Zıvralı Yarar, E.; Howlin, P.; Charlton, R.A.; Happé, F.G. (2020) Age-related effects on social cognition in adults with autism spectrum disorder: A possible protective effect on theory of mind (in press) Autism Research

DOI: 10.1002/aur.2410

Accepted for publication 30 September 2020

Age-related effects on social cognition in adults with autism spectrum disorder: A possible protective effect on theory of mind

Authors' details

Esra Zıvralı Yarar[a], Patricia Howlin[b], Rebecca Charlton[c†], and Francesca Happé[d†]

a. Assistant Professor, Department of Psychology, Social Sciences University of Ankara

b. Emeritus Professor, Institute of Psychiatry, Psychology & Neuroscience, King's College London

c. Reader, Department of Psychology, Goldsmiths University of London

d. Professor, Institute of Psychiatry, Psychology & Neuroscience, King's College London

[†]Joint senior authors

Correspondence details

Dr. Esra Zıvralı Yarar

Address: Ankara Sosyal Bilimler Universitesi, Haci Bayram Mh. Cankiri Cd. No:2 Ulus/Altindag, Ankara/Turkey

Telephone: +90 505 714 7932

Email: esra.yarar@asbu.edu.tr

Acknowledgements

EZY was funded by the Republic of Turkey Ministry of National Education PhD Research Fellowship between 2013 and 2017. This paper presents independent research funded by the Republic of Turkey Ministry of National Education. FH is part funded by the NIHR Biomedical Research Centre at South London and Maudsley NHS Foundation Trust and King's College London. We thank Professor Dermot Bowler and Dr Amanda Roestorf for their help with this study. The views expressed are those of the author(s) and not necessarily those of the Republic of Turkey Ministry of National Education.

Lay Summary

People with autism spectrum disorder have difficulties with social understanding. Some age-related studies in typical development have shown a decline in social understanding in older age. We investigated whether a similar pattern is present in adults with ASD. We found that understanding what someone is thinking was not worse in older versus younger autistic adults. Also, we reported further evidence suggesting that emotional empathy difficulties were related to difficulties with understanding one's own emotions rather than with autism itself.

Abstract

Impaired social cognition has been suggested to underlie the social communication difficulties that define autism spectrum disorder (ASD). In typical development, social cognition may deteriorate in older age, but age effects in ASD adults have been little explored. In the present study we compared groups of younger and older adults with and without ASD (N=97), who completed a set of social cognition tasks assessing theory of mind (ToM), and self-report measures of empathy and alexithymia. While typically-developing (TD) younger adults outperformed elderly TD and younger ASD participants, younger and older ASD adults did not differ in their ToM performance, and the elderly ASD and TD groups performed equivalently. By contrast, ASD adults reported lower empathy scores and higher levels of alexithymia symptoms compared to TD adults regardless of age. The difference between ASD and TD groups in self-reported empathy scores was no longer significant when alexithymia was covaried (with the exception of the Perspective Taking subscore). Results suggest a possible age-protective effect on ToM in the ASD group. In addition, empathy difficulties appear to be associated with alexithymia rather than ASD per se. Possible interpretations are discussed, and future directions for autism aging research are proposed.

Keywords: Autism spectrum disorder, aging, social, cognition, theory of mind, empathy, alexithymia

Introduction

Atypical social cognition may explain difficulties in developing and maintaining social relationships in autism spectrum disorder (ASD; note the terms ASD and autism are used interchangeably throughout the paper) (Happé, 2015). Social cognition is multi-faceted and includes theory of mind (ToM), emotion perception, emotional empathy and awareness of own emotions. ToM is the ability to attribute mental states, such as intentions, thoughts, and beliefs, to oneself and others in order to predict and explain behavior. This can be distinguished from understanding emotional states (sometimes described as “affective” rather than “cognitive” ToM) (Sebastian et al., 2011). Emotion perception refers to the ability to identify and label emotions from facial, vocal and bodily cues. Emotional response to others - emotional or affective empathy - has been suggested to be a multi-dimensional skill involving understanding others’ feelings and being able to generate an appropriate affective response to them (Davis, 1983). Difficulty recognizing and labelling one’s own emotions, referred to as “alexithymia” (Nemiah, Freyberger, & Sifneos, 1976) appears to be associated with difficulties recognizing and responding to others’ emotional states. These domains have been explored in autistic children and younger adults (Happé, Cook, & Bird, 2017; Harms, Martin, & Wallace, 2010) although investigations of middle age and later life are scarce.

