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Impaired Identification of Impoverished Animate but not Inanimate Objects in Adults with High-functioning Autism Spectrum Disorder.

Hollie G. Burnett, Sven Panis, Johan Wagemans, and Tjeerd Jellema

From the Department of Clinical Psychology, University of Edinburgh, Edinburgh, UK (H.G.B.); Laboratory of Experimental Psychology, KU Leuven, Leuven, Belgium (S.P., J.W.); Leuven Autism Research (LAuRes), KU Leuven, Leuven, Belgium (J.W.); Department of Psychology, The University of Hull, Hull, UK (T.J.).

Address for correspondence: Tjeerd Jellema, Department of Psychology, The University of Hull, Cottingham Road, HU6 7RX Hull, United Kingdom. T.Jellema@hull.ac.uk

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Lay Abstract

This study investigated the ability of individuals with a mild form of autism, called high-functioning autism (HFA), to recognise pictures of every-day objects. The pictures were degraded in order to make the objects harder to recognise. Previous studies suggested that the recognition of degraded objects is impaired in individuals with severe forms of autism. A further finding is that individuals with autism have problems related to social interactions with others, but are fine when 'interacting' with non-living objects, such as computers and tools. Therefore the current study also looked at whether the recognition of impoverished objects was influenced by the objects' animate or inanimate nature.

In the first picture presented, 1000 small elements (each having the shape of a grain of rice) were shown, all with random orientations. In the next 19 consecutively presented pictures, about 200 of these element gradually formed the contour line of an object, such that in the final picture the object was clearly visible. This sequence gave the subjective experience of an object gradually appearing out of a fog.

We found that the HFA group required more pictures to recognise the degraded objects than a control group. Crucially, this difference depended on the nature of the objects as it was only found for animate objects; with respect to inanimate objects the groups did not differ. The results suggest a specific impairment in individuals with HFA in recognising animate objects. The results are discussed in relation to social functions of the brain.

Scientific Abstract

The ability to identify animate and inanimate objects from impoverished images was investigated in adults with high-functioning autism spectrum disorder (HFA) and in matched typically-developed (TD) adults, using a newly developed task. Consecutive frames were presented containing Gabor elements that slightly changed orientation from one frame to the next. For a subset of elements, the changes were such that these elements gradually formed the outline of an object. Elements enclosed within the object's outline gradually adopted one and the same orientation, outside elements adopted random orientations. The subjective experience was that of an object appearing out of a fog.

The HFA group required significantly more frames to identify the impoverished objects than the TD group. Crucially, this difference depended on the nature of the objects: the HFA group required significantly more frames to identify animate objects, but with respect to the identification of inanimate objects the groups did not differ. The groups also didn't differ with respect to the number and type of incorrect guesses they made. The results suggest a specific impairment in individuals with HFA in identifying animate objects. A number of possible explanations are discussed.

Keywords: Autism spectrum disorder (ASD); concept forming; Gabor; impoverished objects; animate; inanimate.

Introduction

One of the earliest cognitive deficits found in children with autism spectrum disorder (ASD) concerns the forming of new concepts or object categories [Johnson & Rakison, 2006]. In particular the distinction between animate and inanimate object categories has been shown to pose challenges for individuals with ASD [Rutherford, Pennington, & Rodgers, 2006]. Various anecdotal cases have been described where the behaviour of children with autism suggested they had somehow not discriminated between the animate and inanimate nature of the objects that surround them. For example, Kanner and Lesser [1958] noted the autistic child ‘‘is aware of people … but considers them not differently from the way he (or she) considers the desk, bookshelf, or filing cabinet’’. A failure to develop a clear differentiation between animate and inanimate concepts will have far-reaching consequences as it impacts on the child’s understanding that different kinds of objects possess different physical, psychological, biological and motion related properties [Rakison & Poulin-Dubois, 2001].

Investigations into the diverse, multi-faceted, nature of the deficiencies in ASD that encompasses cognitive, emotional and motor domains, have been characterised by a tendency to focus on either low- or high-level aspects. An influential high-level approach argues that individuals with ASD fail to represent, and therefore understand, other’s thoughts and intentions, that is, they lack a Theory of Mind [Baron-Cohen, Leslie, & Frith, 1985; Baron-Cohen, 1995], the ability to read the behaviour of others (and of themselves) in terms of epistemic mental states (e.g. desires and beliefs). It has been proposed that it is especially the spontaneous/automatic reading of other’s behaviour on the basis of social cues that is impaired in ASD [Senju, Southgate, White, & Frith, 2009; Jellema et al., 2009;

Hudson, Liu, & Jellema, 2009]. Low-level approaches include those claiming that individuals with ASD have a specific cognitive profile characterised by a focus on local rather than global processing, often referred to as weak central coherence [Happé & Frith, 2006; Happé & Ronald, 2008], or characterised by enhanced low-level visual processing [Mottron et al., 2013]. However, the findings are often conflicting and paint a mixed picture of strengths and weaknesses, and of perceptual and attention preferences [e.g. Koldewyn, Jiang, Weigelt, & Kanwisher, 2013]. Some reports suggest that when matching for intellectual disability, weak central coherence in ASD disappears [Bernardino et al., 2012]. Furthermore, studies examining coherent form detection, which requires global processing, tend to find this capacity to be generally intact in ASD [Koldewyn, Whitney, & Rivera, 2010; Milne et al., 2006] or to be linked to ASD severity, with even superior coherent form detection in mild ASD and impairments in more severe forms [Tsermentseli, O'Brien, & Spencer, 2008].

Another low-level approach focuses on deficits in executive functions [Russell, 1998], such as response inhibition and cognitive flexibility [Delis, Kaplan, & Kramer, 2001; Geurts, Corbett, & Solomon, 2009; Van Eylen et al., 2009; Burnett & Jellema, 2013].

