Cambridge Educational Research e-Journal

ISSN: 2634-9876 Journal homepage: http://cerj.educ.cam.ac.uk

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To cite this article:

Bailey, J., Parsons, O. E., Baron-Cohen, S., & Baker, S. T. (2022). A Pilot Study of Autistic and Non-Autistic Adults’ Systemizing in a Learning Task Using Observational Measures of Attention, Misunderstanding, and Reasoning. Cambridge Educational Research e-Jounal, 9, 1-16. https://doi.org/10.17863/CAM.90555

Cambridge Educational Research e-Journal | Vol. 9 | 2022

DOI: https://doi.org/10.17863/CAM.90555

A Pilot Study of Autistic and Non-Autistic Adults' Systemizing in a Learning Task Using Observational Measures of Attention, Misunderstanding, and Reasoning

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ABSTRACT

This pilot study compared autistic (N = 15) and non-autistic (N = 19) adults in a systemizing (physics reasoning) task using observational measures of attention, reasoning, and communication. Autistic adults mentioned more non-salient details (autistic; M = 4.43, non-autistic; M = 0.89) and had a greater ratio of attention to non-social versus social stimuli (autistic; M = 5.70, non-autistic; M = 3.27). Misunderstandings were more frequent (autistic; M = 2.07, non-autistic; M = 0.47) and longer (autistic; M = 64.63 seconds, non-autistic; M = 5.89 seconds) for autistic adults. However, the form of reasoning employed in the task was similar for both groups. The results suggest that the autistic adults experienced the task differently and had more difficulties. Implications for inclusive educational environments are discussed. This pilot study is presented to encourage a larger scale study using these novel methods.

KEYWORDS

autism, attention, reasoning, misunderstanding, systemizing, physics

ACKNOWLEDGEMENTS

The authors thank Professor Michelle Ellefson for input on earlier versions of this work and Michaela Herriett for additional coding. Funding for this work was provided by a Cambridge Humanities Research Grant. SBC received funding from the Wellcome Trust 214322\Z\18\Z. For the purpose of Open Access, the author has applied a CC BY public copyright licence to any Author Accepted Manuscript version arising from this submission. The results leading to this publication have received funding from the Innovative Medicines Initiative 2 Joint Undertaking under grant agreement No 777394 for the project AIMS-2-TRIALS. This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation programme and EFPIA and AUTISM SPEAKS, Autistica, SFARI. SBC also received funding from the Autism Centre of Excellence, SFARI, the Templeton World Charitable Fund, the MRC, and the NIHR Cambridge Biomedical Research Centre. The research was supported by the National Institute for Health Research (NIHR) Applied Research Collaboration East of England. Any views expressed are those of the authors and not necessarily those of the funder.

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Autism is a neurodevelopmental condition associated with difficulties in sensory processing, cognitive flexibility, and social interaction (American Psychiatric Association, 2013; Fletcher-Watson & Happé, 2019). Autism is associated with poorer educational outcomes for autistic student, both in terms of academic achievement (Estes et al., 2011) and wellbeing (Ambler et al., 2015; Griffiths et al., 2019; Hannah & Topping, 2012; McLeod et al., 2021). However, the extent to which autistic students experience difficulties with individual learning tasks is still largely unknown. Whilst previous studies have identified differences in specific cognitive processes, the ways in which these differences express in a complex learning task needs further exploration. This study gives new insights into the experience of autistic individuals in a simulated learning task and develops measures that can be taken into the classroom to further explore the learning experience of autistic children, adolescents, and adults through observation.

Educational challenges facing autistic pupils and students include bullying (Ashburner et al., 2019), anxiety (National Autistic Society, 2017), higher rates of exclusion (Brede et al., 2017), and lower levels of participation in higher education (Sarrett, 2018). Increasing teachers' knowledge and understanding of the experience of autistic young people is a priority for autism research (Pellicano et al., 2014). Whilst the growing body of research exploring the perspective of autistic pupils and students is extremely important (Howard et al., 2019), a more complete understanding comes from complementing these findings with observational methods which pay attention to the frequency of differences and difficulties in specific learning contexts.