Studies of younger autistic adults have shown poorer performance on ToM tests compared to typically-developing (TD) controls (Mathersul, McDonald, & Rushby, 2013; Murray et al., 2017; Rogers, Dziobek, Hassenstab, Wolf, & Convit, 2007). Emotion perception difficulties have been reported at the behavioral and neural level, suggesting emotion recognition difficulties in at least some adults with ASD compared to TD (Harms et al., 2010). Results for affective empathy are mixed, with reports of either no difference between autistic and non-autistic groups (Bernhardt et al., 2013; Mul, Stagg, Herbelin, & Aspell, 2018) or lower empathic concern in younger autistic adults (Lombardo, Barnes, Wheelwright, & Baron-Cohen, 2007; Mathersul et al., 2013). Bird and Cook (2013) have shown that comorbid alexithymia, rather than ASD per se, predicts emotion recognition and empathy difficulties in ASD. Alexithymia occurs in approximately 50% of people with autism (Kinnaird, Stewart, & Tchanturia, 2019), and younger autistic adults show more difficulties understanding their own emotions than TD younger adults (Lombardo et al., 2007; Mul et al., 2018). Some of the above studies included older adults in their samples (e.g., Bernhardt et al., 2013; Mathersul et al., 2013), yet the mean age remained below 50 years.

How aging affects social cognition in older autistic adults remains largely unknown. To our knowledge only one study has investigated ToM in older autistic adults (aged 50-79, mean age 61 years), reporting similar ToM performance by ASD and control groups (n=57 and 56, respectively; Lever & Geurts, 2016). The same authors have also examined self-reported empathy in a wide age group (aged 19-79 with a mean of 46 years), which included 79 older adults aged 53 plus, and found no age-related effect (Lever & Geurts, 2018). Age effects on emotion perception and alexithymia in older autistic adults have not yet been studied. Considering age-related changes generally, Lever and Geurts (2016) have suggested three possible developmental trajectories for older autistic adults: a similar age-related decline in ASD as in the general population, an attenuated pattern of decline (so-called “safeguard hypothesis”), or a detrimental pattern of cognitive loss (“double jeopardy”). Few studies have examined these potential trajectories. Results suggest trajectories may differ between cognitive abilities (e.g., visual memory versus generativity; Geurts & Vissers, 2012), but the trajectory in social cognitive abilities is unknown.

Studies of older, non-autistic adults generally report an age-related decline in ToM ability, with a few exceptions (Beadle & Christine, 2019). Whether declining ToM ability with age reflects domain-specific or domain-general decline is debated. Some studies have shown intelligence to fully mediate age-ToM associations (Li et al., 2013), whereas others have not (Phillips et al., 2011). Thus, it remains unclear whether age-related ToM difficulties in typical development reflect a specific socio-cognitive decline or underlying general cognitive decline in older age.

A general decline has been reported for emotion perception accuracy with older age in typical development (Gurera & Isaacowitz, 2019). However, data on age-related differences in empathy skills in the general population are mixed, with studies showing both reduced and intact empathy skills in aging (Beadle & Christine, 2019). Some research suggests that older adults report lower cognitive empathy than younger adults, but affective empathy does not differ (Beadle & Christine, 2019). However, both better and poorer affective empathy in older compared to younger adults has been described (Beadle & Christine, 2019; Sun, Luo, Zhang, Li, & Li, 2018). Empathy abilities have been shown to be higher among individuals with higher levels of education (Schieman & Van Gundy, 2000), with education often considered a proxy of intellectual functioning, and age-empathy associations became non-significant when controlling for education, fluid and crystallized intelligence (Phillips, MacLean, & Allen, 2002). Therefore, age related decline in empathy abilities in typical development may be related to decline in general cognitive abilities.

