The Impact of Autism Spectrum Disorder on the Categorisation of External Representations

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Abstract

The knowledge structures and reasoning processes that underlie the use of external representations (ERs) in individuals with autism spectrum disorder (ASD) are not well understood. This paper compares the organisation of knowledge of ERs in young people with a diagnosis of ASD and an age-matched typically developing control group. ASD and non-ASD participants (twenty-eight in each group) were given an untimed ER card-sorting task. The ERs were based on representations used in educational software, for example graphs, charts, and text. Cluster analysis of the card sort task revealed similar clusters for both groups: maps, drawings, text, graphs and charts, and network and tree diagrams. However, comparison of the card sorts of the two different groups showed a difference in 'basic level' categories. While in the non-ASD group, maps and non-maps were the most distinctive category, analysis of the ASD cluster revealed, in addition, another 'basic level' category of textual representations. These results are discussed in relation to theories of information processing in autism. Our ultimate research aim is to develop educational software tailored to the specific needs of users with ASD. We wish to use our research results to inform requirements for the development of such educational software, in which ERs are able to support differences in information processing for individuals with ASD.

Keywords: Autism Spectrum Disorder (ASD); external representations; categorisation; organisation.

Introduction

To investigate aspects of knowledge of external representations (ERs) which influence their usability, we examined the clustering of ERs by young people with and without autism spectrum disorder (ASD).

As more children are diagnosed with ASD, there is a need to develop software (particularly the user interface) that takes into account the specific needs of individuals affected by ASD. Current estimates suggest that 1% of the population have a diagnosis of ASD, which includes autism and Asperger's Syndrome (Baird et al., 2006). The characteristics that are associated with ASD include impairments in social reciprocity and language development, restricted (obsessional) interests, and repetitive behaviour (Diagnostic and Statistical Manual of Mental Disorders, 2000).

In order to inform the design criteria for effective and efficient user interfaces for those with ASD, particularly their textual and visual aspects, we were interested to explore how the differences in cognitive abilities in individuals with ASD impacted upon the usability of ERs. Here, ERs are defined as representations, used in educational software and diagrammatic reasoning, including graphs, charts, text, drawings, maps, network diagrams and tree diagrams.

Research has shown that ASD is related to an imbalance in cognitive abilities. For example, Minshew and Goldstein (2001) have shown that individuals with ASD have relatively weaker language skills. In contrast, other studies have reported that spatial cognition in ASD might be intact or even superior to that of individuals without ASD (Kamio and Toichi, 2000; Caron et al., 2004). This implies that spatial reasoning within ASD might be preferred, and of higher utility.

Research indicates that individuals with ASD might represent information internally in different ways to those without ASD, in order to compensate for certain impaired brain areas (Jolliffe and Baron-Cohen, 2001). The difference in how information is internally represented might impact the way information is processed. For example, Mottron et al. (2006) describe how individuals with ASD may process and perceive visual information differently, based upon a different organisation of the visual regions of the brain.

Matessa (2008) proposes a cognitive model in which the reduced declarative function associated with ASD is compensated by a 'visual module', where for example, mental imagery processing is used for sentence comprehension (e.g. Grandin, 1995; Kana et al., 2006). As described by Kunda and Goel (2008), the bias towards visual processing in individuals with ASD may explain differences in cognition.

The above research in ASD might imply that weaker language skills and a deficit in text processing in ASD might be a result of a lack of declarative processing which is not fully compensated by visual processing. If this is the case, user interface design for ASD individuals needs to accommodate this difference. In particular, ERs need to be developed which support and enhance visual processing of text, implying that interfaces for individuals with ASD should be guided by specific requirements. These may differ to those aimed at individuals without ASD.

This paper reports the results of an ER card sort study, focusing on a number of relevant issues: participants' perception of similarity and dissimilarity of ERs; the level of difficulty in understanding different ERs reported by participants; and their preferences for different types of ERs. These issues will be discussed in respect to differences in information processing in ASD and non-ASD individuals.

Hypotheses

Our research aim is to investigate differences in the effectiveness and efficiency of ERs between young people with and without ASD. Specifically, we explore the following three hypotheses:

Hypothesis 1:
Young people with and without ASD will show discernable differences on the perception of similarity and dissimilarity of ERs. Individuals with ASD will perceive the visual features of textual representations, reflecting a bias towards visual processing, whereas individuals without ASD will perceive text in ways that reflects declarative processing.