Understanding differences in the ways that autistic individuals experience and think about learning tasks is important for developing inclusive teaching practices. Barriers to educational inclusion for autistic pupils and students can manifest in a range of cognitive, social, and emotional domains (Bailey & Baker, 2020). Inclusion goes beyond the implementation of strategies to support pupils' areas of difficulties; effective inclusion involves organizational change to anticipate and meet the needs of pupils (Jordan, 2008; Qvortrup & Qvortrup, 2018). This study supports this change by adding to our understanding of the potential areas of difference in the way that a task is experienced and thought about. These differences can manifest as 'incorrect' responses where assumptions have been made about how the question or instruction is understood. Differences can also be experienced as additional effort expended in adapting to the required way of thinking or acting. Addressing assumptions about autistic individuals' experiences and thinking is therefore essential to inclusive learning.

Previous studies have found that autism is associated with differences across a wide range of cognitive processes that are relevant for education (Bailey & Baker, 2020). For this study, we focused on processes likely to impact directly on an individual's ability to engage with a task and for which a visible or audible behavioural measure can be used. To capture the breadth of relevant domains, we selected indicators that reflected the experience of the activity (attention), thinking about the activity (reasoning), and communication (misunderstandings). This approach allows for the findings to guide inclusive educational practice by identifying difficulties and differences that can be noticed and responded to by a teacher.

Attention. Differences between autistic and non-autistic individuals have been found in multiple aspects of visual attention. The commonly used diagnostic manual DSM-5 includes reduced eye contact as a diagnostic criteria (American Psychiatric Association, 2013). Superior visuospatial skills have been identified in autistic individuals in tasks such as the embedded figures task in which participants have to find a specific shape in a larger image (Almeida et al., 2010; Jolliffe & Baron-Cohen, 1997), experimental visual search tasks (O'Riordan et al., 2001; Plaisted, O'Riordan, & Baron-Cohen, 1998; Plaisted, O'Riordan, & Baron-Cohen, 1998), attentional gradient tasks (Robertson et al., 2013; Robertson & Baron-Cohen, 2017), as well as naturalistic visual search tasks (Gonzalez et al., 2013; Wade et al., 2017). Visual attention has been further studied, with findings of a bias away from social stimuli and towards non-social stimuli (Gale et al., 2019). Studies have shown poorer performance for autistic individuals than non-autistic individuals in switching attention and inhibiting non-salient details (Davis et al., 2017; Goldstein et al., 2001). A meta-analysis by Geurts et al. (2014) confirmed difficulties with inhibiting proponent response and interference control associated with autism, despite a complex picture from the individual studies. A naturalistic experimental design identified a greater cost to performance of autistic children than non-autistic children from distractions in a classroom setting (Hanley et al., 2017).

In complex educational environments, inhibiting attention to non-task-related information can be vital to performance in the task. As tasks are often presented in multiple steps, switching attention as the task moves on and inhibiting previously salient information are also important. It is, therefore, useful to understand more about the differences in the locus of attention during completion of a complex reasoning task. In a task guided by an instructor, differences in the aspects of the visual scene that are attended to will affect the information received about the task and the environment; different elements in the environment will be noticed and reduced visual attention to the instructor may reduce the amount of non-verbal communication such as the instructor's own visual gaze or hand gestures that is available to the learner.

Reasoning. Brosnan et al. (2016, 2017) reported a bias away from intuitive reasoning and towards deliberative reasoning in autistic individuals. The drive to think in terms of systems and rules defines the extreme systemizing cognitive style, referred to as if-and-then reasoning, and is associated with autism (Baron-Cohen, 2022; Greenberg et al., 2018). Autistic individuals' reasoning may focus more on detail than context (Hill & Frith, 2003; Vermeulen, 2015). Autistic individuals have more entrenched folk physics beliefs, which hold more firmly than those of typically developing individuals in the face of counter-evidence (Baker et al., 2009).

Reasoning underpins everyday learning activities. Reasoning patterns influence the working out of an answer, and so, understanding reasoning could shed light on how individuals with autism approach assessments in educational contexts. Yet, it can be very difficult to understand the way in which the individual thinks about the task from simply recording a multiple-choice answer. Reasoning style is more likely to be evident in responses to open-ended questions and by closely examining self-explanations of how the individual arrived at the answer.

