Circumscribed Interests in Autism: Can Animals Potentially Re-engage Social Attention?

Georgitta J. Valiyamattam[1*]

Harish Katti[2]

Vinay K. Chaganti[3]

Marguerite E. O'Haire[4]

Virender Sachdeva[5]

*-corresponding author, georgia11felicity@gmail.com

[1]Department of Psychology, Andhra University, Visakhapatnam, India

[2]Centre for Neuroscience, Indian Institute of Science, Bengaluru, India

[3]Department of Commerce, Osmania University, Hyderabad, India

[4]Department of Comparative Pathobiology, Purdue University College of Veterinary Medicine, West Lafayette, IN, United States

[5]Child Sight Institute, Nimmagadda Prasad Children's Eye Care Centre, L V Prasad Eye Institute, GMRV Campus, Visakhapatnam, India

## Abstract

A prominent subtype of restricted and repetitive behaviour or interests (RRBs) in autistic children comprises circumscribed interests (CI). CIs occur in 75-95% of children on the autism spectrum, are highly fixated and repetitive interests and generally center on non-social and idiosyncratic topics. The increased salience of CI objects for autistic children also results in a decreased attention to social stimuli and can interfere with social interactions, relations and activities. A parallel line of robust evidence points to greater social engagement and lesser social anxiety in autistic children in the presence of animals with impacts on crucial biomarker indices including skin conductance and salivary cortisol. Neuroimaging evidence also reports a greater activation of reward systems in the brain in response to animal stimuli in autistic individuals, whereas a similar activation is not present for human faces. Behavioral evidence as seen in studies using an eye tracking of visual gaze patterns also reveal a comparatively higher preference for animal stimuli in autistic individuals. The potentially greater social reward attached to animals in ASD, puts forward the interesting and yet unexplored possibility of the presence of competing animal stimuli reducing the disproportionately high visual preference to CI objects.

We examined this possibility through a paired preference study using images of human and animal faces paired with CI and non-CI objects, within an eye tracking paradigm. 32 children (ASD n=16; TD n=16) participated in the study (3391 valid observations). Autistic children showed a significantly greater visual attention to CI objects across their pairings with non-CI objects and social images. Within typical controls, a significantly higher visual attention was seen for social images regardless of their pairing with CI or NCI objects. A key finding was that, while pairing with a CI object reduced the overall amount of social attention elicited in the ASD group, the reduction in attention was not similar for human and animal faces. When paired with CI objects, animal faces elicited greater social attention than

human faces from autistic children.

These results thus suggest that social attention deficits in ASD may not be uniform across human and animal stimuli. Animals may comprise a potentially powerful stimulus category modulating visual attention in ASD.

***Key words:*** *animals, animal assisted intervention; autism spectrum disorder; circumscribed interests; restricted and repetitive behaviour; eye tracking; children*

## Introduction

Social attention deficiencies in ASD have been well documented from an early age (e.g., Jones & Klin, 2013; Tegmark, 2016; Papagiannopoulou et al., 2014). Potential explanations have included either a reduced reward perception from viewing social stimuli (Scott-Van Zeeland et al., 2010; Schultz, et al., 2000) or an active avoidance of eye gaze as a regulatory mechanism for the potential hyper arousal and/or threat experienced in the process (Dalton et al., 2005; Kylliäinen & Hietanen, 2006; Bradley et al., 2001). Social attention deficits are also often accompanied by a relatively greater interest in inanimate stimuli (e.g., Klin et al., 2002; Pierce et al., 2016 and 2011; Klin et al., 2009) These inanimate stimuli may comprise objects with circumscribed interests which form a powerful component attracting a disproportionately high amount of attention in ASD (American Psychological Association, 2013). Circumscribed interests (CIs) are a prominent subtype of restricted and repetitive behavior or interests (RRBs) and form an integral part of the ASD symptom profile. They occur in 75-95% of autistic children (Turner-Brown et al., 2011; South et al., 2005) and are intense, inflexible and repetitive interests observed across autism severity levels (Turner-Brown et al., 2011; Lam et al., 2008; Freeman et al., 1981).They may also be related to the deficits in attentional disengagement that children on the autism spectrum display (Landry & Bryson, 2004; Zwaigenbaum et al., 2005), emerging from possible impairments in subcortical systems (Posner & Dehaene, 1994) and resulting in an abnormal perseveration with certain elements. This atypical prioritization also suggests a greater activation of neural reward circuits in response to CI objects (Cascio et al., 2014; Dichter et al., 2012).

CIs differ in content across individuals diagnosed with ASD and generally center on non-social and idiosyncratic topics (Anthony et al., 2013; Parsons et al., 2017). Baron- Cohen and Wheelwright (1999), divided commonly observed areas of CIs into 15 categories including physics, mathematics, crafts, people and sports/games among others, with certain categories of CIs being more powerful than others.  Exemplars of CIs include animations, dinosaurs, space/physics, vehicles such as trains/planes, blocks, clocks, aliens, traffic signs, famous people, sports schedules and skyscrapers among others (Sasson et al., 2011; Sasson et al., 2008; South et al., 2005, Klin et al., 2007). While many of these interests may also be shared by typical individuals, the narrow areas of these preoccupations and the intensity in their pursuit act as key distinguishing factors in ASD. The increased salience of CI objects can result in a decreased attention to social stimuli and interfere with peer interactions, social norms and daily chores. For instance, eye tracking research by Sasson and Touchstone (2014) using a paired preference paradigm showed that visual attention to human faces reduced significantly in individuals with ASD when the images were paired with high interest CI objects. Similar results were also reported in earlier research. Individuals with ASD were less likely to explore social images when presented alongside images of CI objects (Sasson et al., 2008).

Studies in the past two decades have also challenged the largely negative conceptualization of CIs and pointed out their potentially functional aspects in certain cases. These include their capacity to provide a sense of comfort, enthusiasm and identity. The presence of CI objects may also act as motivators for social relationships with peers who share similar interests and lead to enhanced eye contact and joint attention skills (Gass, 2013; Boyd et al., 2007; Winter-Messiers, 2007). While such a positive incorporation of CIs into the intervention process is encouraging and merits attention, the intensity of CIs and their capacity to dominate other experiences continue to be legitimate concerns. In particular, the atypical pattern of social attention that the presence of CI objects trigger can have important developmental consequences. By significantly reducing the precedence to and opportunities for social experiences, it may trigger a further consolidation of the social functioning deficits that characterize autism.

While existing research has compared visual attention to social stimuli comprising human images versus CI objects, a similar comparison has not been extended so far to social stimuli comprising animals. Popular and anecdotal accounts of the social functioning benefits of animals for autistic children have been further consolidated in recent years with robust empirical evidence. Improvements have been seen on crucial biomarker indices including reduced skin conductance and cortisol awakening responses in the presence of animals indicating lesser arousal and enhanced social functioning (O'Haire et al., 2015; Viau et al., 2010). Studies using rigorous observational models describe significantly greater social motivation, positive moods and vocalizations such as laughing and smiling along with a greater social engagement in autistic children in the presence of animals (e.g. Byström & Persson, 2015; Stevenson et al., 2015; Funahashi et al., 2014; O'Haire et al., 2013; Ajzenman et al., 2013; Gabriels et al., 2012; Silva et al., 2011; Martin & Farnum 2002). Neuroimaging evidence further reports a greater activation of neural reward systems in ASD in response to animal stimuli (Whyte et al., 2016). A preference for animal stimuli in ASD has also been reported through eye tracking (Valiyamattam et al., 2020; Grandgeorge et al., 2016; Muszkat et al., 2015) and other experimental studies (Prothman et al., 2009; Celani, 2002).

The possibly greater social reward attached to animal faces posits an interesting question- Can the presence of competing animal stimuli reduce the disproportionate visual preference to CI objects? The present study aims to assess this possibility using a paired preference paradigm involving both human and animal faces paired with CI and non-CI stimuli. To ensure that human and animal faces represented a class of social stimuli rather than an element of circumscribed interest, this study was conducted on a sample of children who did not report people or animals as an area of circumscribed interest (*see Table 3 for a description of the circumscribed interests reported in the study sampl*e).

## Methods

**Ethics.** All implemented protocols received necessary ethical approvals from the institutions participating in the study. Written informed consent (in English/Telugu) was obtained from school authorities and caregivers. Verbal assent was obtained from the participants where applicable.

**Participants.**

***Recruitment and Eligibility.*** Three special education schools and one regular school in the city of Visakhapatnam, India participated in the study. Inclusion criteria for participants with ASD were: a) age between 5-12 years b) parent and/or teacher reported diagnosis of ASD c) normal or corrected to normal vision as certified by an optometrist and d) a score of ≥11 on the Social Communication Questionnaire (SCQ) and ≥70 on the Social Responsiveness Scale-2 to indicate a diagnosis of ASD. Exclusion criteria for ASD participants were a) a comorbid diagnosis of congenital deafness, intellectual disability, seizure disorder and any acute medical, genetic conditions or psychiatric conditions such as schizophrenia b) an inability to follow instructions and c) an inability to achieve eye tracker calibration. Inclusion criteria for typically developing (TD) participants were a) age between 5-12 years b) no parent and/or teacher reported diagnosis of ASD c) normal or corrected to normal vision as certified by an optometrist and d) score of ≤10 on the Social Communication Questionnaire (SCQ) and ≤69 on the Social Responsiveness Scale-2, to indicate the absence of an ASD diagnosis and social deficits.