Hypothesis 2:
For young people with ASD the perception of how easy or difficult an ER is to understand will depend on how far the ER supports visual processing. The perception of individuals without ASD will be less dependant on the ERs ability to enable visual processing.

Hypothesis 3:
Young people with ASD will show a strong preference for ERs that enhance spatial reasoning, whereas ERs that restrain visual processing will be least preferred. These preferences will be different or less distinctive in individuals without ASD.

To address these hypotheses we conducted an ER card sort task. By means of this task, participants' perception of similarity and dissimilarity of ERs and their ER knowledge structure can be made explicit. Card sorts have been used as a technique for eliciting and structuring expert knowledge (e.g. Schreiber et al, 1999). Using card sorts, Minshew et al. (2002) suggest that there are differences in category formation in ASD.

Methodology

Participants

The study involved 28 high-functioning young people with ASD (24 male; 4 female) aged between 11-15; and 28 young people without ASD (18 male; 10 female) aged between 11-14.

The groups were matched on age, mathematical ability (according to the UK maths curriculum years 7-9, Key Stage 3), and verbal ability (Wechsler Abbreviated Scale of Intelligence).

Each group was enrolled (respectively) in specialist and non-specialist schools, in years 7, 8 and 9 of the UK curriculum. Every effort was made to include schools that were of a similar socioeconomic status. All schools were urban and non-faith. Additionally, neither of the schools were fee paying nor impoverished schools.

Design and materials

Participants' knowledge of ERs (their view of which ERs were similar and belonged together) was assessed by a card sort task.

The ER stimuli were based on a card sort task developed by Cox and Grawemeyer (2003) and Cox et al. (2004), who examined ER clustering by typical adults. For the study reported in this paper, the original ER stimuli were adapted in view of participants' younger age range. The types of ERs deployed as stimuli were based on ERs used within educational software and diagrammatic reasoning for young people between 11 and 15 years of age. Additionally, the number of cards was limited to 40, as it was found that the time spent to sort and organise a higher number would be too great for young people.

Figure 1 shows examples of the ER stimuli that were used in this study.

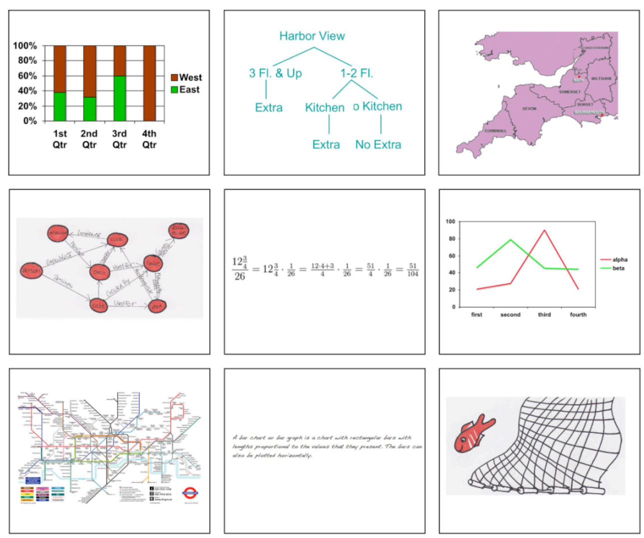

Figure 1: ER examples used in the card sort task (40 stimuli in total)

Each ER was mounted on a 12.5cm by 7.5cm white card that was numbered on the reverse.

The 40 cards utilised different representations that were primarily used for educational purposes and in educational software, carefully chosen for use in this study. The ERs included graphs, charts, text, mathematical notations, drawings, maps, network diagrams and tree diagrams. The primary aim was to see how the cards were classified and distinguished by the two populations.

Tasks

For each participant the 40 cards were shuffled and presented in a random order. Participants were instructed: "*Here is a stack of representations. I would like you to sort them into different piles, each representing a particular category. You decide on what the categories are, and how many. I would like you to label your categories when you have finished. After you have given each of your piles a name I would like you to write down a number from 1 to 10 of how easy it is to understand the category. 1 is easy to understand and 10 is difficult to understand.*"

In order to identify preferences for particular ER types, participants were asked, at the end of the session: "*Which out of the cards did you like the most and why. Which one did you like the least and why.*"

Data collection

The clusters participants created were recorded along with the cluster's name, as well as the representations in each cluster (using the relevant card number from reverse). Additionally, participants' ratings of how easily the ERs within a cluster could be understood, and the most and least liked ER, were also noted.