Misunderstandings. DSM-5 refers to difficulty in understanding what other people are thinking (also known as 'theory of mind' (Baron-Cohen, 1997)) as a core diagnostic criterion for autism (American Psychiatric Association, 2013). Recent work reframes communication difficulties within the active construction of meaning by both parties in an interaction. For example, Milton's concept of the 'Double Empathy Problem' refers to difficulties in autistic and non-autistic individuals understanding each other (Milton, 2012). Big data confirm empathy difficulties in autistic people (Greenberg et al, 2018). Heasman and Gillespie (2018) have studied misunderstandings between autistic individuals and their family members by exploring the multiple perspectives within family dyads, but we are aware of no studies carried out on misunderstandings in educational contexts.

Misunderstandings are an interesting aspect of communication in educational contexts as they can result in considerable barriers to inclusion if the purpose or the parameters of the activity are misunderstood by the learner. Similarly, if the instructor misunderstands the learner, the next steps in the learning activity may be less effectively tailored to their learning needs. If misunderstandings are more closely monitored, there is potential to respond effectively in real time during an activity to build greater clarity into instructions.

The present study used an open-ended systemizing activity based on exploring the notion of a 'fair test', common in science education. Adult participants in the study were invited to explore an unfamiliar physical apparatus with occasional prompts from a researcher, who acted as an instructor or 'guide' for the simulated learning task. Verbal and non-verbal cues were video-recorded and coded, to allow in-depth investigation of attention, reasoning, and misunderstanding during the activity. This pilot study is part of a broader study that looked at differences in physics task performance. Through this observational pilot research, we aim to understand the ways in which autistic individuals experience learning activities in a semi-naturalistic setting. We tested whether autistic individuals pay more attention to non-social and non-task-related elements in the environment, use different forms of reasoning, and experience more and longer misunderstandings than non-autistic individuals. The differences explored in this study therefore relate closely to everyday learning experiences and provide methods that can be used in naturalistic study designs.

Method

We measured the frequency and duration of specific behaviours relating to attention, reasoning, and misunderstanding in video recordings of autistic and non-autistic individuals completing a systemizing (physics reasoning) task.

Participants

We recruited 15 adults with a self-confirmed diagnosis of autism (10 males, 5 females) and 19 control participants (11 males, 8 females) for the pilot study from the Cambridge Autism Research Database (CARD) (Table 1). The groups were similar in gender and age composition. The Autism Spectrum Quotient (AQ; Baron-Cohen et al., 2001; Wheelwright et al., 2010) was completed by both autistic and control participants as a screening tool to quantify autistic traits. All the participants in the autism group scored above the threshold of 26 (Woodbury-Smith et al., 2005).

Table 1

Participant Characteristics

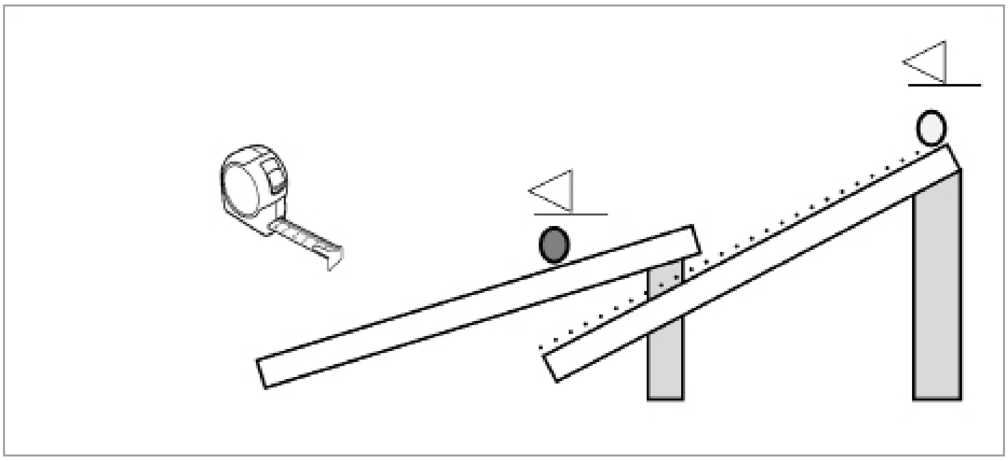
	Autism	Control
Participants (males: females)	15 (10:5)	19 (11:8)
Age range in years (mean, range)	36.7 (24 – 51)	30.1 (20 – 52)
Autism Spectrum Quotient (mean, SD)	39.4 (4.5)	18.5 (10.7)

Materials

The systemizing (physics reasoning) task. The task used two wooden ramps of around 1 metre in length, with several differences between them; the height of the box(es) on which they rested was different, one had a layer of carpet on the surface whilst the other was smooth, and they were placed in a staggered position. The ramps both had flags to allow for different starting positions to be identified (see Figure 1). There were two balls, of which the blue ball was noticeably heavier than the pink ball. This is a novel task, based on a design from Chen and Klahr (1999).

