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Sorting Preference in Children with Autism: The Dominance of Concrete Features

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Abstract The current study investigates preference to sort objects on the basis of either concrete or abstract features in children with and without autism. Participants were asked to sort a set of books into two groups that could be differentiated according to concrete (color, size) or abstract criteria (category membership: sports/games). The results showed that those with autism, unlike controls, were significantly more likely to sort according to a concrete criterion. In a further phase of testing, those with autism still did not sort according to abstract criteria, even when this was the only basis for sorting systematically. The findings are interpreted as evidence for a preference in autism to process concrete over abstract features of stimuli.

Keywords Autism · Concrete and abstract information · Categorization

Evidence from clinical reports shows that individuals with autism are captured more by concrete characteristics of their surroundings, such as color or shape, than socially relevant information. For example, one autistic boy reported that while viewing stage productions at school his attention was drawn to the changing colored lights on the curtains rather than to the actors and their speeches (Frith, 2003). A heightened awareness of color and light was also found in a young girl with autism who showed an obsessive interest in this aspect of her environment (Park & Youderian, 1974). These reports are supported by empirical research which provides evidence of atypical focus of attention in those with autism (Klin, Jones, Schultz, & Volkmar, 2003; Weeks & Hobson, 1987). Klin et al. using an eye tracking paradigm, demonstrated that individuals with autism attend to non-essential inanimate details rather than people when viewing different scenes from television or movies. Further evidence of processing concrete details in preference to socially relevant information comes from a study by Weeks and Hobson (1987). They discovered that individuals with autism were more inclined to sort photographs of people according to the type of hat they were wearing, whereas control participants preferred to sort by facial expression. Importantly, in Weeks and Hobson's task only one-third (5/15) of those with autism were not able to sort according to facial expression when given explicit instructions to do so, suggesting that the majority were *capable* of processing in this manner. Therefore, their failure to use facial expression as a sorting criterion apparently was not due to a deficit in processing this information. Both of these studies suggest a specific insensitivity to social stimuli in individuals with autism which might account for their social difficulties and problems in understanding others' thoughts and feelings.

One explanation for these findings is that individuals with autism may be less inclined to process abstract information regardless of whether or not it involves social content. Abstract information in this sense refers to information which cannot be directly perceived but instead must be abstracted from the available input. For example, in order to successfully sort by hat type in Weeks and Hobson's (1987) task one need only attend to the concrete characteristics of the stimuli presented on the cards. An individual does not need to identify

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the object as a hat since he can simply match on the basis of the object's shape. This ''matching'' strategy is argued by Shulman, Yirmiya, and Greenbaum (1995) to require merely a localized or piecemeal way of processing. In contrast, sorting by facial expression requires abstraction of meaning (e.g. happy) from the concrete information presented, coupled with perception of similarities on a level that transcends the details of the features of specific faces.

Our interpretation is supported by evidence which suggests that individuals with autism attend to concrete rather than abstract characteristics of a stimulus even when it lacks social relevance. Ropar and Mitchell (2002) administered a shape constancy task to individuals with and without autism. Participants were required to estimate the shape of an illuminated circular disc which was presented at a slant inside a darkened chamber. Thus, the projected image of the slanted stimulus was elliptical in shape. They found that non-autistic control groups exaggerated the circularity of the projected shape significantly more than those with autism. This suggested control participants were influenced by the abstract characteristics of the stimulus (i.e. its circularity) when recreating the image. The more accurate estimates of the autistic group were then achieved by their attention to the perceivable concrete features, while ignoring the abstract properties. Individuals with autistic disorder have also demonstrated superior performance in relation to comparison participants on the embedded figures test (Joliffe & Baron-Cohen, 1997; Shah & Frith, 1983; but see Brian & Bryson, 1996). This task requires an individual to find a simple figure (e.g. triangle) within a larger meaningful figure (e.g. pram). The embedded item is more easily detected if one can avoid interpreting the larger figure as meaningful and can instead focus on the concrete features of the stimulus such as its lines, shapes, and angles. Further evidence that individuals with autism do not process abstract information in the same way as those without the disorder comes from a study carried out by Pring, Hermelin, and Heavey (1995). They presented participants with a picture puzzle task and the standard block design task, both requiring one to recreate a pattern using individual blocks. The picture puzzle task depicted a meaningful scene (i.e. Winnie the Pooh) while the block design stimuli involved a non-meaningful geometric pattern. Those with autism performed significantly better than those without autism on the block design. On the picture puzzle task, those with typical development performed well, and similarly to those with autism. Pring et al. (1995) argued that the typically developing group performed better on the picture puzzle than block design because they were processing abstract characteristics of the stimuli. In contrast, Pring et al. (1995) suggested that those with autism were utilizing a segmentation strategy based on concrete features which facilitated solution of block design.