One challenge autism research is facing is to understand how relatively low-level deficits, such as impairments in cognitive flexibility or a preference for local processing, may give rise to a cascade of impairments culminating in high-level deficits in social reciprocity and Theory of Mind. For example, the ability to switch between concepts rapidly and accurately may affect success in especially social interactions, as in social interactions the mental states and intentions of those interacting may change rapidly and unexpectedly. Further, an inability to pull together multiple strands of information, as is required for global processing [Happé & Frith, 2006], or a lack of perceptual integration skills causing a disturbance in the interplay between mid and high-level vision [Verbeke et al., 2005; Evers et al., 2014], could all result in a failure to extract higher-level meaning from social cues, culminating in impaired social understanding.

One other relatively basic ability that could have far-reaching repercussions for social functioning and for the establishment of a Theory of Mind is the ability to discriminate between, and hence attach appropriate characteristics to, animate and inanimate objects. Several strands of evidence suggest that individuals with ASD may be more apt, and/or more interested, in visually processing inanimate than animate objects. For example, individuals with ASD were less likely to identify animate motion [Blake, Turner, Smoski, Pozdol, & Stone, 2003; Congiu, Schlottmann, & Ray, 2010]. Individuals with ASD were also better at discriminating between pictures of buildings than pictures of people [Boucher & Lewis, 1992], and were impaired in recognising degraded faces but not degraded household objects after being primed with the un-degraded versions [Loth, Gomez, & Happé, 2010]. However, there are also reports of intact perception of animacy in HFA [e.g. McAleer, Kay, Pollick, & Rutherford, 2011], but these studies tend to focus on the recognition of intentions derived from animacy rather than recognition of specific animate objects, which may recruit different abilities.

Not much is known about the possible mechanisms underpinning these aberrant results. Does it reflect a poor discrimination between objects categories in general, or is it more specifically linked to the animate or inanimate categories? Studies of electrophysiological markers for social percepts (faces) suggest a specific dysfunction in systems for processing animate stimuli in individuals with ASD, rather than a non-specific information processing problem (McPartland et al., 2011).

The current study

The study aimed to explore possible impairments in the forming of new object concepts from impoverished images in individuals with HFA, and to determine whether the animate or inanimate nature of the objects impacts on the identification rates. Not only the correct responses, but also all the incorrect guesses made prior to giving the correct answer, were analysed. A crucial aspect of the current study is that the objects were presented such that local details were absent as much as possible. The objects could only be identified on the basis of their interrupted outline, which did not contain any sharp angles or characteristic details. These outlines were formed by Gabor elements against a background of other Gabor elements. Gabors are sinusoidal gratings, typically with a Gaussian envelope, which are frequently used as stimuli in psychophysical and neurophysiological experiments [Hess & Field, 1999]. Over successively presented frames, the outlines gradually adopted the correct shape, while the elements enclosed by the outline gradually adopted one and the same orientation, giving the impression of an object gradually emerging from a dense fog. Presumably, participants would try and group disjoint elements into an outline and surface on the basis of the elements' proximity and similarity in orientation. This grouping process would then presumably be facilitated (or possibly hampered) by top-down input from candidate object representations. Several iterations of this cycle of feed forward and feedback processing might be necessary, in which different object representations are tested against the available evidence [Panis & Wagemans, 2009; Sassi, Vancleef, Machilsen, Panis, & Wagemans, 2010].

Due to the presumed local over global preference, the availability of merely global information is expected to make the task more challenging for the HFA group, which might help 'bring out' possible impairments in the animate-inanimate domain. In contrast, in the

Burnett and Jellema [2013] study, the to-be-identified objects did contain local information as the outlines were uninterrupted. Hence, the HFA group in the Burnett and Jellema [2013] study could still have benefited from their superior local processing mode in identifying objects.

There is little knowledge of how adults with HFA perform on concept forming (identification) tasks, with most studies focussing on severely impaired individuals. The current study uses a sample of adults (university students) with HFA (or Asperger's syndrome) who have IQ scores within the normal range, no developmental delay in language or cognitive abilities, and no substantial motor deficits. They do, however, display reciprocal social and communication deficits, but all to a lesser degree than in autism [Frith, 2003]. As both the clinical and control group consisted of university students with fairly similar daily routines, a good approximation of the influence of the factor 'HFA' on concept forming could be obtained.

Method

Participants

Clinical Group

Twenty students (15 males; mean age = 22.1 years, SD = 6.6), with a diagnosis of HFA or Asperger's syndrome from prior psychological reports based on DSM-IV criteria [American Psychiatric Association, 2000], were recruited through disability services from universities in the North-East of England (UK). Evidence of diagnostic history for ASD was acquired and the ADOS (Autism Diagnostic Observation Schedule, module 4) was completed with a trained examiner (HGB). The ADOS is a semi-structured, standardized assessment of communication, social interaction, and imagination, designed for use with children and adults suspected of having ASD [Lord, Rutter, DiLavore, & Risi, 1999]. A score of 7-9 indicates autism spectrum and a score of 10 or more indicates autism. All participants met the ADOS criteria for HFA or Asperger syndrome [mean total ADOS score = 7.9; Table 1]. There was no evidence of language delay and all participants had a cognitive ability within the average range or above. Their mean IQ score was 117.1 [assessed using the Wechsler Adult Intelligence Scale, WAIS-III, Wechsler, 1997], their mean AQ (Autism Quotient questionnaire) score was 30.7 [range = 18 - 44; Baron-Cohen, Wheelwright, Skinner, Martin & Clubley, 2001]. The AQ is a fifty-statement, self-administered, questionnaire designed to measure the degree to which an adult with normal intelligence has traits associated with ASD. The idea is that each individual occupies a position on a population-wide continuum, determined by the extent to which they possess autistic(-like) traits. Although the AQ is not a diagnostic tool, a score of 32 or higher (out of 50) has been shown to be indicative of ASD [Baron-Cohen et al., 2001].