Figure 1

Equipment as Set Up for the Beginning of the Task, Showing a Tape Measure and Two Ramps Varying in Height, Surface, Start Flag Position and Ball Weight



Measures

Attention. We measured visual attention towards non-social elements as the ratio between time spent by the participant looking at the equipment (including the clipboard of results) and time spent looking at the instructor-researcher. Brief periods spent by participants in looking at neither were excluded from the totals. We measured attention to the task as the frequency of mentions of non-task-related details, for example a non-task-related feature of the equipment "the carpet held in place by screws, ten screws holding it in place" or conversation diverging from the task.

Reasoning. Our broad definition of reasoning included any participant talk that referred to causation, decision-making, or comparison. We classified reasoning type as deliberative (analogical, deductive, inductive) or intuitive (probabilistic or folk) in each period of participants' reasoning talk (Table 2). Also of interest was the extent to which individuals expressed their reasoning verbally, so we calculated reasoning time for each participant as the total time spent on reasoning talk.

Table 2

Examples of Reasoning Types

Reasoning type	*Example*
Analogical	*"the weight of it stops it moving so quickly, like if you have a heavy lorry it's gonna move more slower than a lorry that's not got a big container on the back"*
Deductive	*"the smooth ramp being the variable allowed the ball to pick up momentum and travel a much greater distance"*
Inductive	*"aah, I see what's happening, the weights inside the blue one are throwing it off, it's giving it some wiggle, am I right?"*
Probabilistic	*"so this has got three for and one against"*
Folk	*"I think that, I suppose obviously the carpet, I just naturally thought that the heavier one would travel faster"*

Misunderstandings. We identified verbal interactions involving misunderstandings in the transcripts and tracked them to their successful correction. Misunderstandings were identified by repeated or re-phrased questions as an indicator that either the participant had misunderstood a question, or the researcher had misunderstood the response. Time to correct the misunderstanding was measured in seconds from the end of the initial question from the researcher to the start of the response that concluded the interaction. Conclusion of the interaction was either marked by a question or instruction with a new focus.

Procedure

The systemizing (physics reasoning) task formed a semi-structured interview around a simple physics experiment carried out by the participant in which two balls are rolled down two ramps and the distance each ball travels from its associated ramp is measured. A standardized procedure was used in which the instructor-researcher asked open questions about the equipment, after which the first experiment was carried out and then questions were asked about the results including whether the set-up constituted a 'good experiment' to prompt consideration of control of variables. The participant was then asked to change the set-up, asked to explain the results, then asked to devise a further set-up to explore a different variable.

The task was video recorded from three positions in the room. The videos were coded by a different researcher using NVivo Qualitative Data Analysis Software, with multiple views used where necessary. The start and end of the task was identified using the verbal cues from the instructor-researcher. The beginning of the task was marked by the opening question "So, can you tell me what you can see here?"; the end of the task by a statement from the instructor-researcher such as "and that's the end of the task".

We transcribed the videos for both instructor-researcher and participant speech, with attention paid to the marking of the start and end of speech segments to allow for duration of speech types to be calculated. Where speech paused for 0.5 seconds or more, separate segments were recorded. The videos were then coded for each of the behavioural measures, either as timed segments of specific behaviours or as codes applied to segments of speech in the transcript. Timed segment data were extracted and processed in Microsoft Excel to obtain durations for each segment and totals for each participant. Additional coding of non-verbal elements was then carried out.

For the measure of visual attention, which involves establishing where the participants were looking, the data could not be collected if it was not possible to see the face and eyes of the participant clearly from any of the multiple camera views. Participants were excluded where the amount of visible gaze was below 50% of the total study time and therefore too low to be representative.

The resultant data were tested for differences between the two groups in each of the measures using t-tests. Individual misunderstandings were further coded for the type of event using codes developed through the analysis process.