Results

ER cluster analysis

From participants' card sorts a similarity matrix for each group was created, which was then input to the SPSS CLUSTER procedure to produce a hierarchical cluster analysis.

One participant from the ASD group was excluded from the analysis, as s/he created only one cluster, justifying each ER with his/her own reason why it should belong to the cluster, which kept changing as s/he went through the pile of cards.

Figure 2 shows the resulting dendrograms from the analysis ('Rescaled Distance Cluster Combined') for the ASD and non-ASD groups, respectively. The dendrograms represent the result of applying complete linkage clustering (agglomerative clustering) to a set of individual items. The clusters are arranged hierarchically with single clusters at the root and individual items at the leaves. The horizontal scale (scaled distance) indicates the distance between the clusters being merged. For example, for both groups map and non-map clusters are 25 units apart.

It can be seen that, overall, both groups showed similar clusters: maps, drawings, text, graphs and charts, and network and tree diagrams. However, looking at the clusters at the scaled distance of 15, it can be seen that for the ASD group the major clusters were: 1. Maps; 2. Text, 3. Drawings, graphs, charts, network diagrams and tree diagrams. In contrast the non-ASD clusters were: 1. Maps, 2. Drawings, text, graphs, charts, network diagrams and tree diagrams. For the ASD group text and non-text clusters were just under 20 units apart, whereas those clusters were only around 7 units apart within the non-ASD group.

Also, the ASD group clustered maths notations with network/tree diagrams and graphs and charts. This contrasts with the non-ASD group, which includes maths with textual representations.

However, in both groups drawings and non-drawings clusters were between 10 and 15 units apart, whereas the remainder of the clusters (network and tree diagrams, as well as graphs and charts) in both groups showed a scaled distance close to 5 units or lower, which included the text/math cluster distinction within the non-ASD group at a distance of around 7 units.

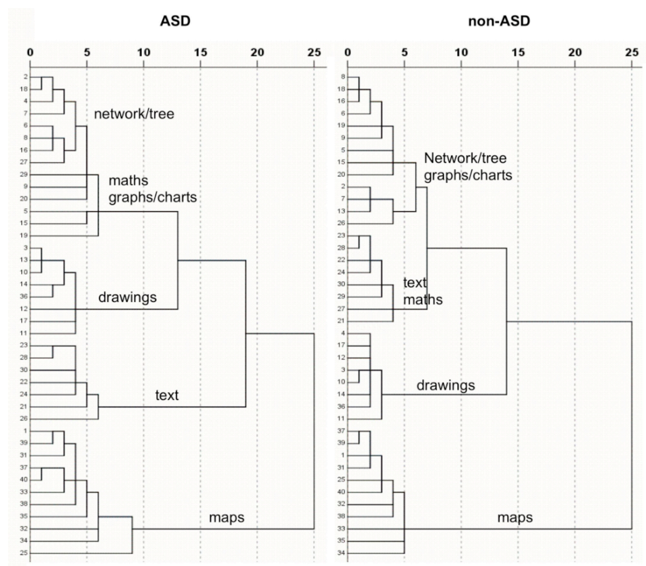

Figure 2: Dendrograms of participants' ER clusters for the ASD group (left), and the non-ASD group (right).

Rating of ER types

Looking at the individual representations that participants clustered together, and the ratings of how difficult participants thought the clusters were to understand (where 1 is easy and 10 is difficult), Table 1 shows means, standard deviations and medians of clusters that include the different representation types[1].

On average, both groups rated clusters that included maps similarly, as the easiest to understand. They also rated textual representations and mathematical notations similarly: as the most difficult to understand.

However, a difference between the groups can be seen in how graphs and charts were perceived. The ASD group perceived those representations easier to understand than the non-ASD group.

[1] Please note that the representation types are not the different clusters participants created.

Table 1: Participants' rating of clusters that include the different ER types.