Please insert Table 1 about here

Typically developed (TD) group

Twenty students (12 males, mean age = 21.2 years, SD = 3.7) were recruited at the University of Hull. All TD participants completed an online version of the AQ prior to the experiment (mean AQ = 12.2; range = 5 – 22). Their mean IQ score was 116.5 [WAIS IV, Wechsler, 1997], which did not differ from that of the HFA group ($P = 0.73$).

All TD and HFA participants had normal or corrected-to-normal vision, and provided written consent prior to the experiment. Participants received course credits or a fee for taking part. The study was approved by the University Ethics committee.

Stimuli

Fifty-six objects were selected from a large set of outline drawings of a wide range of animate and inanimate objects [Wagemans et al., 2008], which in turn were based on line drawings by Snodgrass and Vanderwart [1980]. Normative identification rates had been established for all outlined objects [Wagemans et al., 2008]; the animate (28) and inanimate (28) objects selected for the current study did not differ in their mean identification rates ($t(54) = .30$, $P = .765$).

The animate category consisted exclusively of animal species and all inanimate objects were man-made. Within both categories, subcategories could be discerned. The largest subcategory in the animate group was formed by land mammals (cow, dog, squirrel, giraffe, kangaroo, monkey, bear, horse, cat, elephant, mouse, sheep, lion, reindeer, rabbit), while smaller subcategories consisted of birds (ostrich, eagle, swan, penguin, cockerel), reptiles (crocodile, snake, tortoise), fish (seahorse, fish), an amphibian (frog), a marine mammal (seal) and an insect (butterfly). The largest subcategory in the inanimate group was formed by graspable objects for daily use (glasses, bell, key, umbrella, candle, watering can, padlock, wineglass, gun, umbrella, iron, anchor, shoe, flag), with smaller subcategories consisting of vehicles (car, bike, plane, pram, truck), furniture (table, lamp, bed, chair), tools (hammer, pliers), instruments (guitar, trumpet) and a building (church). Each frame contained exactly 1000 Gabor elements (Fig. 1). The mean numbers of elements on the object outline, enclosed within the outline (object surface area), and in the background (outside the outline) did not differ between the animate and inanimate objects (all Ps > 0.05). Overall the mean number of elements on the outlines was 105, the mean number of elements forming the object surface 158.

Each stimulus sequence consisted of 20 consecutively presented frames. In the first frame, all elements had a random orientation. In each subsequent frame all elements changed their orientation slightly with respect to the previous frame. However, for the subset of elements that formed the outline and surface area of the objects these orientation changes were coordinated, such that over the course of the 20 frames these elements gradually formed the object. In the last frame of the sequence, the elements were perfectly aligned along the object's outline, while the elements making up the interior of the object (enclosed by the outline) had adopted an identical orientation parallel to the main object axis orientation. The remaining elements located outside the object continued to adopt random orientations throughout the entire 20 frame sequence (see Sassi, Vancleef, Machilsen, Panis, & Wagemans, 2010, for more details). Thus, the object could be identified on the basis of two cues: the object's outline and the object's interior, of which the outline was the most informative. The maximum on screen height and width of the objects was 10 and 14 cm (7 and 10 degrees of visual angle). The light grey Gabor elements were presented against a uniform darker grey background.

Please insert Figure 1 about here

To exclude the possibility that systematic differences in the geometrical complexity of the images of animate versus inanimate objects could affect the identification scores for these two categories, we quantified the complexity of the objects using the measures of compactness and homogeneity. Compactness was defined as (length outline)/(surface area)^2. Homogeneity was defined as (length outline)/(number of peaks)^2, where the number of peaks was based on an adaptive smoothing algorithm [Horng, 2003]. Thus silhouettes with fewer peaks have higher homogeneity values. For both tasks, the silhouettes of animate and inanimate end-objects did not differ from each other in compactness ($t(54) = 0.79$, $P = 0.43$) or homogeneity ($t(54) = 1.73$, $P = 0.09$).

Procedure

Participants were seated in front of a 21 inch PC monitor at a distance of approximately 80 cm (20° x 32° visual angle, height x width). All instructions and visual stimuli were presented on screen (E-prime, Psychology Software Tools Inc., Sharpsburg, USA; 600 x 800 resolution). Participants were instructed that they should verbally identify the emerging object as fast as possible, and that they could make an unlimited number of guesses. The experimenter recorded all guesses and the frame number (indicated at the top right corner of the screen) at which the correct answer was given. The flow of the frame presentation was thus not interrupted by any answers provided, but occurred with fixed presentation durations, without intervals in between consecutive frames (ISI = 0; all answers were written down by the experimenter simultaneously with the presentation).

First two practise trials were presented to familiarise the participants with the task (these objects were not included in the experiment), after which the experimenter verified the participant's understanding of the task. Then fifty-six experimental trials were presented, half of which contained animate objects (28 trials) and the other half inanimate objects (28 trials). Each trial started with a prompt to press the spacebar to start the trial. The first 10 frames of the stimulus sequence were shown in a rapid succession of 1 frame per second; participants were allowed to guess during these first 10 frames but no one did (there simply wasn't enough information to even make a guess). Starting from frame 11 (50%) the frames were shown at a rate of 2s per frame.

In some cases, there was an alternative name for the object, which strictly speaking was incorrect, but which, given the rough object outlines, was plausible. For example, the donkey could be mistaken for a horse. Further, in common language different names are sometimes used for the same object, such as crocodile and alligator. These plausible alternative names were scored as correct answers. Very rarely, participants had not correctly identified the object by frame 20 (in less than 3% of the total number of trials). Rather than ignoring these data, we assigned them a score of 21. Trial order was individually randomized.