Ethics

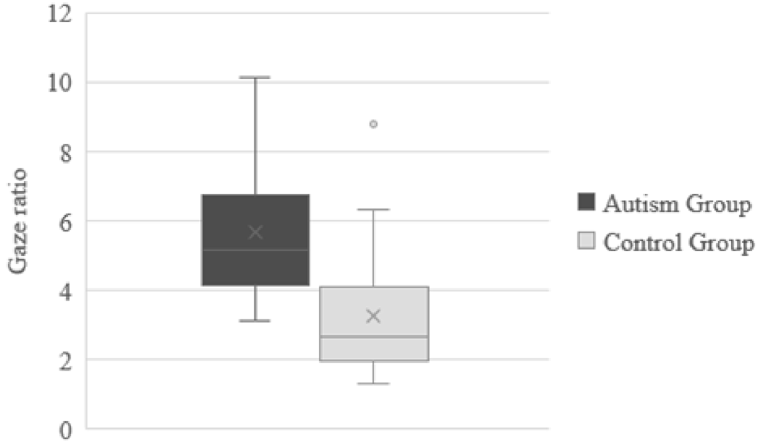
Approval for this study was obtained from the Faculty of Education, University of Cambridge. Informed consent was obtained from all participants prior to their involvement in this study in addition to the consent obtained on recruitment to the Cambridge Autism Research Database (CARD).

Results

Attention. Four participants, all from the autism group, were excluded from the gaze ratio analysis due to limited gaze data. All remaining participants scored greater than 1 on the gaze ratio, indicating more time looking at the equipment than looking at the instructor-researcher (see Figure 2). A t-test showed that autistic individuals had a greater gaze ratio (5.70) than non-autistic individuals (3.27), t(28) = 3.22, p = .002. Autistic individuals spent relatively more time looking towards non-social stimuli than non-autistic individuals.

Figure 2

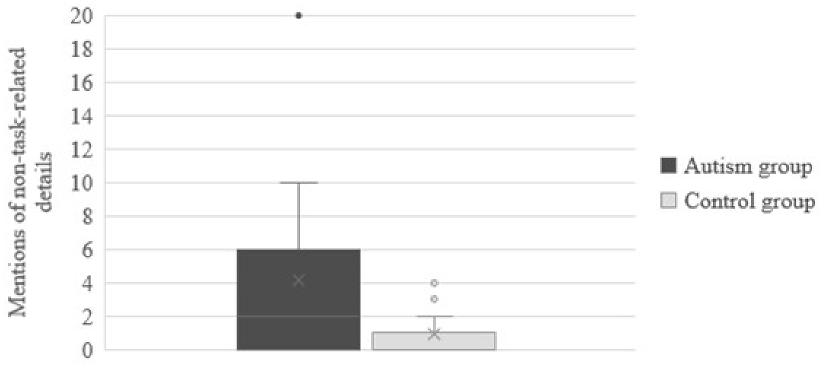
Boxplot of gaze ratio by group



Non-task-related details were mentioned by a greater proportion of individuals with autism (79%) than control participants (42%). Figure 3 shows a difference between the groups in the number of mentions of non-salient details. Levene's test showed that the variances of the autism group were different from the control group, F(1,31) = 4.87, p = .03, so equal variances were not assumed for the t-test and the degrees of freedom adjusted. The t-test showed that, on average, autistic individuals made more mentions of non-task-related details during the task (M = 4.43), than non-autistic individuals (M = 0.89), t(14.25) = 2.40, p = .02.

Figure 3

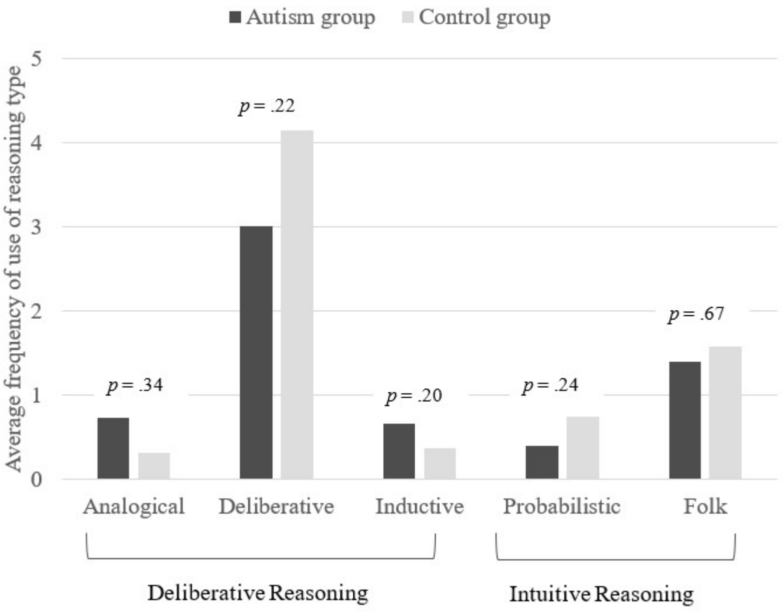
Boxplot of frequency of mentions of non-task-related details by group