ER type	ASD			Non-ASD		
	Mean	SD	Median	Mean	SD	Median
Maps	3.80	2.75	3.00	3.71	2.44	3.00
Graphs and charts	4.25	2.96	3.50	4.66	2.06	5.00
Trees and networks	4.45	2.92	5.00	4.67	2.13	5.00
Text	4.72	3.04	5.00	4.96	2.46	5.00
Maths	4.77	3.28	4.00	4.71	2.58	5.00
Drawings	4.30	2.84	4.00	4.06	2.40	4.00

Preferences

Participants were asked to identify an ER that they liked most and one they liked least out of the 40 stimuli, and to give a reason why. During this task, 5 participants within the ASD group were unable to identify a preferred ER. Also, one participant within the non-ASD and 6 participants in the ASD group failed to identify a representation that they liked least.

Figure 3 shows the categories of the preferred ERs. It is interesting to see that both groups preferred maps most (11 out of 23 within ASD; 12 out of 28 within non-ASD).

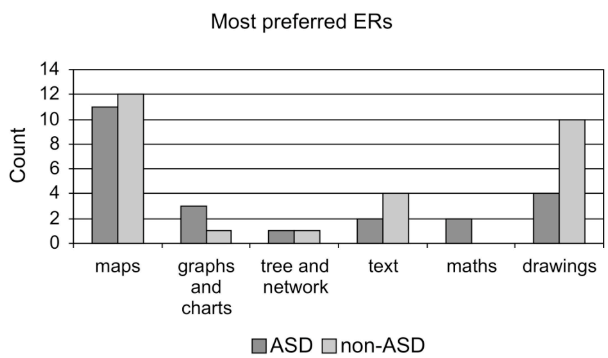

Figure 3: Most preferred representation types.

Within both groups, participants expressed preferences across the different ER types. Remarkably, no participant of the non-ASD group expressed a preference for an ER that included mathematical notations.

Figure 4 shows the least preferred representations for the ASD and non-ASD group. While the ASD group preferred text least (7 out of 22), the non-ASD group mainly disliked mathematical notations (8 out of 27).

Turning to the distribution of the least and most preferred ERs, 4 out of the 7 participants in the ASD group that preferred text the least, preferred maps the most. In contrast, in the non-ASD group, 5 out of 6 participants who preferred text least, preferred drawings the most.

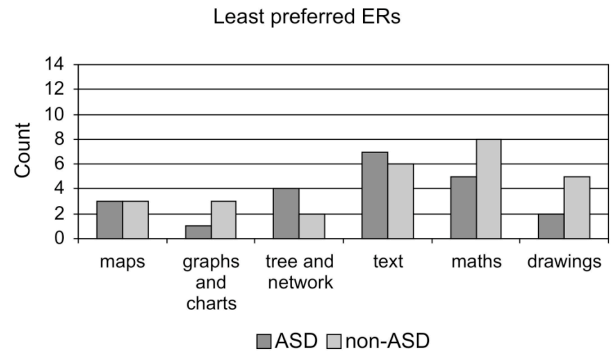

Figure 4: Least preferred representation types.

The explanations given by participants as to why they preferred a particular representation included, for example this from a participant in the ASD group: "I like this map, because it is a picture of Cornwall, where I go on holiday". An explanation given by a participant in the non-ASD group was: "I like this drawing, it is like a picture – easy to understand". The explanations given for least preferred ERs included, for example from a participant in the ASD group regarding a textual representation: "Looks really boring and complicated." Another comment from the ASD group was: "don't like English". Comments from participants without ASD regarding maths included: "I don't like maths" or that representation "looks complicated".

Discussion

The results indicate that high-functioning young people with ASD share many similarities to young people without ASD. We discuss possible explanations for our findings below.

ER clusters

In respect of our first hypothesis that there will be discernable differences in the perception of similarity and dissimilarity of ERs (especially for text) between participants with and without ASD, the difference between the groups was supported to some extent.

The clearest top level distinction for both groups was maps. Maps can be seen as the most spatial type of ER and have been identified as a 'basic level' ER category in Cox and Grawemeyer (2003). Rosch (1978) suggests that from an early age 'basic level' categories are formed, which are the most distinctive. Maps are isomorphic with the real world and of different levels of categorical structure. The comprehension of maps seems to be natural and is required early in life as described by Liben (2001).

However, the results of the cluster analysis also showed that the ASD group distinguishes textual representations differently to the non-ASD group. While the text cluster of the non-ASD group is less distinct from other clusters, the ASD group clearly separates text from other ERs. For the ASD group, textual representations – after maps - form a distinct cluster at the high level branching factor, which means that text and non-text clusters were perceived to be highly dissimilar.