If individuals with autism process information at a concrete in preference to an abstract level, then we might expect this to affect how they categorize objects, irrespective of whether the stimuli are social or nonsocial. Research carried out by Shulman et al. (1995) found that individuals with autism fail to group objects into categories which involve abstract representations. In a free sorting task participants were asked to make groups of ''things that go together''. Individuals with autism were able to successfully group together items with similar color or shape, but they performed worse than control groups when required to sort items which represented a category such as trees, beds, animals, tools, vehicles, and humans. Shulman et al. (1995) suggest that individuals with autism are more adept at processing concrete features than abstract categories, and this may reflect a more general deficit in processing. Arguably, forming categories based on abstract information is a more difficult skill as this requires the internal manipulation of representational knowledge.

However, the idea of a general deficit in processing on a representational level is challenged by research showing that individuals with autism can categorize according to meaningful criteria such as function or semantic relatedness (Baron-Cohen, 1991; Ropar & Mitchell, 2001; Tager-Flusberg, 1985a, b). One might argue that these studies include certain features which help those with autism to attend to abstract criteria. In two studies individuals with autism were explicitly asked to sort according to a pre-fixed category (Baron-Cohen, 1991; Tager-Flusberg, 1985b). Shulman et al. (1995) argue that being provided with the category label is easier than having to infer the category from the stimuli set. The benefit of having a category cue word (e.g. fruit) also was found to assist individuals with autism in recalling a list of thematically related words (Tager-Flusberg, 1991).

Other studies which have shown that individuals with autism do use abstract information to assist with categorization have used a matching-to-sample paradigm (Ropar & Mitchell, 2001; Tager-Flusberg, 1985a). Tager-Flusberg's study required participants to match a target picture (e.g. armchair) with either a semantically related (e.g. rocking chair) or non-related alternative (e.g. sedan car). Participants with autism successfully selected the semantic options to match the target items. However, one limitation of the task is that the semantic items were also more structurally similar to the target than to the non-related alternatives. Thus, individuals with autism may have matched the items on the basis of visual similarities rather than abstract relatedness. In Ropar and Mitchell's (2001) task this problem was avoided by asking participants to match atypically colored stimuli (e.g. blue banana) with either a colored patch that was semantically related (e.g. yellow) or one that was visually similar (e.g. blue). Individuals with autism, like mental age matched controls, were more likely to select the alternative that was semantically related to the target. Although this supports the view that individuals with autism do process stimuli on an abstract level, the unusual color of the items may have cued attention to the semantically related option. This may have resulted in children responding as if they were being asked to choose the "correct" color. An additional drawback of matching to sample paradigms like those used by Tager-Flusberg (1985a) and Ropar and Mitchell (2001) is that they force participants to use one of two strategies. This could result in an individual picking the correct option by eliminating the alternative. Furthermore, the alternatives act as cues to a particular strategy which an individual may not have generated on their own.

In sum, research which shows that individuals with autism categorize according to abstract criteria has either explicitly provided participants with the category label for sorting, or certain perceptual features may have assisted participants to sort in this way. This suggests they may have a cognitive weakness that results in attention to concrete features of stimuli in the absence of cues towards abstract properties. Hence, we predict that individuals with autism would rely on concrete more than abstract features when asked to sort stimuli so long as two conditions are met. First, participants must be required to *infer* the relationship between the stimuli without being explicitly told the category label. Second, there should be no visual characteristics of the stimuli which could lead one to categorize according to abstract properties.