The total experiment lasted on average 10 minutes. The exact duration was determined by the participant's performance, as following a correct answer any remaining frames were shown at high rate (just to show the participant that the answer they had provided was indeed correct). All participants completed an online version of the AQ questionnaire

[Baron-Cohen et al., 2001] directly after the experiment (duration 5 minutes). Following the experiment (on the same or a subsequent day) the WAIS (TD and HFA) and ADOS (HFA) were administered.

Results

A 2x2 repeated measures ANOVA, with End-object (animate vs. inanimate) as within-subjects factor and Group (TD vs. HFA) as between-subjects factor, showed a significant main effect for End-object ($F(1, 38) = 28.1$, $P < 0.001$, $\eta_p^2 = 0.43$), reflecting that the images of animate objects (M = 13.6, SD = 1.6) required more frames to identify than those of inanimate objects (M = 12.7, SD = 1.3) (Fig. 2A). The main effect for Group was also significant ($F(1, 38) = 16.5$, $P < 0.001$, $\eta_p^2 = 0.30$), with the TD group (M = 12.4, SD = 1.3) performing better than the HFA group (M = 13.8, SD = 0.9). The Group by End-object interaction was significant ($F(1, 38) = 11.8$, $P = 0.001$, $\eta_p^2 = 0.24$). Subsequent *t* tests showed that the number of frames required by the TD group to identify the animate and inanimate objects did not differ ($t(19) = 1.26$, $P = 0.22$). The HFA group, however, required more frames to identify animate objects than inanimate objects ($t(19) = 6.5$, $P < 0.001$). The animate objects were more readily identified by the TD group than by the HFA group ($t(38) = 5.0$, $P < 0.001$), while with respect to the identification of inanimate objects the TD group was only marginally better ($t(38) = 2.4$, $P = 0.020$, Bonferroni corrected $\alpha = 0.0125$).

Please insert Figure 2 about here

Analysis of incorrect guesses

All incorrect guesses, i.e. guesses made before the correct answer (if any) was given, were recorded to be able to determine whether any differences existed between the two participant groups in absolute number of guesses and/or in the relative numbers of animate and inanimate guesses. This is relevant as a tendency to generate a lot of guesses might in itself increase the chance of giving the correct answer. The mean number of incorrect guesses prior to the correct answer per trial was marginally higher for the HFA group (M = 0.21, SD = 0.12) than for the TD group (M = 0.11, SD = 0.07; $t(38) = 3.07$, $P = 0.04$). Thus, the better identification rates of the TD group were not due to generating more guesses. Further, both groups made significantly more animate than inanimate guesses. In the TD group, 70.1 % of all incorrect guesses were animate (29.9% was inanimate; $t(19) = 6.7$, $P < 0.001$). In the HFA group, 64.3% of incorrect guesses were animate (35.7% was inanimate; $t(19) = 3.2$, $P = 0.005$). The proportions of animate and inanimate guesses made by the TD and HFA groups did not differ ($t(38) = 0.74$, $P = 0.46$). Finally, the proportions of animate guesses when the ultimate object was animate compared to inanimate did not differ ($P = .74$) and did not interact with the factor Group ($P = .88$).

Correlations of task performance with various measures

It is important to examine the heterogeneity of responses, particularly in the HFA group. Is the atypical processing of animate objects a characteristic that applies to all individuals in the HFA group, or to a subset, and is heterogeneity related to the severity of ASD symptoms? Hereto correlations were calculated between their performance (mean score for animate objects minus mean score for inanimate objects) and two measures of ASD severity, AQ and ADOS. The Pearson correlations with AQ were not significant in either the TD ($r = 0.22$, $P = 0.38$) or HFA ($r = -0.18$, $P = 0.45$) group, nor was there in the HFA group a significant correlation with the ADOS scores ($r = 0.007$, $P = 0.98$).

We further examined a possible contribution of the factors IQ and Sex to the atypical animate processing. Neither factor correlated significantly with performance (IQ-TD, $r = 0.052$, $P = 0.89$; IQ-HFA, $r = 0.19$, $P = 0.42$; Sex-TD, $r = -0.06$, $P = 0.80$; Sex-HFA, $r = 0.26$, $P = 0.26$).

Discussion

The present study explored whether individuals with HFA have an impairment in identifying impoverished objects as compared to closely matched, typically-developed, controls, and whether it mattered if the object that had to be identified was animate or inanimate. We used a new identification task involving images built up from Gabor elements, a subset of which gradually, from one frame to the next, formed an object. This gave the illusion of an object gradually appearing out of a dense fog, devoid of local information.

The HFA group was significantly poorer in identifying the objects than the TD group,

However, crucially, the poorer identification rate was due almost exclusively to the identification of the animate objects. With respect to inanimate objects, the HFA group was only marginally poorer than the TD group. These results are in line with the findings by

Burnett and Jellema [2013], who used impoverished objects that still contained local details due to their uninterrupted outlines. However, in the current study the 'animate impairment' was even more pronounced, possibly because the objects were devoid of local information.

It should be noted though that with a less severe correction for multiple comparisons, the HFA group would perform worse than the TD group also in the inanimate condition. Burnett & Jellema [2013] found a very similar trend towards poorer identification of impoverished inanimate objects in the HFA group compared to the TD group. Possibly, the overall identification impairment reflects impaired visual integration skills [Happé & Ronald, 2008]. It is consistent with the idea that individuals with ASD have impairments in the forming of new concepts (strictly speaking in identifying impoverished objects) [cf. Johnson & Rakison, 2006] and that they rely more than TD individuals on local information [Happé & Frith, 2006]. Other factors such as speed of response and attention may play a role too, but this requires further study.