Some of the textual representations referred to the main visual ER stimuli categories, such as, a textual description of bar charts, or some text fragments that refer to networks. The non-ASD group clustering shows a less clear distinction between the textual representations and graphs/charts or tree/network diagrams clusters. However, for ASD participants there is a clear distinction of textual representations, which suggests a further categorisation at the 'basic level' (in Rosch's 1978 terms).

A different organisation of certain brain regions within ASD (e.g. Mottron et al., 2006) may imply that individuals with ASD perceive textual information as a distinctive visual category rather than a linguistic category. This may also explain why mathematical notations were semantically clustered with graphs and charts. In contrast, the non-ASD group formed a linguistic category that included maths and textual representations, presumably based on superficial features as opposed to deeper meaning.

A visual instead of a linguistic text category might underpin a bias towards visual processing in individuals with ASD (Kunda and Goel, 2008) and/or the use of mental imagery for sentence processing (Grandin, 1995; Kana et al., 2006).

Rating of ER types

According to our second hypothesis, we expected to see differences between the groups in the perception of how easy or difficult ERs were to understand according to the ERs ability to enable visual processing. This difference was less than expected.

Both groups rated high and low spatial ERs in similar ways. Participants from the ASD and the non-ASD group rated maps (high spatial) as the easiest to understand. As described in Cox and Grawemeyer (2003) maps are isomorphic with the real world. They are not as metaphorical as other ERs, for example, a bar chart, where the length of the bars act as a metaphor for the values they present. This might explain why both groups rated clusters that contained maps as the easiest of the different ER types to understand.

Additionally, both groups rated clusters that contained text as one of the most difficult to understand. For individuals with and without ASD, processing textual information seems to be more difficult than processing graphical information. However, this depends on whether participants' introspections are accurate. A better indication might be derived by gathering ER reasoning performance measures, rather than subjective self reports

A difference between the groups was found in how graphs and charts were perceived. Participants from the ASD group seem to perceive those representations easier to understand than participants from the non-ASD group, who rated clusters that contained graphs and charts as one of the most difficult to understand. This supports our hypothesis that participants with ASD will find ERs that enable visual information processing easier then participants without ASD.

Preferences

In our third hypothesis we expected differences in ER preferences based upon how the ER would enable information processing. Here also, the difference between the groups was much less marked than expected.

Both groups preferred maps. Maps can be seen as one of the most spatial types of ER. As predicted individuals with ASD preferred highly spatial ERs. This was also true for participants in the non-ASD group.

The ASD group rated mainly text and the non-ASD group rated mainly maths as the least preferred ER. Here also, participants from the ASD as well as the non-ASD group disliked low spatial ERs the least.

It was interesting to see that within both groups a dislike of a low spatial ER seems to relate to a preference of highly spatial ERs, such as maps or drawings.

Garcia-Garcia and Cox (2008) describe how graphs and charts were more commonly used in the UK national curriculum than maps. Out of the ERs used within the card sort, tree and network diagrams were encountered the least in educational material. There does not seem to be a link between the frequency of particular ERs within educational material and ER preferences.

Conclusion and Future work

The research presented in this paper is part of a process by which the assessment of ASD and non-ASD capabilities will lead into the design of educational software, specifically design principles for user interfaces for different populations, in this case ASD user groups.

A positive finding from our investigation was that high-functioning young people with ASD were similar in many ways to young people without ASD. Both groups identified 'maps' as the clearest top level distinction, which confirms the result of Cox and Grawemeyer (2003), who identified maps as a 'basic level' ER category. The difference between the groups in how text was clustered might reflect the impairments of cognitive abilities within ASD.

The results of this study will enable us to design educational software that is tailored to young people with ASD. The detection of participants' ER classification and preferences will help us to create user interfaces that reflect children's wishes, which might enhance learning outcomes. The results could help not only in supporting an individual's learning, but also in providing easier forms of interactions, which are tailor-made rather than the same for everyone. Additionally, to cater for strength in visual processing, educational software should also at some stage address weakness with text.

The next step in our research is therefore to investigate how user interfaces could be adapted to the special needs of the ASD population, based upon the differences in information processing we have discussed. This will include the detection of preferences for ERs via a computerised environment.

Finally, further research is needed to delineate the differences between individuals with and without ASD, in terms of category formation, category assignment, identification of concepts, identification of instances of category members and the overlap between categories.

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