The aim of our study was to devise a task which met these two conditions to determine whether individuals with autism sort items according to concrete features in preference to an abstract criterion such as category membership. We created 24 books which could be sorted into two groups on the basis of either concrete features (color: orange/green, size: large/small, and people: present/absent) or category membership (sports/games). Table 4 shows how both concrete and abstract features were carefully counterbalanced. Three different concrete features were included which allowed us to explore whether any were more salient than the others. In typically developing children color is generally preferred over size as a criterion for matching objects (Pitchford & Mullen, 2001). In order to group the stimuli according to color or size one only needs to attend to the immediately perceivable concrete characteristics of the book. This strategy could not be used to successfully sort by category membership because no single perceptual feature could be used to discriminate between sports and games. For example, not all pictures depicting sports included a ball, therefore one could not use a *ball present/ball absent* criterion to distinguish between the sports and games. If individuals with autism are less inclined to process information at an abstract level, we predict that they would instead use a strategy which relies on concrete features when sorting the stimuli. A further aim was to investigate whether individuals who initially failed to sort by category membership, would later sort according to sports and games when presented with books that were all the same size and color. Would those with autism who initially used a concrete strategy be able to shift to sorting according to an abstract criterion?

Method

Preparation of Stimuli

Wittgenstein (1953) famously used the concept *game* to argue against a rigid definitional model of category structure and for a more flexible account based on a complex network of similarity relationships. He argued that the numerous activities that we call games (e.g., board-games, card-games, etc.) had no single feature that was common to all but that people classified them together according to a criterion of *family resemblance*. Many current theories of categorization propose that the process of classifying an object as a member of a particular category requires comparing its similarity to other members of the category relative to members of alternative categories (e.g. Spalding & Murphy, 1996). Therefore, classification is easy if all exemplars of a category are similar to each other and dissimilar to other objects not in the category but harder if category members and non-category members are similar to each other.

With this in mind, we generated a list of sports and games and then obtained pictures from either clip art or the internet for each of the items. After considering the clarity of the pictures and the familiarity of the items we reduced the set to 24 (12 sports and 12 games) which are listed in Table 1. There were several advantages in selecting the categories of games and

Table 1 Mean ratings (in centimeters) of the sports and games stimuli

# Code in Fig. 1		Sport/game	Outdoor/indoor	Active/passive	Physical/mental
1	Scrabble	11.4	11.2	10.6	11.5
2	Connect-four	11.2	11.3	10.8	11.5
3	Chess	9.1	10.9	10.5	11.7
4	Jenga	11	10.6	9.7	7
5	Operation	11.4	11.7	9.9	8.1
6	Kerplunk	11.6	11.4	10.4	8.6
7	Rugby	2.1	0.1	0.2	1.5
8	Mousetrap	11.7	11.3	10.3	9.8
9	Monopoly	11.6	10.9	10.8	10.8
10	Cluedo	11.4	9.4	10.7	11.2
11	Draughts	10.9	10.3	10.6	11.2
12	Dominos	11.2	9.9	11	10.4
13	Tennis	3.6	3.1	0.5	3.1
14	Cards	10.4	9.6	9.1	10.9
15	Football	4.7	2.3	0.7	2
16	Sailing	0.8	0.1	1.7	2.7
17	Running	0.5	3.8	0.6	2.2
18	Cricket	4.1	3.3	2.4	2.8
19	Car-racing	1.9	1.7	4.2	5.1
20	Badminton	3.6	7.1	1.5	2.9
21	Volley-ball	4.2	4.4	1.2	2.3
22	Rowing	1	0.2	0.7	2.4
23	Hockey	3.1	3.6	1.4	2.7
24	Golf	3.2	0.4	4	4

Note: The numbers in the first column represent the game or sport they are adjacent to in Fig. 1.

sports for the current study. First, a wide range of sports and games are commonly known and are readily identifiable, most importantly by members of each of the three participant groups in this study. Previous studies have shown that individuals with autism have a good knowledge of various games and sports (Boser, Higgins, Fetherston, Preissler, & Gordon, 2002; Lewis & Boucher, 1991).

Second, one problem that arises when exploring preferences in sorting behaviour is that perceptual similarity can correlate with abstract properties of an object (Goswami, 1998). This problem was avoided in the current study because there was a substantial amount of within-category variation in regard to concrete features. Therefore, it was unlikely that individuals would sort sports and games according to the similarity of features in the pictures on a concrete level. However, the similarity structure of the two categories is strong enough on a number of abstract dimensions to allow correct discrimination of the category members.