***Sample Characteristics.*** A total of 54 autistic children and 47 TD children joined the study. Of these, 33 children were excluded as -a) 2 children did not meet the ASD diagnostic criteria on the SCQ and SRS-2 b) 26 children with ASD did not meet the criteria for normal or corrected to normal vision c) 3 children were unable to follow experiment instructions d) 2 children could not achieve eye tracker calibration and e) 5 children did not give verbal assent for participation. Similarly, 24 TD children were excluded as they did not meet the criteria for normal or corrected to normal vision. The final sample of ASD participants consisted of 16 children (M= 13, F=3; *M*age 9.94yrs). Out of the TD sample consisting of 23 children, 13 males and 3 females were randomly selected so as to match the ASD and TD groups on gender in line with previous research (Sasson & Touchstone, 2014), considering evidence of gender differences in interests with respect to social stimuli and CI objects (e.g., DeLoache et al., 2007). The final sample of TD participants therefore consisted of 16 children (M= 13, F=3; *M*age 9.10yrs) *(Table 1 shows the demographic details of the participants).*

***Measures.***

*Screening Measures.*

Two standardized measures namely the Social Communication Questionnaire (SCQ)-Lifetime version and the Social Responsiveness Scale (SRS-2) were used for the purpose of autism screening. The SCQ is completed by the parent or caregiver and corresponds with the Autism Diagnostic Interview-Revised (ADI-R) (Lord et al., 1994; Norris & Lecavalier, 2010; Le Couteur et al., 2003). A brief measure, it comprises 40 “yes/no” items, scored as 0 or 1, with 1 ratifying the presence of the autism symptom (Rutter et al., 2003). A cut-off score of ≥11 was used for ASD screening (Norris & Lecavalier, 2010). The Social Responsiveness Scale (SRS-2) (Constantino & Gruber, 2012), is a 65-item rating scale completed by a parent/teacher/other adult informant. Symptom severity is measured on a 4-point Likert scale scored from 0 to 3, with a higher score indicating greater social impairment. In addition to full-scale scores, the SRS-2 provides scores on five subscales namely social awareness, social motivation, social communication and interaction, social cognition and restricted and repetitive behaviours (RRB) (Constantino & Gruber, 2014). A cut-off score of ≥70 on the SRS-2 was used for ASD screening (Constantino & Gruber, 2014).

Raven's Colored Progressive Matrices (RCPM) was used for IQ assessment. It consists of 36 items spread across three sets of 12 items each. While its routine applicability is for children (4 to 11 years), its use can also be broadened to include the elderly and those with mental/physical functioning deficits (Raven et al., 1996).

The total score on the Repetitive Behavior Scale –Revised (RBS-R) was used to assess the presence of restricted and repetitive behaviors in the study sample. The RBS-R comprises 43 items subsumed within six subscales namely Stereotypic Behavior, Self-Injurious Behavior, Compulsive Behavior, Ritualistic Behavior, Sameness Behavior and Restricted Behavior that examine the presence and severity of a repetitive behavior based on information provided by parents or caregivers (Bodfish et al., 1999, 2000). The Cambridge Obsessions questionnaire (Baron-Cohen & Wheelwright, 1999) was used to collect broad information regarding the content of obsessions among the participants which was then classified according to the categorization provided by Baron- Cohen and Wheelwright (1999) *(See Table 3).*

*Visual Gaze Fixation Measure.* The Tobii X3-120 eye tracker and the Tobii Pro Studio Software (Tobii, Stockholm, Sweden) were used to collect visual data. Due to the high freedom from head movement rate (19.7″ x 15.7″ - width x height) and precise data that the Tobii X3-120 provides (Tobii, Stockholm, Sweden; www.tobii.com), it has found extensive use in research on developmental disabilities (e.g., Pierce et al., 2016; Sasson et al., 2011)

*Visual Stimuli.* Participants were shown 60 paired color photographs. The pairings were as follows: *humans and animals*= 10 images; *humans and CI objects* =10 images; *humans and non-CI objects* =10 images; *animals and CI objects* =10 images; *animals and non-CI objects* =10 images; *CI objects and non-CI objects* =10 images. The human images consisted of adult Indian male and female faces drawn from the IISCIFD Indian face dataset (Katti & Arun, 2017), whereas the animal and object images were acquired from internet sources. Object images consisted of CI and NCI object categories used in earlier research and reported to be of high and low autism interest respectively (South et al. 2005; Sasson et al., 2008, 2011; Sasson et al., 2012; Unruh et al., 2016). CI object categories consisted of vehicles, airplanes, trains, clocks, and blocks, whereas NCI object categories consisted of tools, musical instruments, furniture, clothes and plants (Sasson & Touchstone, 2014) with two exemplars from each category included in the stimulus set. All images were edited using Adobe Photoshop 7.0 for a uniform gray background and to control for light intensity. During preliminary piloting, brightness was regulated to permit comfortable viewing by children and the same was maintained throughout the experiment.

*Data capture procedures.* The images were presented on a 21.5″ high-definition LCD monitor (1920×1080 pixel) using Tobii Pro studio© software. Participants were seated on a height adjustable chair either individually or in the lap of a caregiver or a research assistant, at an approximate distance of 60cm from the screen. A manual five-point infant calibration was used where the child had to follow an animated cartoon around the screen. If calibration was unsuccessful, recalibration was performed and only those participants who achieved a successful calibration as verified by the Tobii X3-120 were retained. Each image pair was presented for 5 seconds. After each image-pair presentation, an interstimulus interval jittered at 1, 1.5 or 2 seconds, was introduced, so as to reorient attention *(see Fig 1).* The image-pairs were presented in a randomized order to counterbalance possible sequence effects. The total experiment had a run time of 390 ± 30 seconds and all participants completed the testing procedures in the same setting, free from distracters and with optimal illumination. Two research assistants facilitated the implementation of the experimental protocols.

**Data Analysis**

Regions of interest (ROIs) were drawn using interfaces provided by Tobii Studio©. ROI boxes encompassed the face including hairline (for human images) as well ear tips as applicable and consisted of closely contoured ellipses along the boundaries of object images. Images were resized using Adobe Photoshop 7.0 so that ROI boxes were as near as possible to 600 x 850 pixels which would then roughly correspond to 26.87 x 18.81 degrees of visual angle. Post-hoc raw data was exported using Tobii Studio ©software (Tobii, Stockholm, Sweden). This included a fixation classification step detecting fixations based on the velocity of directional shifts of the eye (I-VT algorithm implemented in Tobii Studio). As in our previous studies, custom MATLAB© scripts were utilized to extract and tabulate fixation related statistics. ROI-wise fixation statistics were tabulated in custom data structures as were dwell statistics obtained by collating fixations at different locations within an ROI, over a single presentation of an image. Image presentations, for which no fixation was made in any ROI, were not used for further analysis.

Anderson-Darling test of normalcy computed on all array-wise data subsets revealed a non-normal distribution ($p \leq 0.05$). In line with previous research in the area (e.g., Sasson & Touchstone, 2014), the study examined visual attention in terms of the three dependent variables of preference, prioritization and duration. Preference was measured in terms of the total fixation time allocated by a subject to a stimulus in an array. Prioritization was measured in terms of the latency of first fixation to any one member of the paired stimuli in an array. Duration was measured in terms of fixation time per visit to a stimulus in an array before a shift in attention occurred. The final data set comprised 3391 observations. With reference to preference, an observation was defined as the total dwell time within an ROI of an image shown to the participant. With reference to prioritization, an observation was defined as the first fixation latency within an ROI of an image shown to the participant. With reference to duration, an observation was defined as the average fixation duration per visit, within an ROI of an image shown to the participant *(See Supplementary files for a detailed count of observations).*

Accounting for the characteristics of the data, separate Wilcoxon-sign rank tests were computed for the three dependent variables to assess the impact of the within-subjects independent variable of object type (CI, NCI, Human, Animal) and between-groups independent variable of diagnosis (ASD, TD) in terms of all possible effects within and across the arrays in which the images were presented. Data was analyzed using the R 3.4.3, Partykit version 3.2-2.

## Results

An array-wise description of within and between groups differences between ASD and TD participants is reported. *Table 2* shows the Mean values and SDs on preference, prioritization and duration indices across arrays.

***CI-NCI Array.*** *(see Figs. 2 & 3)* Results indicated a significant effect of diagnosis and object category. Within autistic children, there was a significantly greater sustained fixation time per visit ($p \leq 0.05$) and total fixation time ($p \leq 0.01$) to CI objects when paired with NCI objects. Within TD participants, shorter first fixation latency was observed for CI objects ($p \leq 0.001$) indicating greater prioritization than NCI objects. Between groups comparisons revealed that for NCI objects, autistic children had significantly lesser sustained fixation per visit and total fixation time ($p \leq 0.01$) than TD children. No differences were observed between the two groups with respect to CI objects.

***Animal-Human Array.*** *(see Fig. 4)* Within autistic children, significantly higher total fixation duration ($p \leq 0.01$) and sustained fixations per visit ($p \leq 0.001$) were reported to animal images when paired with human images. Within TD children significantly shorter first fixation latency ($p \leq 0.05$) greater sustained attention and higher fixation durations (both p values $\leq 0.001$) were observed for animal images as compared to human images. Between groups comparisons revealed that TD children reported higher total fixation durations and better sustained attention to both animal and human images (all p values $\leq 0.001$) when compared to autistic children.