Reasoning. Whilst autistic participants showed a trend towards more frequently used analogical and inductive reasoning than control participants, and less frequently used deductive, probabilistic, and folk reasoning, these differences were not statistically significant (Figure 4).

Figure 4

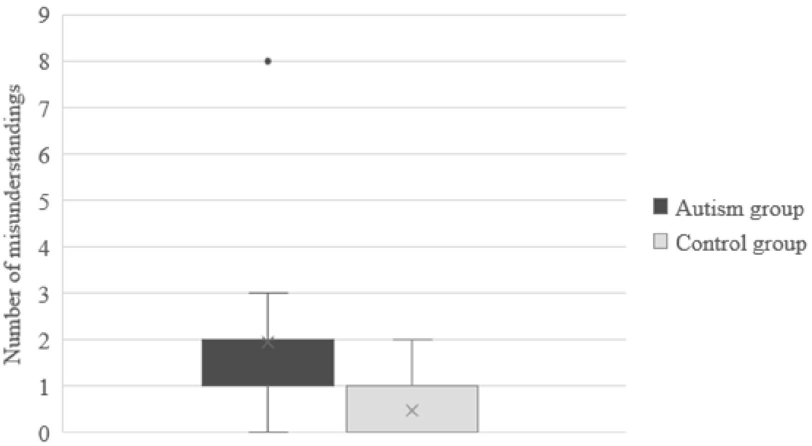
Average uses of each reasoning type for autism and control groups



Misunderstandings. Verbal interactions involving misunderstandings were evident in a greater proportion of autistic individuals (93%) than non-autistic control participants (42%). Figure 5 shows a difference between the groups and the presence of an outlier in the autism group with eight misunderstandings. This outlier was kept in for the initial analysis as variability is a feature of autism that is relevant to the aims of this study. A t-test showed that autistic individuals experienced more misunderstandings (M = 2.07) than non-autistic individuals (M = 0.47), t(31) = 3.45, p < .001. When analysis was repeated without the outlier, the difference in the group mean was also significant with autistic individuals (M = 1.62) still experiencing more misunderstandings than the control group (M = 0.47), t(30) = 4.37, p < .001.

Figure 5

Boxplot of frequency of misunderstandings by group

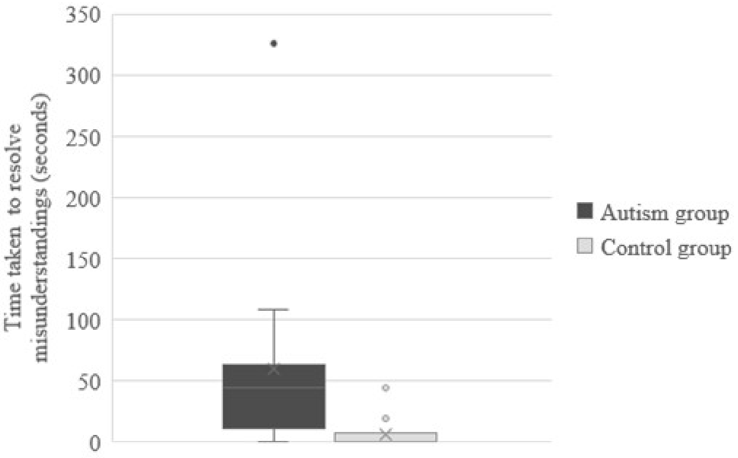


The impact of misunderstandings on the overall task was considered by comparing the amount of time spent resolving misunderstandings in the task. The outlier in the autism group is still evident in the boxplot shown in Figure 6. Levene's test showed that the variances of the autism group were different from the control group, F(1,31) = 5.51, p = .03, so equal variances were not assumed for the t-test and the degrees of freedom adjusted. A t-test showed that autistic individuals lost more time in the task to misunderstandings (M = 64.63 seconds) than non-autistic individuals (M = 5.89 seconds), t(13.35) = 2.66, p = .01. When analysis was repeated without the outlier, Levene's test showed that the variances of the autism group were different from the control group, F(1,31) = 12.54, p = .001, so equal variances were not assumed. The difference between the duration of misunderstandings for autistic individuals (M = 44.55) and non-autistic individuals (M = 5.89) was also significant, t(13.71) = 3.91, p < .001.