To obtain some measure of the strength of this similarity structure, 28 adults with an average age of 16 years 10 months rated the 24 items on one of four salient attributes identified by the investigators; category label (sport or game), location (where it is typically played: outdoor or indoor), mode (active or passive), or activity (physical or mental). Individuals were asked to place a mark on a line which was 12 centimeters (cm) in length to indicate how they judged the item on each attribute. If a person marked the line at 0 cm on the sports/game dimension this would indicate they thought the item to be a sport, while a mark closer to 12 cm would suggest the item was more likely to be considered a game. Location, mode, and activity were considered to be attributes relevant to all items in the stimulus set that would reflect common dimensions upon which people typically thought about and discriminated between the items. The group was an opportunity sample consisting of 4 males and 24 females who visited the University of Nottingham during an open day. Participants were required to rate each item according to its membership of the two categories or in relation to its position between the opposite values of an attribute (8 rated according to category label, 7 location, 6 mode, 7 activity) by making a mark on a 12 cm horizontal line between the two attribute values.

Table 1 presents the mean rating for the 24 items for each of the four attributes. The mean value for the sports items was 2.73 cm (SD = 1.43) whereas for the games items it was 11.08 cm (SD = 0.72), indicating strong agreement between the raters as to the category membership of the items. Correlational analyses based on these averages revealed a significant relationship between the category label and the other three attributes (location, $r(22) = .94$, $P < .001$, mode, $r(22) = .95$, $P < .001$, activity, $r(22) = .91$, $P < .001$). To illustrate the coherence of the sport and game categories, Fig. 1 presents each of the 24 items plotted as a point in a 3D similarity space according to its values for the three other attributes. The 3D plot clearly illustrates the clustering of the sports in the bottom left corner of the space (representing values closer to the physical/outdoor/active end of the scale) and the games in the top right corner of the space (representing values closer to the mental/indoor/passive end of the scale. The graph and table indicate that the items selected are good examples of sports and games and also show that sports and games are coherent categories which can be easily distinguished according to a number of attributes.

Participants

Forty-four children with autism were tested. All had been formally diagnosed by experienced clinicians and met DSM-IV (American Psychiatric Association, 1994) criteria for autistic disorder. None were known to have a diagnosis co-morbid with any other disorder. Those with autistic disorder were matched on a group basis for chronological age (CA) and verbal ability with 45 children with mental retardation (MR). Individuals with MR were excluded if they were reported in their statements to have any autistic features or if they had a specific disorder of known etiology (e.g. aphasia, dyslexia, fragile-x). Children with autistic disorder and MR were recruited from specialist schools in the midlands region of England and North Wales. Typically developing children were recruited from Nottinghamshire. All three participant groups came from a middle socio-economic background. Children were tested in a familiar setting within their school and received candy for participation. Parental consent was obtained for all children who took part in the study.

The British Picture Vocabulary Scale (Dunn, Dunn, Whetton & Pintilie, 1982) was used to assess verbal mental age (VMA) in both clinical groups. This was an appropriate basis for matching to ensure that the two groups were similarly proficient in comprehending verbal annunciations of the names for different sports and games. Previous research has shown that typically developing children under age 5 sort visually (Gelman & Markman, 1986, 1987; Ropar & Mitchell, 2001). Therefore, seven individuals with autistic disorder who had a VMA lower than 5 years were excluded. These seven individuals either sorted visually or had severe difficulty understanding task demands. A further four individuals with autism and 11 with MR were excluded because they failed to understand the aim of the task or sort in a systematic way even when instructions were repeated. More information on how these individuals performed is provided in the sub-section on *Coding*. The details of the remaining 33 children with autism (29 males; 4 females), 34 with MR (25 males; 9 females), and 23 typically developing 8-year-olds (12 males; 11 females) are listed in Table 2. The mean chronological age of the MR group was 13 year 7 months and the VMA was 8 years 7 months. The mean CA of the autistic group was 12 years 11 months and the VMA was 8 years 6 months.

Stimuli

We created 24 books ostensibly about the sports and games listed in Table 1. Examples of the stimuli can be seen in Fig. 2. The books were all of the same general