***Animal-CI arrays and Human-CI arrays.*** *(see Figs. 5 & 6)* Within autistic children, the focus on CI objects was the highest across all presentations. However, when paired with CI objects, animal images attracted significantly greater sustained fixations per visit as compared to human images ($p \leq 0.05$). Between groups analysis revealed that TD children reported significantly greater sustained attention and total fixation durations to all social stimuli (both animals and humans) than autistic children when paired with CI objects (all p values $\leq 0.001$). TD children also showed a quicker latency to fixate on human images when paired with CI objects as compared to the ASD group ($p \leq 0.001$).

***Animal-NCI arrays and Human-NCI Arrays.*** Within group comparisons for autistic children did not reveal a strong preference for NCI objects unlike CI objects. When paired with NCI objects, animal images drew significantly higher sustained fixations per visit and total fixation durations than human images ($p \leq 0.05$). Between groups analysis revealed that TD children reported significantly greater sustained attention, higher total fixation durations (all p values $\leq 0.001$) and quicker first fixation latencies (animal: $p \leq 0.001$; human: $p \leq 0.01$) to all social stimuli when paired with NCI objects as compared to the ASD group.

***Social Images-CI and Social Images-NCI Arrays.*** Within the ASD group, a significantly lesser total fixation duration was seen to social images when paired with CI objects ($p \leq 0.05$) and greater sustained attention per visit, quicker latencies and higher total fixation duration to social images when paired with NCI objects (all p values $\leq 0.001$). TD children reported a significantly greater sustained attention per visit, quicker latencies and significantly higher total fixation duration for social images regardless of whether they were paired with CI or NCI objects (all p values $\leq 0.001$).

*(See Supplementary files for a visualization of results across all arrays)*

## Discussion

The present study examined the dynamics of visual attention to human and animal stimuli when paired with CI and non-CI objects. Comparisons both within the ASD group and between ASD and TD revealed that autistic children showed a significantly greater visual interest to CI objects across all the pairings (with NCI objects, human images and animal images) as revealed by a significantly greater preference, prioritization and sustained attention. Typical children however did not report a similar inclination towards CI objects.

The results obtained also revealed a significantly lesser visual prioritization to social images in autistic children when compared to typical controls across pairings with CI and NCI objects. Thus, unlike earlier findings (Sasson & Touchstone, 2014), the differences in visual attention to social stimuli between the ASD and TD groups did not absolutely level out in the absence of CI pairings. Typical controls showed a significantly higher attention to social images regardless of their pairing with CI or NCI objects.

While overall social attention was lesser in autistic children, social attention patterns within the ASD group varied across CI and NCI pairings. Social attention declined significantly in the presence of CI objects whereas a similar pattern was not seen for NCI objects. Comparable results have been reported in earlier studies which indicate that a decline in the focus on social stimuli in autistic children may be context-dependent and modulated by stimulus salience in competing stimuli as seen with objects of high autism interest/circumscribed interests (Sasson & Touchstone, 2014; Sasson, et al., 2008). The findings in the present study thus add to existing evidence of overall social attention deficits in autism and the powerful influence that objects with circumscribed interests may exercise in modulating visual attention. Unruh et al. (2016) explain this phenomenon as the effects of “motivational toxicity” (Bozarth, 1994), a term referring to a complex neurobiological mechanism emerging from the field of addictions and compulsive behavior and implicating the reward circuitry and associated systems such as the limbic system. Motivational toxicity refers to a decreased motivation for one activity or stimulus due to an increased preference for another and may provide the key connecting link between seemingly varied phenotypic manifestations of autism such as reduced social motivation and restricted and repetitive interests and their expressions in various behavioral preferences and preoccupations (Unruh et al., 2016). The capacity of CI stimuli in drawing attention away from social stimuli can have harmful ramifications for the development and consolidation of social attention biases, social information processing and corresponding neural specificities and may further strengthen the existing non-social bias in the ASD neural reward circuitry.

While studies comparing attention to social versus CI stimuli have so far focused on social stimuli comprising human faces, the present study extended the social stimulus category to include both human and animal faces as animate categories that elicit social responses, affect and interaction. A key finding observed was the significantly greater sustained attention per visit to animal faces as compared to human faces when paired with CI objects. While pairing with a CI object reduced the overall amount of social attention elicited, the reduction in attention was not similar for human and animal faces. Animal faces prompted lesser attention reductions in autistic children than human faces. Animal faces also elicited more social attention from autistic children as compared to human faces when paired with NCI objects. Animals also received significantly greater visual attention than human images when animal and human images were paired together in both autistic children and typical controls indicative of an overall greater preference for animal stimuli in children, irrespective of diagnosis.

The findings in this study cumulatively indicate that social attention deficits may not be uniform across human and animal stimuli and animals may comprise a potentially powerful stimulus category modulating visual attention in children with ASD. Possible explanatory paradigms for the greater attention to animal stimuli include the biophilia hypothesis indicating an inherent desire in humans to connect with other forms of life and life-like processes in nature (Wilson, 1984) and particularly animals (Beck, 2014). Several studies reveal this preference for animal stimuli. For instance, New et al. (2007) reported an animate monitoring bias in humans. When presented with complex natural scenes and their duplicates with alterations, individuals were faster at detecting the changes in animals when compared to other inanimate objects. On similar lines, greater amygdala activation was seen in response to photographs of animals among photographs of famous persons, landmarks or objects indicating a categorical selectivity for animal pictures (Mormann et al., 2011). The preference to animal stimuli has also been explained in terms of the possible effects of neoteny or the preservation of the morphological and behavioural juvenile traits in several domesticated animals through selective breeding. The resultant infant-like features and behaviour in terms of a greater playfulness and lesser aggressiveness, can be attractive to humans from an evolutionary point of view triggering a lesser perception of threat and greater approach and nurturance behaviours (Beck, 2014; Lorenz, 1943). Animal presence has also been linked to a greater secretion of oxytocin – a hormone key to social attention, eye-contact, bonding and behaviours (Beetz et al., 2012; Kosfeld et al., 2005; Odendaal & Meintjes, 2003; Uvnäs- Moberg et al., 2000). Considering that individuals with autism experience similar social benefits and elicit a comparable preference for animals as their neurotypical counterparts, biophilia and the effects of neoteny and oxytocin secretion can be hypothesized as possible explanatory factors for the greater visual attention to animals. In fact, animals have been found to elicit a heightened social awareness in autistic children (Martin & Farnum, 2002) which may also suggest consequent social attention benefits.

The findings of this study thus add to the existing neural and biomarker evidence base of a greater preference towards animal stimuli in children on the autism spectrum. Similar findings have been reported in behavioural and neuroimaging research, with animal stimuli eliciting preferential attention from children with ASD (Valiyamattam et al. 2020; Celani, 2002; Prothman et al., 2009; Grandgeorge et al., 2016; Muszkat et al., 2015; Whyte et al., 2016) perhaps modulated by greater reward (Whyte et al., 2016).

**Limitations and Recommendations**

The present study used non-individualized CI object categories that have been found by previous research to engage disproportionately preferential attention in autistic children (South et al. 2005; Sasson et al., 2008, 2011; Sasson & Touchstone, 2014). While some previous studies examining circumscribed interests in autism have used non-individualized CI images (e.g., Sasson & Touchstone, 2014), others have used individualized stimuli (e.g., Foss- Feig et al., 2016). While the object categories in the present study represented areas of circumscribed interests for the participants *(See Table 3),* it could not be determined whether they reflected each participant's unique/most salient circumscribed interest. However, across all study participants, the CI object categories consistently commanded a disproportionately greater amount of visual attention than other daily living objects or social stimuli that they were paired with, indicative of their status as high autism interest objects.

The use of static images in a paired preference paradigm instead of dynamic stimuli may also be considered a potential limitation. However, the use of static stimuli has been justified on several grounds in previous research (Unruh et al., 2016; Sasson & Touchstone, 2014). These include firstly, a better experimental control in terms of matching the stimulus pairs on low level visual properties that attract attention in autistic children as seen in detail-oriented tasks (Mottron et al., 2006; O'Riordan et al., 2001). Such a matching would be extremely difficult to achieve in the case of complex dynamic stimuli. Also, the use of static stimuli in eye tracking paradigms with ASD individuals have been found to elicit the same attentional atypicalities though with differing intensities (e.g., Sasson & Touchstone, 2014; Sasson et al., 2008, 2011; Elison et al., 2012). Further researchers like Parish-Morris et al., (2013) argue that as seen in their study, children across diagnostic groups may be overwhelmed by the properties of dynamic stimuli related to circumscribed interests thus making group differences between ASD and typical controls incomprehensible.

A small number of outliers to the total gaze time of 5 seconds or 5000 milliseconds were observed. These may have been triggered by several factors. In the Tobii software, fixation events were counted if they started when the stimulus was still present although some part of it may have extended into the duration of the interstimulus interval resulting in outliers emerging from such transition effects. Inadvertent interferences in errorless eye tracker functioning beyond the control of the experimenter may also been seen as a potential cause.  Examples include unidentified background applications or other technological irregularities such as the computer being able to detect an eye tracker whereas Tobii studio being unable to (Error Codes, Tobii, n.d.). The proportion of outliers were however very minor when compared to the valid observations obtained.