The intriguing finding that the impairment was limited to animate objects, while inanimate objects remained largely unaffected, supports the idea of a processing impairment in ASD specifically for animate objects [cf. Hobson, 1987], rather than a general identification impairment [Landry & Bryson, 2004]. Support for the notion that the identification impairment was specific for animate objects comes from the study by Evers et al. [2014], where a distinction was made between man-made and natural objects, rather than between man-made and animate objects. Their natural objects included plants, trees, fruits and just a few animals, while the animate category in the current study consisted exclusively of animals and humans. Crucially, Evers and co-workers [2014] found no identification differences in the ASD group (nor in the TD group) between the man-made and natural objects. This supports the notion that the identification impairment may be limited to animate objects, i.e. living creatures that exert control over their limbs and bodies to make/adopt a variety of movements/postures.

The notion that individuals with HFA have relative difficulty processing animate stimuli relative to TD individuals is not new. However, the unique contribution of the current study is that it shows that such an impairment does not depend on relatively low-level visual processes such as figure-ground discrimination and grouping/integration of contour elements. Rather, it suggests that the impairment occurs at a higher, conceptual, level [cf. Evers et al., 2014]. It seems that, even though in the HFA group animate concepts are readily available (as indicated by the similar guess patterns), for the individuals with HFA the shapes (outlines) of objects are less uniquely, or less prominently, linked to the identity of those objects in the animate domain than in the inanimate domain. An uncertainty seems to creep in specifically with respect to the association between the shape and identity of animate objects. These insights should contribute to a better qualification of the huge phenotypic variability found in ASD, which variability complicates the diagnosis and treatment of this disorder [Mundy, Henderson, Inge, & Coman, 2007].

Interestingly, the behavioural results are echoed by neuroanatomical findings that animate and inanimate objects tend to be processed and represented in designated, largely non-overlapping, brain areas. For example, the lateral posterior part of the fusiform gyrus is primarily activated by faces [McCarthy, Pruce, Gore, & Allison, 1997], whereas the medial fusiform gyrus seems more responsive to tools [Wiggett, Pritchard, & Downing, 2009]. A similar dissociation is seen in the lateral temporal lobe, where the superior temporal sulcus

(STS) specifically responds to the form and motion of animate objects [Allison, Puce, & McCarthy, 2000; Jellema & Perrett, 2003, 2005], whereas the superior temporal gyrus seems primarily responsive to tools [Beauchamp, Lee, Haxby, & Martin, 2002]. The interpretation of simple geometric shapes in motion as either conveying social interactions or mechanical actions also elicited responses in distinctly different temporal areas [Martin & Weisberg, 2003]. Human lesion studies [e.g. Warrington & Shallice, 1984; Caramazza & Shelton, 1998] further highlighted the dissociation. Therefore, selective malfunctioning in areas dedicated to animate processing might be related to the reported behavioural effects. Especially the STS is interesting in this respect as the STS has been reported to be anatomically and functionally compromised in ASD [e.g. Zilbovicius et al., 2006].

There are, however, a number of factors, other than the (in)animate nature of the objects, which could in principle have contributed to the different identification scores. These will be examined next.

If the form of the animate objects was more complex than that of the inanimate objects, then this could have selectively disadvantaged individuals with ASD in their recognition of animate objects as they are thought to have impaired visual integration skills [Happé & Ronald, 2008]. However, the compactness and homogeneity scores did not differ between the sets of animate and inanimate objects, indicating they were equally complex in terms of their shapes (outlines).

If the HFA group were more familiar with, or had been more exposed to, inanimate than animate objects, while the TD group were equally familiar with both groups of objects, then that could in principle explain the different identification rates. However, given that the two participant groups were very closely matched (both groups consisted of undergraduate students from the same universities, following the same courses, with similar daily routines), this is an unlikely explanation. Moreover, all objects (animate and inanimate) were selected for being well-known, everyday, objects and were typical exemplars of their category, not requiring any specialist interests.

Different guess-patterns could in principle have affected the identification rates. If one group would generate a lot more guesses than the other, or would generate a disproportionate number of guesses in one category, then their chances of making a correct guess would increase. A failure to generate guesses could have reflected a cognitive deficit, but might also reflect the task requirement to produce the responses verbally to the examiner, which is a 'social' response. However, the analysis of the incorrect guesses showed that, if anything, the HFA group made more guesses than the TD group, while the proportions of animate and inanimate guesses were very similar in both groups. Thus, any differences in identification of the objects in the two tasks cannot be attributed to different guess patterns.

Could a general deficit in establishing abstract categories [Dawson & Lewy, 1989; Landry & Bryson, 1994] have selectively disadvantaged the identification of animate objects in the HFA group? It might be that the extent to which the different exemplars that make up an abstract category differ from each other in shape and appearance affects the identification scores. Some anecdotal evidence seems to support this notion. For example, Temple Grandin commented on the problems she experienced with the abstract category of dogs [Grandin, 1995]. In order to identify a newly encountered breed of dog as a dog (dog breeds differ hugely in size and shape), her memory for already established examples of dog breeds needed to be deliberately updated with the new breed, as she lacked the abstract concept of what a dog is. If it would be true that the objects that comprise animate concepts come in a wider range of forms and shapes than the objects that comprise inanimate concepts, then such a general deficit in forming abstract concepts could indeed selectively impair the identification of animate concepts. However, most exemplars of animate concepts that were used in the current study [e.g. chicken, penguin, giraffe, crocodile, squirrel] do not come in such big shape varieties as dogs. Moreover, the Snodgrass & Vanderwart [1980] set used only "canonical/prototypical" object representations. The inanimate objects that were used also come in large shape varieties, probably even more so than the animate ones (e.g. lamp, plane, car, shoe, table). A selective disadvantage for animate concepts due to a general deficit in forming abstract concepts is therefore unlikely.