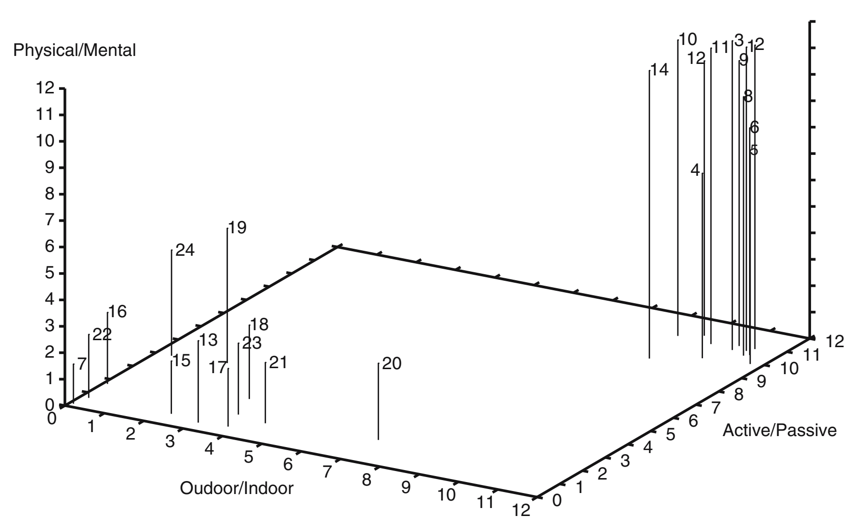

Fig. 1 Graph of mean ratings of the sports and games stimuli

Table 2 Details of participants

Group	CA (yrs;mos)	VMA (yrs;mos)
Autistic disorder (n = 33)		
Mean	12;11	8;6
SD	2;1	2;4
Range	9;11–16;10	5;6–14;1
MR (n = 34)		
Mean	13;7	8;7
SD	1;4	1;11
Range	10;3–15;8	5;6–13;7
Typical (n = 23)		
Mean	8;8	
SD	0;3	
Range	8;3–9;2	

type and were identical in thickness. Each had a colored picture on the cover to indicate what the book was about. The pictures varied in size from 7–12 cm in width and 9–13 cm in height. A label with the name of the sport or game was also displayed on the front of the book, printed in black ink on a white background. In addition to category membership (12 sports, 12 games), the books varied in size (12 large—29.5 × 20.5 cm; 12 small—22.5 × 17.5 cm), color (12 orange, 12 green), and whether people were present (12) or not present (12). These dimensions were carefully counterbalanced and any could have potentially been used as a criterion for sorting considering there was an equal number of each. The pictures depicting games and sports also varied in terms of background type. They either showed an indoor scene, an outdoor scene, or neither (e.g. badminton racquet and shuttlecock on blank background). These three different backgrounds were used mainly to detect whether anyone sorted according to type of background displayed on the book, however it was not possible for them sort the books into two groups of 12 using this strategy. Appendix table provides details of the characteristics of each book. Two brown cardboard boxes were provided for participants to sort the books into (both 32 × 22 × 7.5 cm).

Procedure

Before each participant entered the room the experimenter mixed up the books on the floor with all the pictures face-side up. When the participant entered the room he or she was told the following: "Look, we have a bunch of books here. Let's read the names written on them to see what each book is about." This was done in order to ensure that participants were able to recognize the content of the book from the label and picture. If the child had difficulty reading any of the labels the experimenter read it aloud. Afterwards the experimenter told the child the following: "There are two kinds of books here which have been mixed up. Half of the books are about one thing and half are about something else. I want you to sort the books into these two boxes for me. So 12 go together in one box and 12 go together in the other. Go ahead now and begin". This wording was formulated as it did not explicitly provide children with the

Fig. 2 Examples of stimuli

criterion for sorting according to sports and games, although participants were told that the books were about different things. After children had finished they were asked how they sorted the books to confirm the strategy they used.

Coding

Any individuals who failed to follow or understand the task instructions, even when repeated, were excluded from the data. Excluded individuals either failed to respond or sort the books into two groups of 12, or sorted inconsistently with their stated criterion. Participants were judged to have systematically sorted according to a particular criterion if he or she sorted 11 of the 12 books in each group consistently according to the strategy they stated. The experimenter noted the sorting strategy used by the participant and whether any books were not placed in the appropriate group. If an individual used a criterion other than color, size, or category membership then specific details about which books were grouped together were recorded. These details were then checked later to see if the sorting strategy used by the individual was consistently applied when sorting the books. If their strategy was sensible and consistently applied, they would be included in the analyzed sample.

Results

Eleven individuals with MR and four individuals with autism were excluded from the data set for the following reasons: one individual with MR and one with autism did not respond at all, three with MR and one with autism did not sort books into two equal groups of 12 and also failed to sort consistently according to a criterion, seven individuals with MR and two with autism sorted books into two groups of 12, but did not sort systematically according to a specified criterion. Importantly, only five of the 15 excluded individuals (four MR, one with autism) suggested alternative criteria such as *ball/no ball* or *team activity/no team*. However, their sorting behavior was not consistent with their chosen strategy. Thus, it seems that the alternative explanation offered for how they sorted was post-hoc rather than used to guide behavior.