While this study offers possible explanations for the greater preference for animal stimuli over human stimuli across pairings, it is limited in its capacity to identify the exact factors that may trigger this phenomenon. The participants in the present study were aged between 6-12 years (late childhood), with a diagnosis of moderate to severe autism. Whether effects seen in the present study can be replicated in a downward extension of the sample comprising toddlers and younger children would be a potential area of further research. It would also be interesting to see whether these effects persist across other autism severity and cognitive levels.

## Conclusion

Overall results from this study add to the existing evidence across experimental methodologies that point to a greater preference for animals in children with autism. The capacity of animals to potentially redirect attention to social stimuli, away from inanimate stimuli particularly those that "trap" attention (Sasson et al., 2008) can be an interesting evidence base for the use of animals in intervention plans for autistic children and deserves further exploration.

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**Table.1**
**Demographic details of the participants**

| **Characteristic** | **ASD (n=16)** | **TD (n=16)** | **t-value (p-value)** |
|---|---|---|---|
| **Age** | 9.94 (1.34) | 9.10 (1.70) | 1.55 |
| **Gender** | 13M/3F | 13M/3F | - |
| **Social Communication Questionnaire (SCQ)** | | | |
| Total | 14.33 (6.02) | 3.92 (1.16) | 5.88** |
| **Social Responsiveness Scale (SRS)** | | | |
| *T*-score (Full-Scale) | 69.19(16.20 ) | 48.18 (4.51) | 4.18** |
| **Repetitive Behavior Scale (Revised)** | | | |
| Total Score | 34.43(18.91) | 4.25(1.36) | 5.48** |
| **Raven's Colored Progressive Matrices (CPM)** | | | |
| Percentile description | **ASD (n=16)** | **TD (n=16)** | |
| | *Between 10th-25th percentile (n=11) Grade IV*<br>*At or below 10th percentile- Grade IV- (n=05)*<br>*Below Average Intellectual Capacity* | *Between 25th and 50th percentiles (n=16) Grade III-*<br>*Intellectually Average* | |

*ASD, Autism Spectrum Disorder; TD, Typically Developing; n, Sample Size; Scores in the cells represent means and standard deviations unless otherwise noted. * p≤0.05 ** p≤0.01*

**Figure. 1**

**Diagram illustrating the stimulus presentation within the eye tracking paradigm. Each target stimulus was displayed for a period of 5 seconds (5000ms) followed by an inter- stimulus image displayed for a variable period of 1, 1.5 or 2 seconds.**

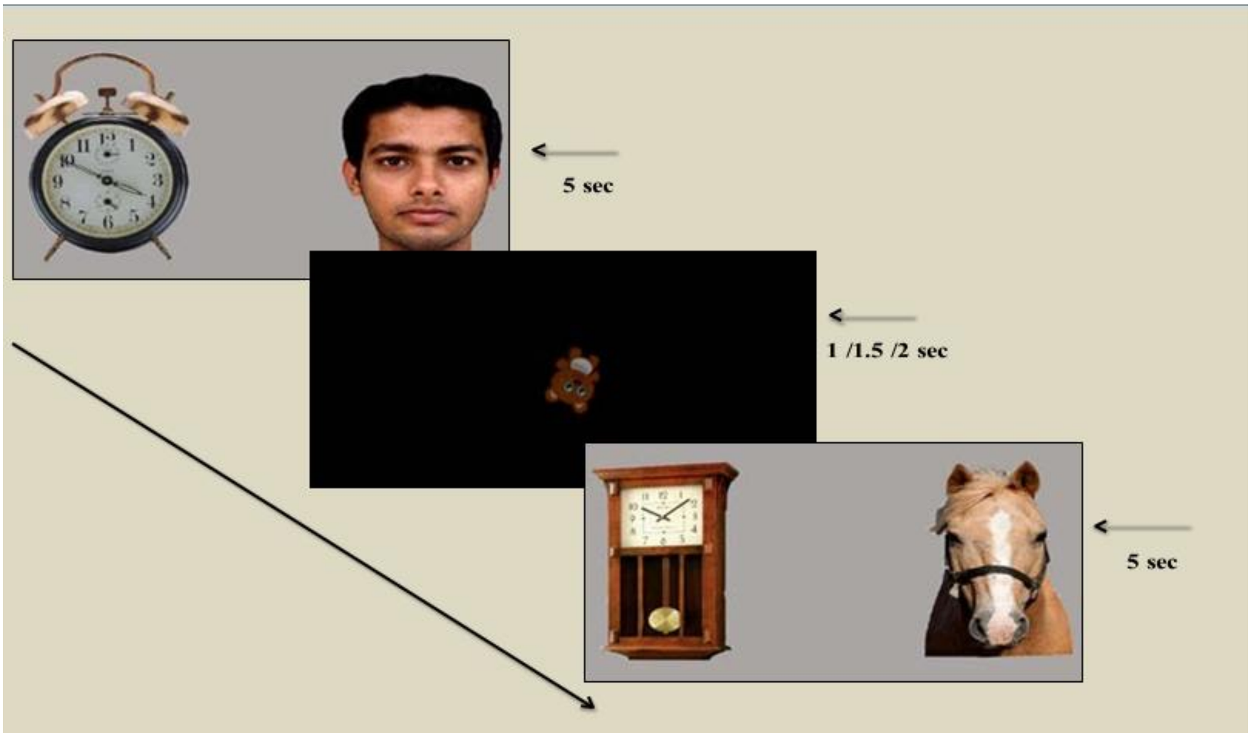



**Figure. 2**

**Differences in visual attention within and between ASD and TD participants on arrays pairing CI and NCI objects -(*Total number of Observations= 3391)***

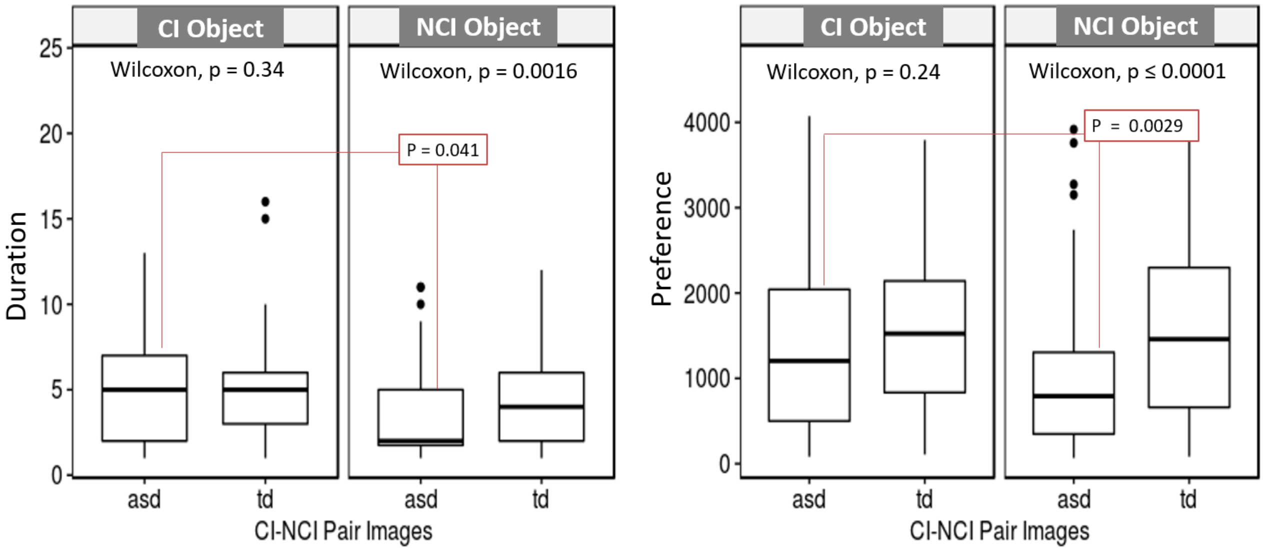


**Figure. 3**

**Heat Diagram illustrating the most attended areas of the image by ASD participants and the disproportionately greater attention to CI objects (train) in ASD.** ***(Gradients of most attended areas on the heat maps range from red through yellow to green)***

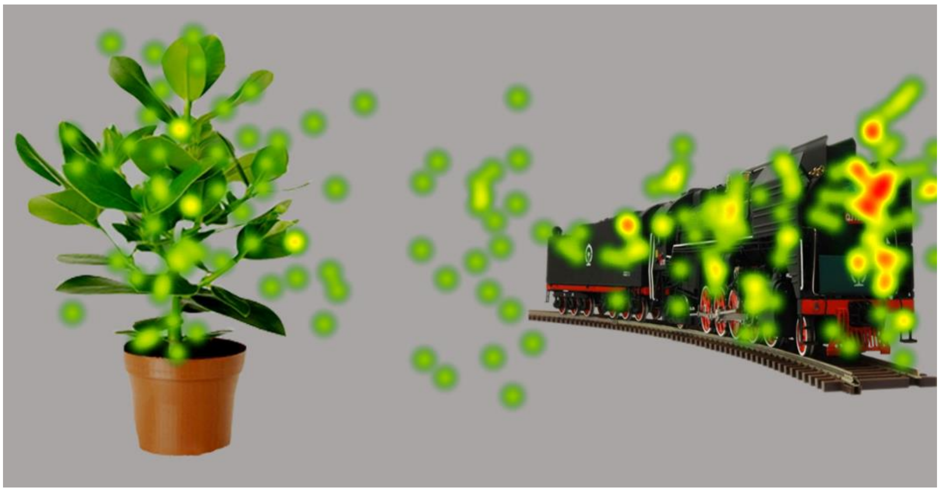


**Figure. 4**

**Differences in visual attention within and between ASD and TD participants on arrays pairing Animal and Human Face Images-(*Total number of Observations= 3391)***