As the task had a standard format, misunderstanding contributed to a greater total time taken for the task for the autistic participants. Autistic participants took an average (mean) of 20 minutes and 30 seconds to complete the task, whilst for non-autistic participants the average task duration was 17 minutes and 14 seconds.

Figure 6

Boxplot of time taken to correct misunderstandings by group



Further investigation of the nature of the misunderstandings was carried out to explore the context. Where misunderstandings occurred at the early stages of the task, for both groups they tended to involve intrusions from expectations of the task before instructions were given. Table 3 shows that nearly two thirds (64.3%) of misunderstandings for the autistic participants and 75% of misunderstandings for the control group involved interference from non-salient information, with the intrusion of the participant's previous attentional focus present only in the autism group. Intrusion of expectations or assumptions occurred in each group, but language interpretation errors were more common in the autism group.

Table 3

Frequency of Misunderstanding Types

Misunderstanding type	Frequency (%)	
	Autism Group	Control Group
Language Interpretation	10 (35.7%)	2 (25%)
Intrusion of Non-Salient Information, of which:	18 (64.3%)	6 (75%)
Intrusion of Previous Attentional Focus	*9*	*0*
Intrusion of Expectations or Assumptions	*6*	*6*
Intrusion of Previous Instructions	*3*	*0*
Total Misunderstandings	28	8

Discussion

This study measured the differences in the ways that autistic and non-autistic individuals experienced a systemizing (physics reasoning) task using novel observational measures. Differences were found in attention and misunderstandings but not in reasoning style. As expected from previous studies (Gale et al., 2019), autism was associated with a bias towards non-social stimuli, with more time spent looking at the equipment and less at the instructor-researcher than for the control group. Whilst this does not necessarily signify a difficulty in the task, it translates into important differences in the way in which the task is experienced. Less time spent looking at the instructor in a learning task reduces the availability of non-verbal communication such as cues from glances at relevant items. For example, a cue to use the tape measure was available only to those participants looking at the instructor-researcher when he glanced in its direction during the task. Conversely, greater time looking at the equipment in this task can lead to noticing more of the details that are central to understanding the task.

The presence of more mentions of non-task-related details by the autistic participants is suggestive of a difference in the way the task was experienced compared to the control group. This could either be due to differences in the understanding of the parameters of the task or due to the difficulties in inhibiting the intrusion of non-task-related information when answering. Given the findings of difficulty with switching and interference control (Geurts et al., 2014; Williams et al., 2014) and theory of mind (Baron-Cohen et al., 1985; Jones et al., 2018) from more narrowly defined tasks, it is possible that any or all of these processes could be involved.

The greater frequency and duration of misunderstandings in the autism group is interesting and suggests that communication differences may manifest as barriers to inclusion. Misunderstandings take the individual's effort away from the learning task which reduces the effort available to engage fully with the task. This is a novel situation and although it resembles a typical educational activity it is simulated and explicitly designed for the purpose of research, so the participants could not apply previous direct experience of the situation. Instead, the participant had to make assumptions about what the instructor-researcher was particularly interested in.

A closer analysis of the nature of the misunderstandings showed that they were commonly the result of a failure to switch from key elements of the previous set-up. Missing out on non-verbal cues, such as the instructor-researcher's own gaze direction or gestures, may also contribute to misunderstandings when a change of focus is being initiated (Baron-Cohen et al., 1997). Misunderstandings can also lead to confusion and frustration, even once a correct response has been achieved, thereby further impacting on the individual's performance in the task. These findings suggest that this is an area worth exploring further, for example by applying the Interpersonal Perception Method (IPM) methods of analysis used in family contexts by Heasman and Gillespie (2018) into educational contexts. IPM compares direct perspectives to meta-perspectives (how we think we are seen by another) and could provide valuable insights into student-teacher communication.