All participants with typical development sorted by category membership but the two clinical groups used a mixture of strategies. Chi-square analyses confirmed that participants with typical development were significantly more likely to sort by category membership than both clinical groups: MR χ^2 (corrected, 1, $n = 57$) = 5.04, $P < .05$), autistic disorder χ^2 (corrected, 1, $n = 56$) = 21.49, $P < .001$). Comparisons between the two clinical groups revealed that those with autism sorted significantly less by category membership than participants with MR: χ^2 (corrected, 1, $n = 67$) = 11.02, $P < .001$). Because all participants with typical development sorted by category, only differences in sorting preferences within the clinical groups are illustrated in Fig. 3 which displays the percentage of individuals using each strategy. Of those who did not sort by category membership, the majority sorted by color: χ^2 (corrected, 1, $n = 67$) = 25.04, $P < .001$.

Although some participants had difficulty pronouncing a few of the labels on the books (see Table 3), there was no difference between groups in terms of the proportion of individuals who needed assistance in reading one or more words: χ^2 (corrected, 1, $n = 67$) = .26, n.s. If having difficulty reading the labels had an influence on sorting then we would expect a correlation between the number of errors made and the strategy used. Specifically, we might expect those who had the most difficulty reading to be those who relied on a concrete strategy. However, a point biserial correlation did not detect a significant relationship between the number of errors made and the sorting strategy applied: $r(65) = .17$, n.s., and neither was it possible to detect such a relationship when analyses were conducted on the two clinical groups independently. Further correlational analyses were carried out between CA, VMA, and strategy choice for the two groups of clinical participants combined and also independently. These revealed that CA did not significantly correlate with strategy selection, although those with lower VMA tended to sort the books according to concrete criteria: $r(67) = -.45$, $P < .001$ for clinical groups combined (significant correlations also emerged for the two clinical groups independently).

A stepwise multiple regression analysis was conducted using a forward inclusion procedure in order to

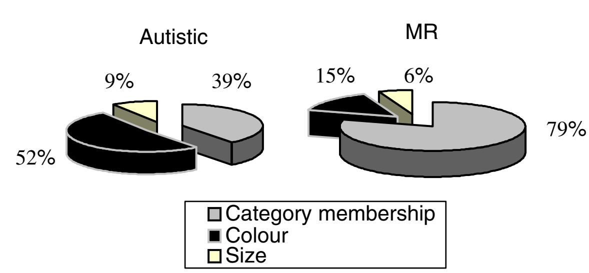

Fig. 3 Pie charts displaying the percentage of different strategies used in the MR and autistic groups

Table 3 The number of labels individuals required assistance with in each clinical group

	No help needed	1–3 labels	4–6 labels	7–9 labels	10–12 labels	20–22 labels
Autistic (n = 33)	12	14	2	1	3	1
MR (n = 34)	7	10	11	2	2	2

determine whether diagnosis predicted sorting independently of VMA. CA was entered in the first step: $R^2 = .00$. VMA was entered in the second step to see if verbal ability could predict performance independently of CA. The R^2 increased to .21 which reflected a significant change: $F(1,64) = 16.48$, $P < .01$. In the third step diagnosis was entered which resulted in a significant increase in ''explained'' variance: $R^2 = .38$, $F(1,63) = 17.35$, $P < .01$. These results indicate that diagnosis predicts sorting strategy independently of VMA.

On discovering that a relatively large number of children with autism used color as a basis for sorting, we investigated whether they would successfully use category membership if offered a second attempt at sorting with books that were uniform in color and size. This second set of 24 books was created with the same pictures and labels as the stimuli used previously, except they were all the same color (blue) and size (20.2×16 cm).

We had an opportunity to test this new set with nine participants in the sample with autism who initially sorted by color. To increase the sample size further, seven more individuals with autism were tested, all of whom sorted according to a concrete criterion in their first attempt. These seven individuals were recruited in the same way, and had a similar socio-economic background as those with autism in the original sample. Together all 16 (12 males; 4 females) had a mean CA of 12 years and mean VMA of 7 years 5 months. Participants were presented with the second set of books and told, ''Now I want you to sort these books...'' followed by repetition of instructions that accompanied presentation of the first set of books.