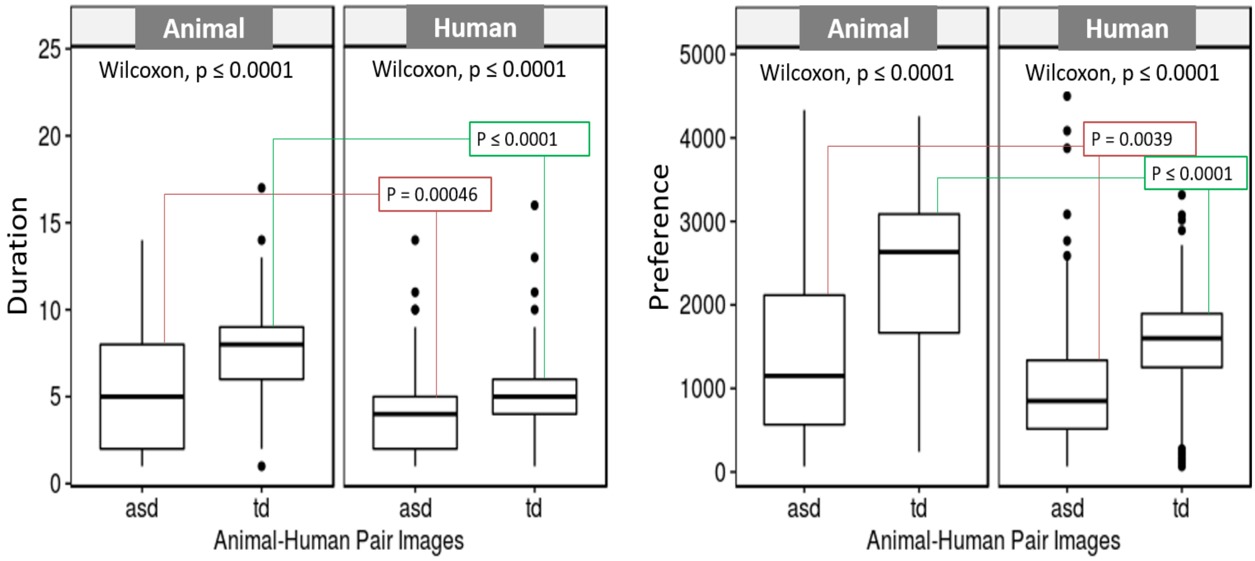


**Figure. 5**

**Differences in visual attention within and between ASD and TD participants on arrays pairing Animal and Human Face Images with CI objects -(*Total number of Observations= 3391)***

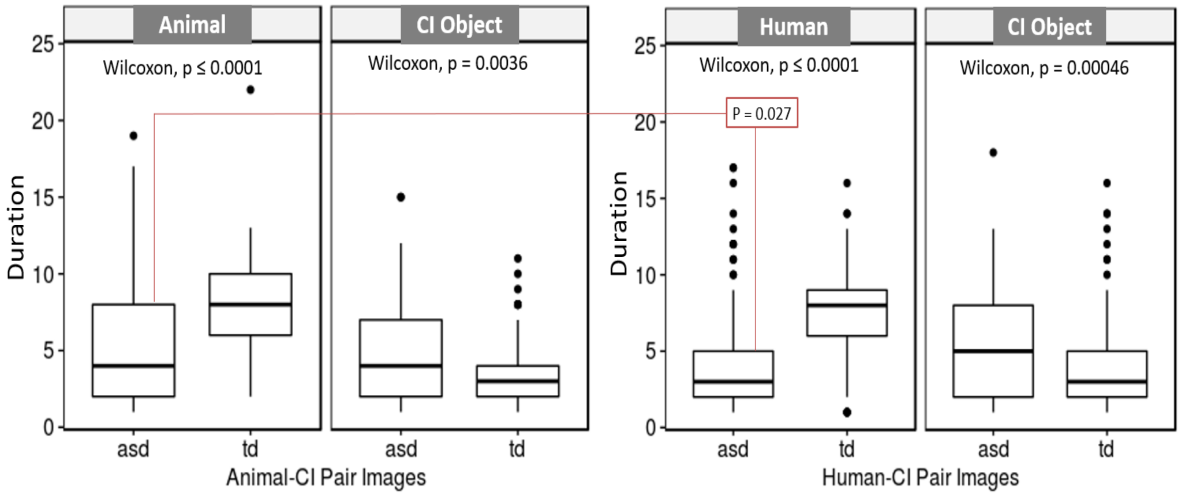



**Figure. 6**

**Heat Diagram illustrating the most attended areas of the image by ASD participants and the greater visual attention to animal images as compared to human images when paired with CI objects (clock) in ASD.** ***(Gradients of most attended areas on the heat maps range from red through yellow to green)***

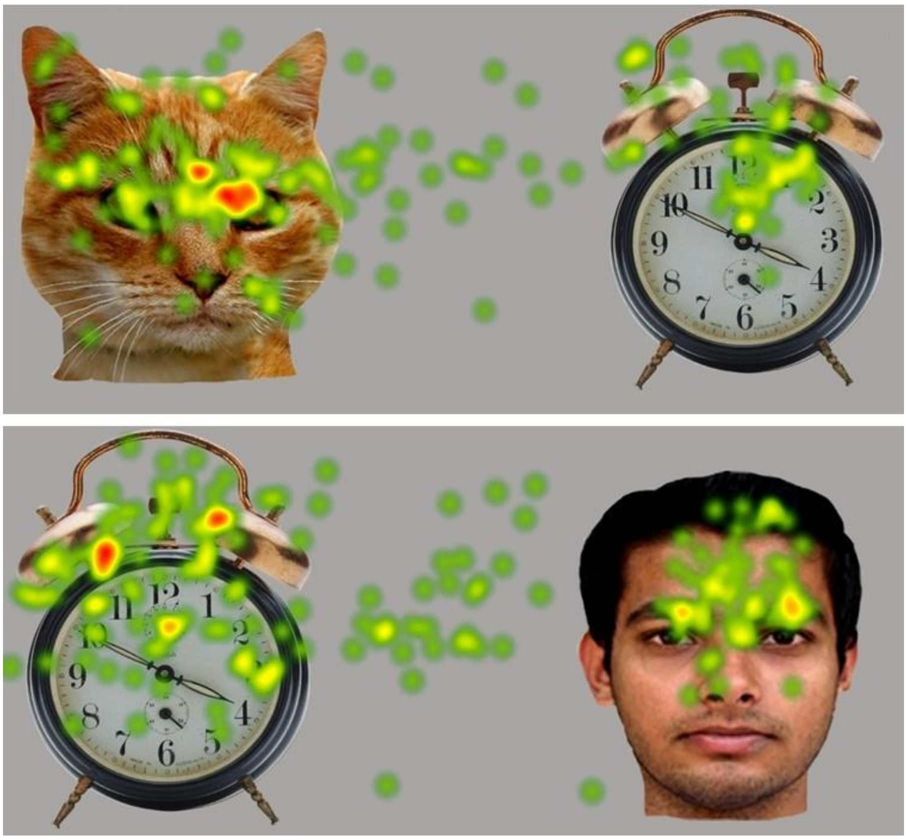


**Table. 2**

**Mean and SD values on Preference (Total Fixation Duration), Prioritization (Latency of Fixation) and Duration (Sustained fixation duration per visit) indices of visual attention across stimulus arrays.**