The findings of this study also suggest high levels of heterogeneity within autism, with most measures showing a larger range in values in the autism group than in the control group. The size and nature of the sample compares well to other studies of autism but is still small. It is difficult to generalize from adults to children and adolescents as developmental trajectories are different in autism (Fletcher-Watson & Happé, 2019). For example, interference control tends to improve with age (Geurts, 2014) and therefore findings from adults cannot be extrapolated to children or adolescents. It is also difficult to generalize from the findings from this study to different forms of reasoning and different educational contexts.

Whilst the observed differences in attention between the autistic and non-autistic individuals are consistent with previous studies, there was no evidence of the expected differences in the reasoning about the task. This could be due to the constraints of the task, however the open-ended prompts from the instructor-researcher allowed for differences in reasoning style to be expressed at multiple points in the task. Both groups used a range of reasoning throughout the task. Forms of reasoning were also used in similar proportions by both groups. An expected bias towards deliberative reasoning (Brosnan, 2017) for autistic individuals was not evident, but could have been masked by a bias towards deliberative reasoning in the content of the task, as deductive reasoning is common in physics teaching (Park & Han, 2002).

The interaction with an unfamiliar instructor-researcher, and the verbal nature of the exchanges during the task, mean that while the task was designed to assess systemizing (through the concept of a 'fair test'), the overall experience was mediated by the participants' communication preferences. It is unclear what portion of our findings are attributable to more general communication differences. Still, the aspect where we found no differences between groups (reasoning style) was language-based, and one of the aspects where we did find differences (visual attention) was coded based on non-verbal behaviours (like where participants cast their gaze). Thus, further research could seek to tease out aspects of autistic experiences during learning activities that are more or less influenced by communication preferences.

Implications for Education Research

This study uses a novel approach which closes the gap between theory and practice by focusing on observational measures in a semi-naturalistic procedure. This approach aids translation from research into educational practice by relating known psychological indicators directly to what teachers can observe in a classroom situation (e.g., what learners pay attention to; their reasoning in response to open-ended questions; and misunderstandings). We developed exploratory research questions based on evidence drawn from studies in more controlled environments within lab-based cognitive studies. These research questions were then tested in a semi-naturalistic, open-ended yet structured, learning activity.

The observational measures developed for this study are simple and adaptable. We observed an open-ended science activity relating to the notion of a 'fair test' and found no differences in reasoning patterns between autistic and non-autistic participants, which was not what we expected based on existing psychological research. This may be due to the domain-specific content of the activity. These observational techniques could be applied to other subject areas to further explore how reasoning in autism may vary by domain. For example, it would be interesting to explore patterns of reasoning in scenarios with a greater role for the participant in conceptualizing the task, and a more narrative focus, for example in history lesson activities where the causes of historical events are considered.

Similar observational methods could be used in relation to other neurodevelopmental conditions such as ADHD, dyslexia, and mental health conditions where differences in the experience of the activity potentially impact on performance.

Implications for Inclusive Educational Practice

The findings of this study have implications for inclusive educational practice in adding to our understanding of the experience of autistic individuals in learning activities. Through this understanding, learning environments and activities can more successfully be designed to meet the needs and individual preferences of autistic learners (Pellicano et al., 2018).

Where misunderstandings were found to be more frequent in the autism group, high quality pedagogy involves anticipating and mitigating such barriers to engagement in learning. For example, underscoring explicit aims and specific instructions can reduce the frequency of misunderstandings by prioritizing clarity about the relevance of particular details, and explicitly de-emphasizing irrelevant details.

Differences in the locus of attention for autistic learners can have implications for the experience of the learning activity and access to visual cues from the teacher. Considered alongside previous findings of a greater cost to autistic students from classroom distractions (Hanley et al., 2017), these findings suggest that attentional focus is important in learning environments. Inclusive educational pedagogy therefore needs to be based on communicating effectively with learners on where their attentional focus should be and minimizing distractions and ambiguity.

The findings represent an important addition to our understanding of the ways in which individuals with autism experience learning environments and add to our understanding of the learning needs of autistic students. This work demonstrates how observational methods can be used to understand the association between pedagogy and cognition, taking findings from experimental psychology one step closer to their application in real-world settings.

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