Three individuals did not need any assistance with reading the 24 labels, five needed help with 1 or 2, another five required help with 4 or 5, and 3 were helped with 11–12 of the words. In regards to how the books were categorized when color and size were held constant, eight of the 16 participants with autism sorted according to category without any further prompting, five sorted randomly, and three attempted to sort by differences in concrete properties which were no longer present (e.g. the color that the books had been in the first attempt at sorting). When presented with each book individually and asked to judge whether it was a sport or game, all but one person with autism did so with 100% accuracy. The remaining individual did not correctly classify sailing and rowing as sports, but was correct otherwise. Therefore, all 16 individuals who initially sorted according to a concrete criterion, showed no serious difficulties with understanding which activities were sports and which were games.

Discussion

Consistent with our predictions, individuals with autism were more likely to use a concrete than an abstract strategy to sort the books. This contrasts with typically developing children and those with mental retardation who preferred to sort according to category membership. It seems there is a bias to attend to concrete details in autism rather than information which can be understood on an abstract level. These results are consistent with Weeks and Hobson's (1987) finding that a concrete feature (hat type) is preferred to a criterion that has more of an abstract relevance (facial expression) when sorting photographs.

On the basis of Weeks and Hobson's (1987) results, it would be tempting to conclude that individuals with autism lack a preference specifically for processing information that is relevant to abstract interpersonal criteria (e.g. facial expressions and how they relate to emotions). However, our results suggest that individuals with autism might also lack a preference for processing representational information that lie outside the interpersonal domain.

Before any broader implications of these findings are discussed, we must consider whether any factors specific to our study might account for the pattern of results. One element that we positively identified as being involved in sorting preference was verbal ability. Those with higher verbal ability were more likely to sort by category membership than those with lower verbal ability. The converse, which is that individuals with low verbal ability tended to sort according to a concrete criterion, is consistent with a finding reported by Ropar and Mitchell (2001). In that study, participants with low VMA were likely to match a blue banana with a blue patch of color, whereas participants with higher VMA tended to match a blue banana with a yellow patch of color. The results of the current study are notable in this context because participants with autism were more likely to use a concrete strategy than comparison participants, even after variance associated with VMA (and CA) had statistically been taken into consideration. This raises the possibility that sorting by concrete features might not be the result of developmental delay in autism as this was not confined to the younger and/or less verbally able individuals with autism.

Even though verbal ability was not sufficient to explain why those with autism sorted according to concrete features, one might still argue that difficulty reading the labels displayed on the books could have influenced their behavior. If their knowledge about the ostensible content of the book was restricted, this may have forced them to resort to a concrete strategy. This explanation, however, seems unlikely for several reasons. The labels were additional information to the pictures which clearly depicted a game or sport. Thus, it was not necessary for individuals to use the labels to sort the books given that they could identify the category from the picture. Besides, many participants in the MR group needed assistance with reading the labels, yet they still preferred to sort according to category membership. Furthermore, analyses confirmed that there was no relationship between assistance required to read labels and strategy used, which means that choosing an abstract criterion for sorting was equally likely for those who independently read the book labels as those who did not.

Another possibility we need to consider is whether the open-ended nature of the task simply confused individuals with autism, preventing them from sorting by category membership. If this were the case we would have expected them to make an unsystematic response rather than using a concrete strategy which was a perfectly plausible option. In fact, more individuals with MR (11) than individuals with autism (4) performed in this way. Nonetheless, it is interesting to consider why attention in autism is not drawn to abstract aspects of stimuli in open-ended tasks.

While category membership is multi-dimensional and requires one to integrate various attributes (e.g. location, mode and activity level), color and size are uni-dimensional properties. Arguably then, the process of identifying similarities and differences across sports and games is more complex and would require more time. Furthermore, the concrete features are dichotomous and make it easy for an individual to apply a simple rule to guide sorting. A rule could not be generated to discriminate between sports and games because the categories are formed according to family resemblance. Therefore, sorting by concrete features might reflect a manner of processing in autism which is less demanding. This interpretation does not imply a deficit in forming more complex abstract categories, but suggests it may be more cognitively taxing. Categories which are abstract but can be easily identified using a rule (living vs. non-living) may be easy to sort, and require no more processing effort than to sort according to a concrete criterion such as color. Klinger and Dawson (1995) found evidence that individuals with autism (and with Down's Syndrome) were able to use a rule to categorize novel stimuli but had difficulty using an abstract criterion.