| Arrays | Mean (Total Fixation Duration) | SD (Total Fixation Duration) | Mean (Latency of Fixation) | SD (Latency of Fixation) | Mean (Sustained fixation duration per visit) | SD (Sustained fixation duration per visit) |
|---|---|---|---|---|---|---|
| **Animal-CI** | **1618.00** | **1171.78** | **1504.22** | **2352.26** | **5.28** | **3.38** |
| **ASD** | **1390.77** | **1116.07** | **1632.42** | **2958.05** | **4.97** | **3.52** |
| O1 | 1416.44 | 1172.90 | 1471.58 | 2744.92 | 5.21 | 3.69 |
| O2 | 1361.82 | 1051.96 | 1813.81 | 3182.11 | 4.69 | 3.30 |
| **TD** | **1833.79** | **1184.39** | **1382.46** | **1570.60** | **5.57** | **3.22** |
| O1 | 2651.21 | 1037.32 | 994.52 | 1460.74 | 7.63 | 2.78 |
| O2 | 959.61 | 522.59 | 1797.35 | 1582.70 | 3.36 | 1.93 |
| **Animal-Human** | **1623.25** | **1012.45** | **1553.12** | **3029.75** | **5.59** | **2.95** |
| **ASD** | **1232.23** | **969.26** | **1959.03** | **4086.10** | **4.65** | **2.95** |
| O1 | 1416.14 | 1049.41 | 1978.65 | 4172.83 | 5.32 | 3.25 |
| O2 | 1047.08 | 845.09 | 1939.27 | 4011.05 | 3.97 | 2.46 |
| **TD** | **1991.77** | **910.06** | **1170.56** | **1350.22** | **6.48** | **2.67** |
| O1 | 2425.89 | 911.62 | 986.41 | 1372.61 | 7.76 | 2.54 |
| O2 | 1543.57 | 657.74 | 1360.70 | 1304.00 | 5.16 | 2.10 |
| **Animal-NCI** | **1634.37** | **1132.11** | **1762.29** | **3376.56** | **5.31** | **3.44** |
| **ASD** | **1355.83** | **1105.87** | **2326.96** | **4655.62** | **4.95** | **3.52** |
| O1 | 1609.25 | 1207.26 | 2338.87 | 4845.61 | 5.92 | 3.73 |
| O2 | 1033.12 | 864.15 | 2311.79 | 4422.45 | 3.72 | 2.79 |
| **TD** | **1882.16** | **1098.79** | **1259.94** | **1328.78** | **5.63** | **3.35** |
| O1 | 2613.94 | 939.39 | 576.13 | 740.23 | 7.84 | 2.73 |
| O2 | 1062.14 | 546.55 | 2026.19 | 1422.96 | 3.17 | 1.97 |
| **CI-NCI** | **1382.70** | **967.76** | **1405.98** | **2264.24** | **4.39** | **2.72** |
| **ASD** | **1245.68** | **1033.89** | **1730.37** | **3081.12** | **4.30** | **2.91** |
| O1 | 1461.30 | 1131.71 | 1392.18 | 3150.32 | 5.11 | 2.95 |
| O2 | 996.12 | 846.31 | 2121.80 | 2965.48 | 3.37 | 2.57 |
| **TD** | **1504.10** | **889.63** | **1118.60** | **1050.39** | **4.47** | **2.53** |
| O1 | 1492.17 | 839.35 | 922.40 | 978.97 | 4.73 | 2.58 |
| O2 | 1517.07 | 944.48 | 1331.93 | 1087.09 | 4.19 | 2.45 |
| **Human-CI** | **1653.49** | **1227.58** | **1722.72** | **2920.37** | **5.39** | **3.46** |
| **ASD** | **1396.57** | **1177.57** | **2280.05** | **3960.21** | **4.94** | **3.57** |
| O1 | 1147.07 | 990.65 | 2082.99 | 3318.55 | 4.36 | 3.52 |
| O2 | 1646.08 | 1294.88 | 2477.12 | 4515.63 | 5.52 | 3.55 |
| **TD** | **1882.79** | **1227.73** | **1225.30** | **1283.34** | **5.80** | **3.32** |
| O1 | 2633.95 | 1230.07 | 793.73 | 938.03 | 7.49 | 2.92 |
| O2 | 1096.58 | 542.81 | 1677.01 | 1435.08 | 4.03 | 2.74 |
| **Human-NCI** | **1554.8** | **1183.61** | **1627.42** | **2692.38** | **5.01** | **3.46** |
| **ASD** | **1263.39** | **1170.52** | **2050.34** | **3618.77** | **4.41** | **3.49** |
| O1 | 1512.19 | 1349.19 | 1980.94 | 3673.85 | 5.22 | 3.95 |
| O2 | 945.36 | 789.75 | 2139.05 | 3561.16 | 3.37 | 2.45 |
| **TD** | **1811.15** | **1136.60** | **1255.59** | **1356.05** | **5.55** | **3.35** |
| O1 | 2565.73 | 992.10 | 752.02 | 1078.69 | 7.72 | 2.78 |
| O2 | 982.17 | 563.14 | 1808.82 | 1416.15 | 3.16 | 2.04 |
| **Grand Total** | **1582.91** | **1124.76** | **1599.40** | **2811.54** | **5.18** | **3.27** |

*ASD, Autism Spectrum Disorder; TD, Typically Developing; CI, Circumscribed Interest Objects; NCI, Non-Circumscribed Interest Objects;O1, Object 1- refers to first stimulus name in the array, O2, Object 2- refers to second stimulus name in the array e.g., Animal –CI Array- O1-Animal, O2-CI object.*

***Total number of Observations, 3391***

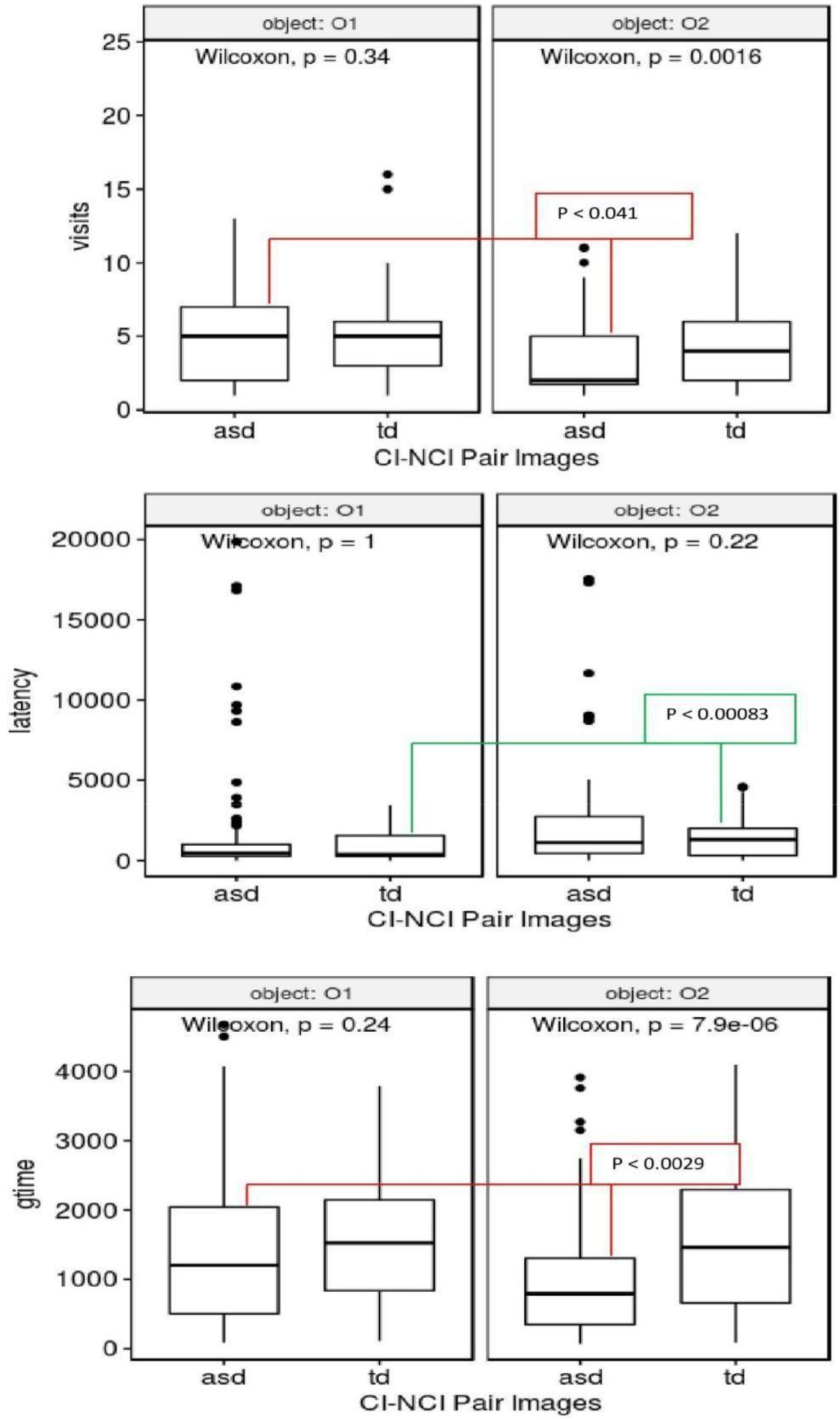
**Table. 3**

**Content of Circumscribed Interests in the sample of participants as seen on the Cambridge University Obsessions Questionnaire and classified according to the categorization by Baron- Cohen and Wheelwright (1999).**

| **Category of Circumscribed interest** | **Number of children displaying the Circumscribed interest** | **Examples of Circumscribed interest areas** |
|---|---|---|
| Folk Physics | 16 (100%) | Vehicles (Trains, buses, cars, motorcycles), fairy lights, clocks, Jenga blocks. |
| Language | 7 (43.5%) | Echoing words, repeating phrases or monosyllables. |
| Attachments | 13 (81.25%) | Toy vehicles, digital watches, stuffed toys. |
| Food | 5 (31.25%) | Particular foods [e.g., Idly (rice cake), Orange cream biscuits], Food related preferences (e.g., same tiffin box, yellow plate and spoon) |
| Sports/Games | 6 (37.5%) | Cricket, Tennis/Badminton. |
| Television/audio | 14 (87.5%) | Cartoon network<br>Fast paced movie songs<br>Mythological television series |
| Sensory | 15 (93.75%) | Likes moving objects (vehicles, spinning or rotating objects- fan blades, tops), insists on sniffing deeply on certain smells (shampoo, petrol, tea/coffee powder) |