Further, individual exemplars of the animate category may adopt a larger variety of shapes than those of the inanimate category due to the animate propensity of limb or body part articulation. However, again, the use of exclusively prototypical object shapes seems to neutralise this. A logical consequence of the propensity of animate objects to move is that they are often seen 'in motion', while inanimate objects tend to be seen 'static'. Whether this somehow might have affected results is unknown and remains to be investigated.

The unlikelihood of the above alternative explanations leaves open the possibility of a genuine impairment in the processing of animate objects in ASD. Such an impairment might be related to malfunctioning of the 'social brain' [Brothers, 1990; Dunbar, 1998; Allison et al., 2000], which brain areas show reduced/aberrant activity in individuals with ASD [e.g. Baron-Cohen et al., 2001; Castelli, Frith, Happé, & Frith, 2002; Dapretto et al., 2006]. Such an impairment would contribute to the paucity of social experiences in individuals with ASD, and, since these experiences provide the foundations for social development [Dawson, 1991], impede social development.

References

Allison, T., Puce, A., & McCarthy, G. (2000). Social perception from visual cues: role of the STS region. Trends in Cognitive Sciences, 4, 267-278.

American Psychiatric Association (2000). Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV). Washington, DC: American Psychiatric Association.

Baron-Cohen, S. (1995). Mindblindness: An Essay on Autism and Theory of Mind. MIT Press.

Baron-Cohen, S., Leslie, M.A., & Frith, U. (1985). Does the autistic child have a 'theory of mind'? Cognition, 21, 37-46.

Baron-Cohen, S., Wheelwright, S., Skinner, S., Martin, J., & Clubley, E. (2001). The Autism Spectrum Quotient (AQ): Evidence from Asperger syndrome/high functioning autism, males and females, scientists and mathematicians. Journal of Autism and Developmental Disorders, 31, 5-17.

Beauchamp, M.S., Lee, K.E., Haxby, J.V., & Martin, A. (2002). parallel visual motions processing streams for manipulable objects and human movements. Neuron, 34, 149–159.

Bernardino, I., Mouga, S., Almeida, J. van Asselen, M., Oliveira, G., & Castelo-Branco, M. (2012). A direct comparison of local-global integration in autism and other developmental disorders: Implications for the central coherence hypothesis. PLOS One, 7, e39351.

Blake, R., Turner, L.M., Smoski, M.J., Pozdol, S.L., & Stone, W.L. (2003). Visual recognition of biological motion is impaired in children with autism. Psychological Science, 14, 151-157.

Boucher, J., & Lewis V. (1992). Unfamiliar face recognition in relatively able autistic children. Journal of child Psychology and Psychiatry, 35, 843-859.

Brothers, L. (1990). The social brain: a project for integrating primate behavior and neurophysiology in a new domain. Concepts in Neuroscience, 1, 27-51.

Burnett, H.G., & Jellema, T. (2013). (Re-)conceptualisation in Asperger's syndrome and typical individuals with varying degrees of autistic-like traits. Journal of Autism and Developmental Disorders, 43, 211-223.

Castelli, F., Frith, C., Happe, F., & Frith, U. (2002). Autism, asperger syndrome and brain mechanisms for the attribution of mental states to animated shapes. Brain, 125, 1839-1849.

Caramazza, A. & Shelton, J.R. (1998). Domain-specific knowledge systems in the brain: The animate–inanimate distinction. Journal of Cognitive Neuroscience, 10, 1–34.

Congiu, S., Schlottmann, A., & Ray, E. (2010). Unimpaired perception of social and physical causality, but impaired perception of animacy in high functioning children with autism. Journal of Autism and Developmental Disorders, 40, 39-53.

Dapretto, M., Davies, M.S., Pfeifer, J.H., Scott, A.A., Sigman, M., Bookheimer, S.Y., & Iacoboni, M. (2006). Understanding emotions in others: mirror neuron dysfunction in children with autism spectrum disorders. Nature Neuroscience, 9, 28-30.

David, N., Schultz, J., Milne, E., Schunke, O., Schoettle, D., et al. (2014). Right temporoparietal gray matter predicts accuracy of social perception in the autism spectrum. Journal of Autism and Developmental Disorders, 44, 1433-1446.

Dawson, G. (1991). A psychobiological perspective on the early socio-emotional development of children with autism. In Sloth & D. Cicchetti (Eds.), Rochester Symposium on Developmental Psychopathology (Vol. 3, pp. 207-234). Hillsdale, NJ: Erlbaum.

Dawson, G., & Lewy, A. (1989). Arousal, attention and the socio-emotional impairments of individuals with autism (pp 49-74). In G. Sawson (Ed.), Autism; Nature, Diagnosis and Treatment, New York; Gilford Press.

Delis, D.C., Kaplan, E., & Kramer, J.H. (2001). The Delis–Kaplan executive function system. San Antonio: Psychological Corporation.

Dunbar, R. (1998). The Social Brain Hypothesis. Evolutionary Anthropology, 6, 178-

190.

Evers, K., Panis, S., Torfs, K., Steyaert, J., Noens, I. Wagemans, J. (2014). Disturbed interplay between mid- and high-level vision in ASD? Evidence from a contour identification task with everyday objects. Journal of Autism and Developmental Disorders, 44, 801-815.

Frith, U. (2003). Autism: Explaining the Enigma. Oxford: Blackwell Publishing.

Geurts, H.M., Corbett, B., & Solomon, M. (2009). The paradox of cognitive flexibility in autism. Trends in Cognitive Sciences, 13, 74–82.

Grandin, T. (1995). Thinking in Pictures. New York: Doubleday Publisher.

Happé, F., & Frith, U. (2006). The weak coherence account: detail-focused cognitive style in autism spectrum disorders. Journal of Autism and Developmental Disorders, 36, 5-25.

