. S., Reznick, J. S., Thal, D., Bates, E., Hartung, P., Pethnick, S., & Reilly, J. S. (1993). *The MacArthur communicative development inventories*. San Diego, CA: Singular Publishing Group.

Freeman, B. J., Ritvo, E. R., Schroth, P. C., Tonick, I., Guthrie, D., & Wake, L. (1981). Behavioral characteristics of high- and low-IQ autistic children. *American Journal of Psychiatry, 138*(1), 25–29.

Frith, U. (2003). *Autism: Explaing the enigma*. Oxford: Blackwell.

Frith, U., Hermelin, B. (1969). The role of visual and motor cues for normal, subnormal and autistic children. *Journal of Child Psychology and Psychiatry, 10*, 153–163.

Gerland, G. (2003). *A real person: Life on the outside*. London: Souvenir Press.

Goldfarb, W. (1956). Receptor preferences in schizophrenic children. *Archives of Neurology and Psychiatry, 76*, 643–652.

Grandin, T., & Scariano, M. (1986). *Emergence: Labelled autistic*. Novato, CA: Arena.

Hermelin, B., & O'Connor, N. (1965). Visual imperception in psychotic children. *British Journal of Psychiatry, 56*, 455–460.

Kientz, M. A., & Dunn, W. (1996), A comparison of the performance of children with and without autism on the sensory profile. *The American Journal of Occupational Therapy, 51*(7), 530–537.

Le Couteur, A., Rutter, M., Lord, C., Rios, P., Robertson, S., Holdgrafer, M., & McLennan, J. (1989). Autism diagnostic interview: A standardized investigator instrument. *Journal of Autism and Developmental Disorders, 19*, 363–387.

Leekam, R. S., Libby, S. J., Wing, L., Gould, J., & Taylor, C. (2002). The Diagnostic Interview for Social and Communication Disorders: Algorithms for ICD-10 childhood autism and Wing and Gould autistic spectrum disorder. *Journal of Child Psychology and Psychiatry, 43*(3), 327–342.

Leekam, S., & Wyver, S. (2005). Beyond 'modalarity' and innateness: Sensory experience, social interaction and symbolic development in children with autism and blindness. In L. Pring (Ed.), *Autism and blindness*, (pp. 26–49). London: Whurr.

Leekam, S., Libby, S., Wing, L., Gould, J., & Gillberg, G. (2000). Comparison of ICD-10 and Gillberg's criteria for Asperger syndrome. *Autism, 4*, 11–28.

Leiter, R. G. (1979). *Leiter international performance Scale*. Woodvale, IL: Soelting Corporation.

Lord, C., Rutter, M., DiLavore, P., & Risi, S. (1999). *Autism diagnostic observation schedule – WPS edition*. Los Angeles, CA: Western Psychological Services.

Lord, C., Rutter, M., & Le Couteur, A. (1994). Autism diagnostic interview – revised: A revised version of a diagnostic interview for caregivers of individuals with possible pervasive developmental disorders. *Journal of Autism and Developmental Disorders, 24*, 659–686.

Mottron, L., & Burack, J. A. (2001). Enhanced perceptual functioning in the development of autism. In J. Burack, T. Charman, N. Yirmiya, & P. R. Zelazo, (Eds.), *The development of autism: Perspectives from theory and research* (pp. 131–148). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Myles, B. S., Hagiwara, T., Dunn, W., Rinner, L., Reese, M., Huggins, A., & Becker, S. (2004). Sensory issues in children with Asperger syndrome and autism. *Education and Training in Developmental Disabilities, 3*(4), 283–290.

O'Connor, N., & Hermelin, B. (1978). *Seeing and hearing in space and time*. London: Academic Press.

Ornitz, E. M. (1974) The modulation of sensory input and motor output in autistic children. *Journal of Autism and Childhood Schizophenia, 4*(3), 197–215.

Ornitz, E. M. (1988) Autism: A disorder of directed attention. *Brain Dysfunction, 1*, 309–322.

Ornitz, E. M., Guthrie, D., & Farley, A. J. (1978) The early symptoms of childhood autism. In G. Serban (Ed.), *Cognitive defects in the development of mental illness* (pp. 24–42). NY: Brunner/Mazel.

Plaisted, K. C. (2001). Reduced generalisation in autism: An alternative to weak central coherence. In J. Burack, T. Charman, N. Yirmiya, & P. R. Zelazo (Eds.), *The development of autism: Perspectives from theory and research* (pp. 149–169). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Reynell, J., & Huntley, M. (1987). *Reynell developmental language Scales* (2nd Rev.). Windsor, England: NFER-Nelson Publishing.

Röder, B., Rösler, F., & Spence, C. (2004). Early vision impairs tactile perception in the blind. *Current Biology, 14*(2), 121–124.

Rogers, S., Hepburn, S., & Wehner, E. (2003). Parent reports of sensory symptoms in toddlers with autism and those with other developmental disorders. *Journal of Autism and Developmental Disorders, 33*(6), 631–642.

Shah, A., & Frith, U. (1993). Why do autistic individuals show superior performance on the block design task? *Journal of Child Psychology and Psychiatry, 8*, 1351–1364.

Turner, M. (1999). Annotation: Repetitive behaviour in autism: A review of psychological research. *Journal of Child Psychology and Psychiatry, 40*, 839–849.

Williams, D. (1999). *Autism and sensing: The unlost instinct*. London: Jessica Kingsley Publishers.

Wing, L. (1969). The handicaps of autistic children: A comparative study. *Journal of Child Psychology and Psychiatry, 10*, 1–40.

Wing, L. (1971). Perceptual and language development in autistic children: A comparative study. In M. Rutter (Ed.), *Infantile autism: Concepts characteristics and treatment* (pp. 173–198). London: Churchill Livingstone.

Wing, L., Leekam, L., Libby, S., Gould, J., & Larcombe, M. (2002). The diagnostic interview for social and communication disorders: background, inter-rater reliability and clinical use. *Journal of Child Psychology and Psychiatry, 43*(3), 307–325.

World Health Organisation (1993). *The ICD-10 classification of mental and behavioural disorders. diagnostic criteria for research*. Geneva: Wold Health Organisation.