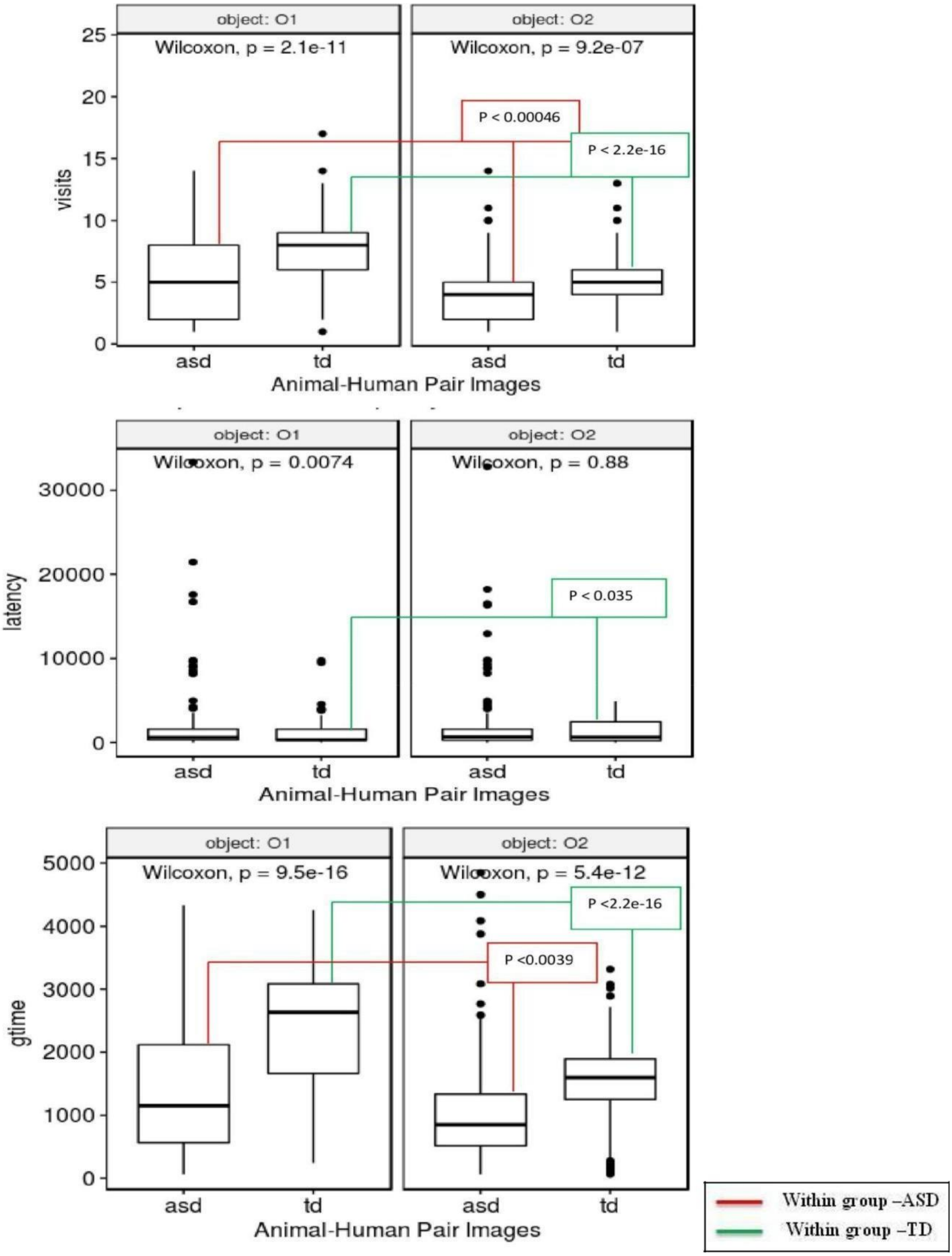
**SUPPLEMENTARY FILES**

**Fig. 1 Differences in visual attention with respect to duration (top), prioritization (middle) and preference (bottom), within and between ASD and TD participants on arrays pairing CI and NCI objects- (*Total number of Observations= 3391)***



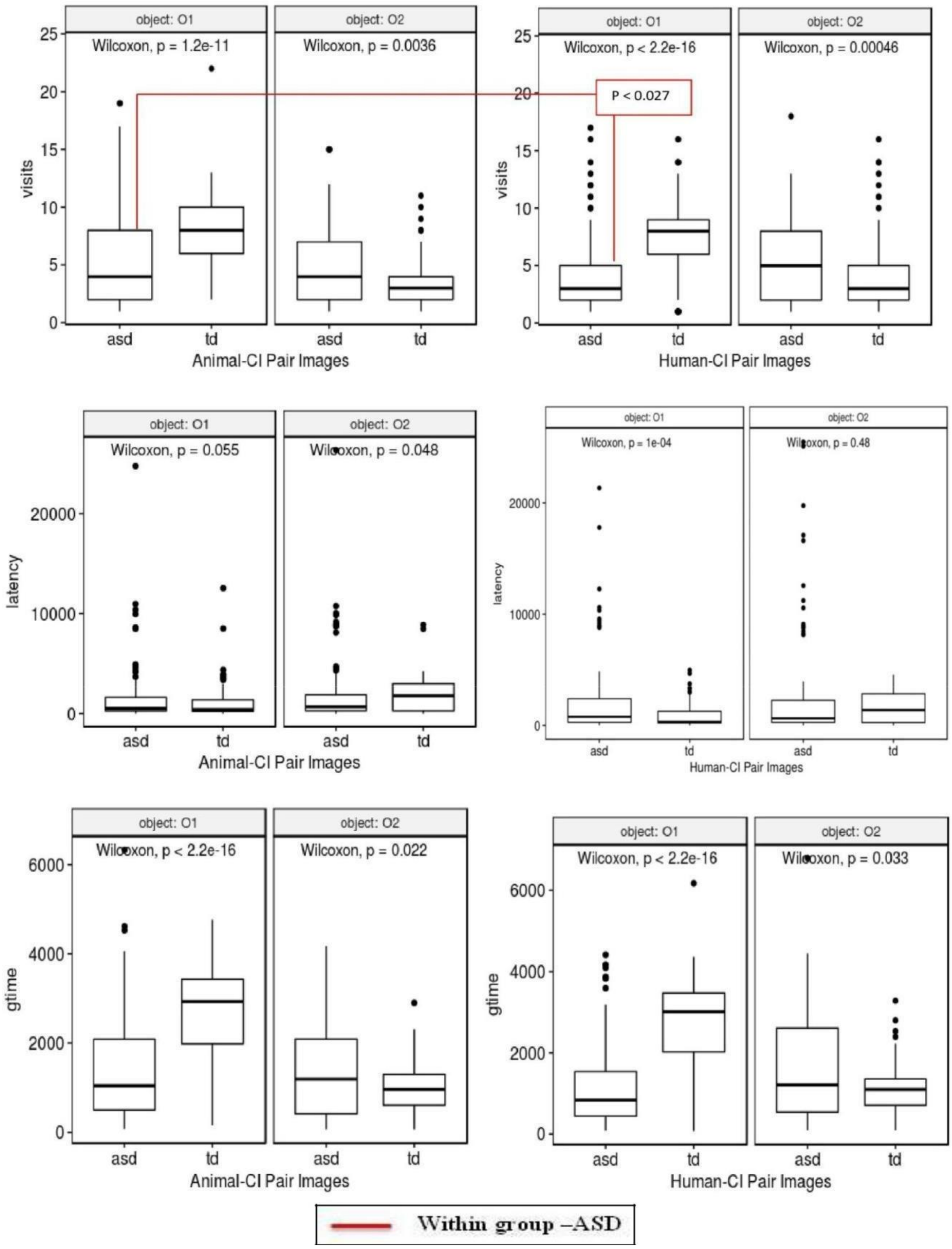

*ASD, Autism Spectrum Disorder; TD, Typically Developing; CI, Circumscribed Interest object, NCI, Non-Circumscribed Interest object; O1, CI object; O2, NCI object; Visits, sustained attention per visit; Latency, time to first fixation; gtime, total fixation duration.*

**Fig.2 Differences in visual attention with respect to duration (top), prioritization (middle) and preference (bottom), within and between ASD and TD participants on arrays pairing Animal and Human Face Images-(*Total number of Observations*= *3391)***