Happé, F., & Ronald, A. (2008). The 'fractionable autism triad': a review of evidence from behavioural, genetic, cognitive and neural research. Neuropsychology Reviews, 18, 287-304.

Hess, R.F., & Field, D.J. (1999). Integration of Contours: New Insights. Trends in Cognitive Sciences, 3, 480-486.

Hobson, R.P. (1987). The autistic child's recognition of age and sex related characteristics of people. Journal of Autism and Developmental Disorders, 17, 63-69.

Horng, L.I. (2003). An adaptive smoothing approach for fitting digital planar curves with line segments and circular arcs. Pattern Recognition Letters, 24, 565–577.

Hudson, M., Liu, C.H. & Jellema, T. (2009). Anticipating intentional actions: The effect of eye gaze direction on the judgement of head rotation. Cognition, 112, 423-434.

Jellema, T. & Perrett, D.I. (2005). Neural basis for the perception of goal-directed actions. In: Cognitive Neuroscience of Social Behaviour (A. Easton and N. J. Emery, Eds.) Psychology Press, New York. Studies in Cognition Series. pp81-112.

Jellema, T., & Perrett, D.I. (2003). Cells in monkey STS that are responsive to articulated body motions and consequent static posture: A case of implied motion? Neuropsychologia, 41, 1728-1737.

Jellema, T., Lorteije, J.A.M., van Rijn, S., van 't Wout, M., De Haan, E.H.F., van Engeland, H. & Kemner, C. (2009). Involuntary interpretation of social cues is compromised in Autism Spectrum Disorders. Autism Research, 2, 192-204.

Johnson, C.R., & Rakison, D.H. (2006). Early categorization of animate/inanimate concepts in young children with autism. Journal of Developmental and Physical Disabilities, 18, 73-89.

Kanner, L., & Lesser, L.I. (1958). Early infantile autism. Paediatrics Clinic of North America, 5, 711–730.

Koldewyn, K., Jiang, Y., Weigelt, S., & Kanwisher, N. (2013). Global/local processing in autism: Not a disability, but a disinclination. Journal of Autism and Developmental Disorders, 43, 2329-2340.

Koldewyn, K., Whitney, D., & Rivera, S.M. (2010). The psychophysics of visual motion and global form processing in autism. Brain, 133, 599-610.

Landry, R., & Bryson, S.E. (2004). Impaired disengagement of attention in young children with autism. Journal of Child Psychology and Psychiatry, 45, 1115-1122.

Loth, E., Gomez, J.-C., & Happe, F. (2010). When seeing depends on knowing: adults with Autism Spectrum Conditions show diminished top-down processes in the visual perception of degraded faces but not degraded objects. Neuropsychologia, 48, 1227-1236.

Lord, C., Rutter, M., DiLavore, P.C., & Risi, S. (1999). Autism Diagnostic Observation Schedule. Los Angeles, CA: Western Psychological Services.

Martin, A., & Weisberg, J. (2003). Neural foundations for understanding social and mechanical concepts. Cognitive Neuropsychology, 20, 3-6, 575-587

Milne, E., White, S., Campbell, R., Swettenham, J., Hansen, P., & Ramus, F. (2006). Motion and form coherence detection in autistic spectrum disorder: Relationship to motor control and 2 : 4 digit ratio. Journal of Autism and Developmental Disorders, 36, 225-237.

McAleer, P., Kay, J.W., Pollick, F.E. & Rutherford, M.D. (2011). Intention perception in high functioning people with autism spectrum disorders using animacy displays derived from human actions. Journal of Autism and Developmental Disorders, 41, 1053-1063.

McCarthy, G., Pruce, A., Gore, J.C., & Allison, T. (1997). Face-specific processing in the human fusiform gyrus. Journal of Cognitive Neuroscience, 9, 605-610.

McPartland, J.C., Wu, J., Bailey, C.A., Mayes, L.C., Schultz, R.T., & Klin, A. (2011). Atypical neural specialization for social percepts in autism spectrum disorder. Social Neuroscience, 6, 436-451.

Mottron, L., Bouvet, L., Bonnel, A., Samson, F., Burack, J.A., Dawson, M., & Heaton, P. (2013). Veridical mapping in the development of exceptional autistic abilities. Neuroscience & Biobehavioral Reviews, 37, 209–228.

Mundy, P.C., Henderson, H.A., Inge, A.P., & Coman, D.C. (2007). The modifier model of autism and social development in higher functioning children. Research and Practice for Persons with Severe Disabilities, 32, 124-139.

Panis, S., & Wagemans, J. (2009). Time-course contingencies in perceptual organization and identification of fragmented object outlines. Journal of Experimental Psychology-Human Perception and Performance, 35, 661–687.

Rakison, D.H., & Poulin-Dubois, D. (2001). Developmental origin of the animate-inanimate distinction. Psychological Bulletin, 127, 209-228.

Russell, J. (1998). Autism as an executive disorder. Oxford: Oxford University Press.

Rutherford, M.D., Pennington, B.P., & Rogers, S.J. (2006). The perception of animacy in young children with Autism. Journal of Autism and Developmental Disorders, 36, 983-992.

Sassi, M., Vancleef, K., Machilsen, B., Panis, S., & Wagemans, J. (2010). Identification of everyday objects on the basis of Gaborized outline versions. i-Perception, 1, 121-142.

Senju, A., Southgate, V., White, S., & Frith, U. (2009). Mindblind Eyes: An absence of spontaneous theory of mind in Asperger syndrome. Science, 325, 883-885.

Snodgrass, J.G., & VanderWart, M. (1980). A standardized set of 260 pictures: norms for name agreement, image agreement, familiarity, and visual complexity. Journal of Experimental Psychology: Human Learning and Memory, 6, 174-215.