Future research needs to see if a concrete strategy (e.g. based on color) is also preferred to an abstract strategy where a rule based strategy can be applied for sorting items into two categories (e.g. living/non-living). If individuals with autism still use a concrete strategy, then this suggests they do indeed have a bias to process concrete properties of stimuli rather than abstract features. On the other hand if a substantially greater number of individuals with autism sort by category which can be defined by a rule, this would point towards a neglect of abstract information specifically when more complex, multi-dimensional concepts are involved, as in categorization by family resemblance.

If dichotomous, uni-dimensional features are more straightforward to identify, it is interesting that individuals without autism in our study nevertheless chose to sort by category membership. It could be that sorting by category membership is just as easy as sorting by concrete features. However, we should then have found an approximately equal number of individuals using each of the two strategies. It seems that abstract information has a special relevance to those without autism but not those with autism. The question then, is what causes this?

As mentioned earlier, there is little evidence to suggest individuals with autism have a deficit which makes them *incapable* of processing abstract information (Baron-Cohen, 1991; Ropar & Mitchell, 2001; Tager-Flusberg, 1985a, b; Weeks & Hobson, 1987). Furthermore, our findings demonstrate that individuals with autism can sort by sports and games when explicitly requested to do so. Therefore, sorting the items primarily by color in the current study suggests a preference for processing concrete over abstract features. Rather than this preference simply being arbitrary, it is more likely to be the result of a cognitive weakness which can lead to a cognitive preference.

Alternatively, it might be that any preference to process information that is relevant to abstract criteria is masked by an inability to disengage attention from the more concrete properties of the stimuli (cf. Hughes & Russell, 1993; Ozonoff, Pennington & Rogers, 1991; Russell, Mauthner, Sharpe & Tisdwell, 1991), especially their color (cf. Pitchford & Mullen, 2001). If the "masking explanation" is correct, then future research might identify an association between a lack of preference for sorting by an abstract criterion and signs of executive dysfunction. Indeed, perhaps those with autism who sorted by category membership had less severe executive impairment than those who sorted according to a concrete criterion. Indeed, it might be that having autism interacts with having executive dysfunction in militating against using an abstract criterion for sorting (cf. Rajendran, Mitchell & Rickards, 2005).

In summary, the current findings suggest that some individuals with autism prefer to sort according to concrete features rather than on the basis of abstract criteria. Importantly, the preference for concrete features observed in the autistic group was evident in a non-social domain which extends previous research (Weeks & Hobson, 1987). Future research might fruitfully focus on the cause and extent of this preference for concrete over abstract properties.

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Appendix Table Characteristics of books

Label/picture	Category	Color	Size	Person/ no person	Outdoor/ indoor/neither
Rugby	Game	Green	Small	Person	Outdoor
Chess	Game	Green	Small	Person	Indoor
Connect-four	Game	Green	Small	No person	Neither
Kerplunk	Game	Green	Large	Person	Indoor
Draughts	Game	Green	Large	No person	Neither
Mousetrap	Game	Green	Large	No person	Neither
Monopoly	Game	Orange	Small	Person	Indoor
Cluedo	Game	Orange	Small	No person	Neither
Dominos	Game	Orange	Small	No person	Neither
Scrabble	Game	Orange	Large	Person	Indoor
Jenga	Game	Orange	Large	No person	Neither
Operation	Game	Orange	Large	Person	Indoor
	12 games	6 green 6 orange	6 small 6 large	6 person 6 no person	1 outdoor 5 indoor 6 neither
Cards	Sport	Green	Small	Person	Outdoor
Cricket	Sport	Green	Small	Person	Outdoor
Sailing	Sport	Green	Small	No person	Outdoor
Tennis	Sport	Green	Large	Person	Neither
Football	Sport	Green	Large	No person	Neither
Badminton	Sport	Green	Large	No person	Neither
Volley-ball	Sport	Orange	Small	Person	Indoor
Car-racing	Sport	Orange	Small	No person	Outdoor
Golf	Sport	Orange	Small	No person	Neither
Running	Sport	Orange	Large	Person	Outdoor
Hockey	Sport	Orange	Large	No person	Neither
Rowing	Sport	Orange	Large	Person	Outdoor
	12 sports	6 green 6 orange	6 small 6 large	6 person 6 no person	6 outdoor 1 indoor 5 neither

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