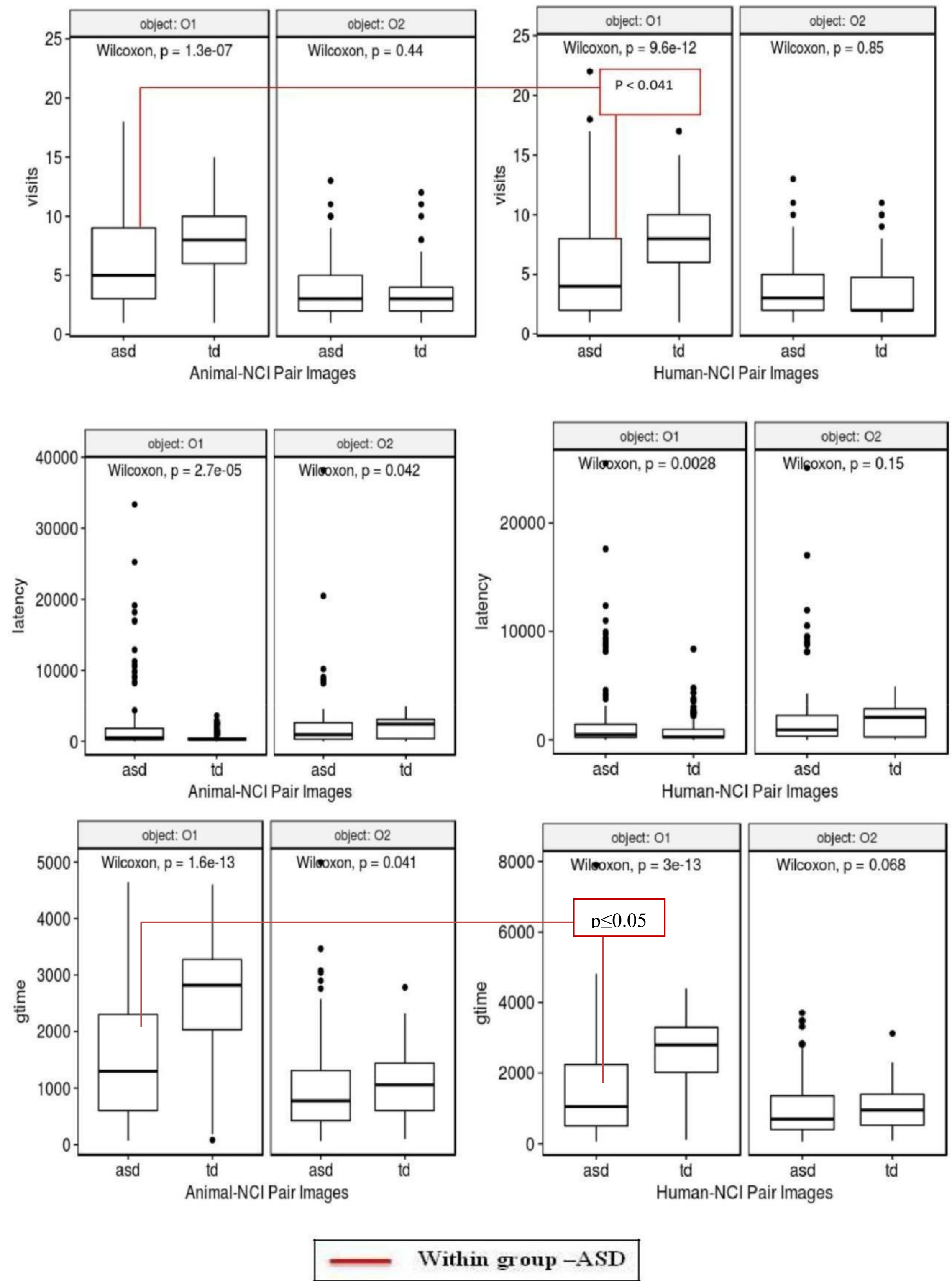

*ASD, Autism Spectrum Disorder; TD, Typically Developing; O1, Animal Image; O2, Human Image; Visits, sustained attention per visit; Latency, time to first fixation; gtime, total fixation duration.*

**Fig. 3 Differences in visual attention with respect to duration (top), prioritization (middle) and preference (bottom), within and between ASD and TD participants on arrays pairing Animal and Human Face Images with CI objects-(*Total number of Observations= 3391)***



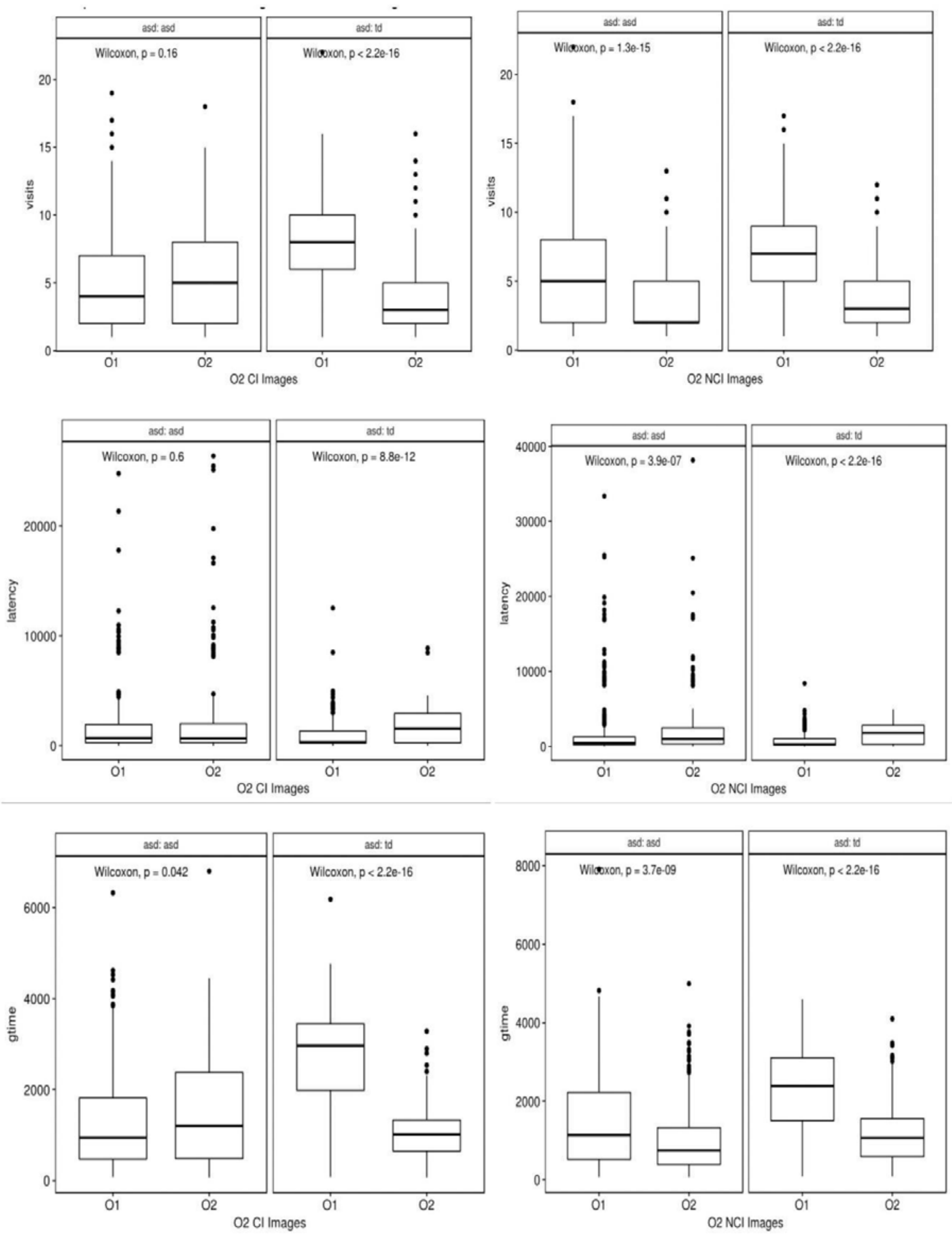

*ASD, Autism Spectrum Disorder; TD, Typically Developing; CI, Circumscribed Interest object; O1, Animal/Human Face; O2, CI object; Visits, sustained attention per visit; Latency, time to first fixation; gtime, total fixation duration.*

**Fig. 4 Differences in visual attention with respect to duration (top), prioritization (middle) and preference (bottom), within and between ASD and TD participants on arrays pairing Animal and Human Face Images with NCI objects-(*Total number of Observations= 3391)***




*ASD, Autism Spectrum Disorder; TD, Typically Developing; NCI, Non-Circumscribed Interest object; O1, Animal/Human Face; O2, NCI object; Visits, sustained attention per visit; Latency, time to first fixation; gtime, total fixation duration.*

**Fig. 5 Differences in visual attention with respect to duration (top), prioritization (middle) and preference (bottom), within and between ASD and TD participants on arrays pairing Social Images (Human and Animal) with CI or NCI objects-(*Total number of Observations*= *3391)***




*ASD, Autism Spectrum Disorder; TD, Typically Developing; CI, Circumscribed Interest object; NCI, Non-Circumscribed Interest object; O1, Social Image; O2, CI or NCI object; Visits, sustained attention per visit; Latency, time to first fixation; gtime, total fixation duration.*

## Table. 1 Observation Counts of Expected and Obtained Observations

| *Participants* | COUNTA of subj (gtime and latency) | SUM of visits |
|---|---|---|
| **asd1** | 99 | 362 |
| **asd2** | 112 | 515 |
| **asd3** | 119 | 676 |
| **asd4** | 110 | 537 |
| **asd 5** | 116 | 719 |
| **asd6** | 95 | 265 |
| **asd7** | 99 | 407 |
| **asd8** | 110 | 636 |
| **asd9** | 98 | 433 |
| **asd10** | 69 | 245 |
| **asd11** | 104 | 488 |
| **asd12** | 96 | 291 |
| **td10** | 116 | 657 |
| **td12** | 114 | 639 |
| **td13** | 115 | 631 |
| **td17** | 102 | 435 |
| **td4** | 117 | 657 |
| **td5** | 117 | 734 |
| **td7** | 116 | 661 |
| **td8** | 118 | 690 |
| **td1** | 200 | 1173 |
| **td11** | 115 | 645 |
| **td14** | 99 | 491 |
| **td2** | 106 | 708 |
| **td4** | 112 | 608 |
| **td6** | 117 | 672 |
| **td9** | 114 | 589 |
| **asd13** | 105 | 481 |
| **asd14** | 118 | 581 |
| **asd15** | 81 | 481 |
| **asd16** | 82 | 492 |
| **Grand Total** | **3391** | **17599** |

Expected observations =3840

Obtained observations=3391 (88.3%)