Tsermentseli, S., O'Brien, J.M., & Spencer, J.V. (2008). Comparison of form and motion coherence processing in autistic spectrum disorders and dyslexia. Journal of Autism and Developmental Disorders, 38, 1201-1210.

Van Eylen, L., Boets, B., Steyaert, J., Evers, K., Wagemans, J., & Noens, I. (2011). Cognitive flexibility in autism spectrum disorder: Explaining the inconsistencies? Research in Autism Spectrum Disorders, 5, 1390-1401.

Verbeke, E., Peeters, W., Kerkhof, I., Bijttebier, P., Steyaert, J., & Wagemans, J. (2005). Lack of motivation to share intentions: primary deficit in autism? Behavioral and Brain Sciences, 28, 718-719.

Wagemans, J., De Winter, J., Op de Beeck, H.P., Ploeger, A., Beckers, T., & Vanroose, P. (2008). Identification of everyday objects on the basis of silhouette and outline versions. Perception, 37, 207-244.

Warrington, E.K., & Shallice, T. (1984). Category specific semantic impairments, Brain, 107, 829-854.

Wechsler, D. (1997). WAIS-III: Wechsler Adult Intelligence Scale–Third Edition: Administration and Scoring Manual, The Psychological Corporation, San Antonio, TX.

Wiggett, J., Pritchard, I.C., & Downing, P.E. (2009). Animate and inanimate objects in human visual cortex: evidence for task-independent category effects. Neuropsychologia, 47, 3111-3117.

Zilbovicius, M., Meresse, I., Chabane, N., Brunelle, F., Samson, Y., & Boddaert, N. (2006).

Autism, the superior temporal sulcus and social perception. Trends in Neurosciences, 29, 359-366.

Legends

Table 1. Participant characteristics. Age is in years. Standard deviation and range are shown between brackets. F, female; M, male; AQ, Autism spectrum Quotient; IQ-T, total IQ score; IQ-V, verbal IQ score; IQ-P, Performance IQ score.

Table 1

	HFA (n=20)	TD (n=20)
Age	22.1 (6.6; 18-33)	21.2 (3.7; 18-35)
Sex	5 F, 15M	8 F, 12 M
AQ	30.7 (8.7; 18-44)	12.2 (4.4; 5-22)
IQ-T	117.1 (9.7; 95-140)	116.5 (7.7; 99-127)
IQ-V	119.6 (13.4; 96-144)	120.0 (6.9; 103-128)
IQ-P	111.0 (12.8; 91-134)	111.5 (10.4; 93-128)
ADOS	7.9 (0.9; 7-9)	

Figure 1. Two examples of stimulus sequences resulting in an animate object (top row; image of a penguin, compactness: 103, homogeneity: 13) and an inanimate object (bottom row; image of a guitar, compactness: 103, homogeneity: 8). In actual trials 20 frames at 5% change were presented.

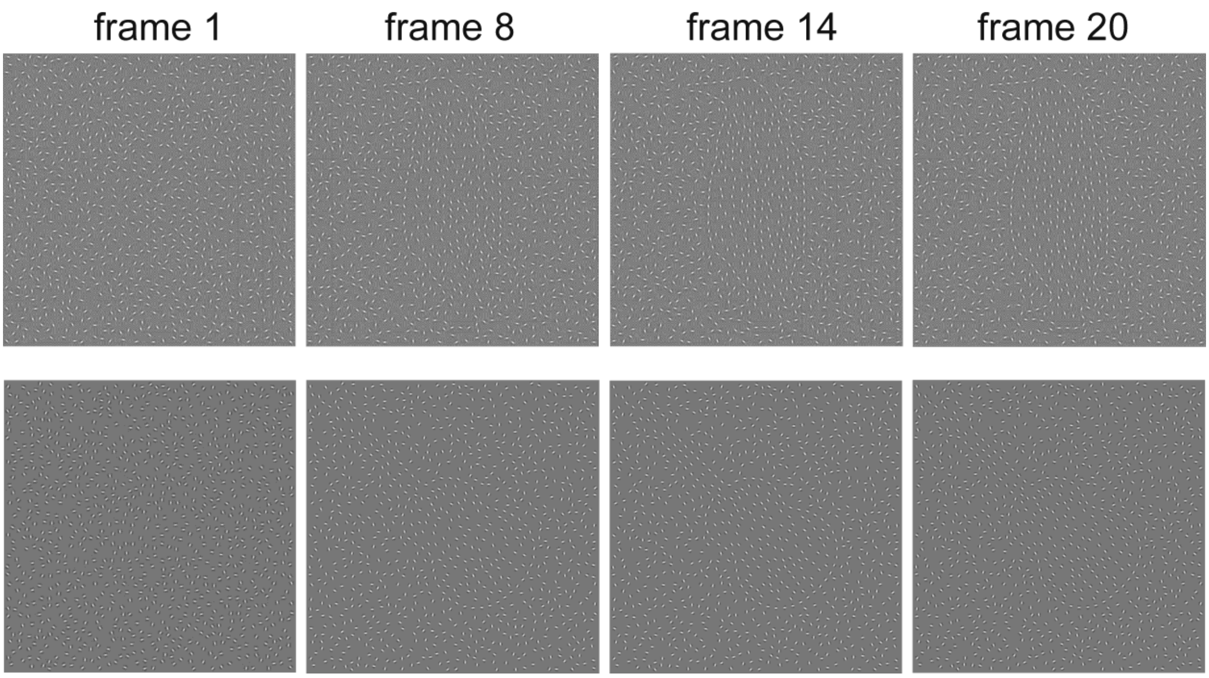

Figure 2. The mean number of images required to correctly identify the animate and inanimate objects is shown for the TD and HFA groups. A higher number of frames reflects poorer identification. Standard errors (SEM) are indicated. Bonferroni corrected α = 0.0125.