In the general population, older adults have been found to show higher alexithymia (lower awareness of own emotions) compared to younger adults (Onor, Trevisiol, Spano, Aguglia, & Paradiso, 2010). However, to our knowledge, effects of other cognitive abilities on age-related changes in alexithymia have not yet been examined, although one study has associated high alexithymia with poorer executive functions (Santorelli & Ready, 2015).

Given the evidence of age-related decline in social cognition in typical development and the notable impairment in ASD, studies in older autistic adults are clearly needed and will have theoretical and practical significance. Knowing about social cognitive strengths and difficulties should allow better planning for the needs and wellbeing (e.g., quality of life, mental health) of individuals with autism in later life.

Aim

This study aimed to investigate age-related effects on social cognition (ToM, alexithymia symptoms and empathy skills) by comparing younger and older ASD and TD adults.

We hypothesized that:

1. TD adults will show age-related decline in ToM, and increased alexithymia symptoms with age.
2. Younger ASD adults will perform more poorly on ToM tasks and report more alexithymia than younger TD adults.
3. An age by study group interaction will be found for ToM performance, with age related decline being greater in the TD group than the ASD group.
4. ASD groups will self-report lower empathy than TD groups, but this effect will be accounted for by differences in self-reported alexithymia.

Methods

Participants

Ninety-seven adults: 58 with a diagnosis of ASD (M_{age}=43.66, SD=16.11) and 39 TD adults (M_{age}=44.95, SD=17.54). The TD group was recruited to match the ASD group on age and gender. Both groups were divided into younger (18-50 years, ASD, n=29 and TD, n=20) and older (>50 years, ASD, n=29 and TD, n=19) age-groups, in keeping with the consensus in the autism-aging literatures (Roestorf et al., 2019).

Adults with ASD were recruited via 1) clinic and research databases hosted at an adult autism assessment service and a university-based research group and 2) research advertisements circulated at King's College London. The TD group was recruited via advertisements and also research databases at King's College London and City University. Ethical approval was granted by the Psychiatry, Nursing and Midwifery Research Subcommittee at King's College London (#PNM/13/14-26).

Since different recruitment methods can result in sampling artefacts, the recruitment sources of participants in the older and younger ASD groups were examined. 18 younger and 17 older adults with ASD (62% of each age group) were recruited through clinical settings related to expert diagnostic services, whereas 11 younger and 12 older adults (38% of each age group) were recruited via adverts or research volunteer databases. Thus, the proportion of participants recruited from different sources was equivalent across the two ASD age groups. Age at first ASD diagnosis was known for 22 adults (76%) in each ASD age group. Since the majority of participants were recruited via a specialist diagnostic clinic, most were recently diagnosed; mean age of diagnosis was 24.00 years (SD=8.72, age-range: 6-42 years) in the younger ASD group and 54.77 years (SD=7.08, age-range: 40-70 years) in the older ASD group.

Inclusion criteria for both study groups were: aged 18 years or older, intellectual ability higher than 70 (as measured by the Wechsler Abbreviated Scale of Intelligence-2nd edition, WASI-II) (Wechsler, 2011) and fluent English. Additional group-specific inclusion criteria were: for the ASD group, a formal ASD diagnosis and for the TD group, no known current or past psychiatric diagnosis. ASD diagnosis was confirmed with the Autism Diagnostic Observation Schedule (ADOS)-Module 4 (Lord et al., 2012) for 39 participants (19 younger and 20 older adults) in the ASD group.

Assessment

Participants completed the WASI-II to estimate full-scale intelligence (FSIQ) with four subtests (Vocabulary, Similarities, Block Design, and Matrix Reasoning) (Wechsler, 2011). Level of income information was measured on a range from 1 (under £7,785 yearly) to 5 (more than £20,395 yearly) (Beecham & Knapp, 1992). The self-report 20–Item Toronto Alexithymia Scale (TAS-20) (Bagby, Parker, & Taylor, 1994) assessed participants' ability to reflect on and name their emotions. Continuous scores and a binary cut-off (total score ≥61) were used to separate groups with and without possible alexithymia. The Interpersonal Reactivity Index (IRI) (Davis, 1983), measured self-reported empathy on four sub-scales: Perspective Taking, Fantasy, Empathic Concern and Personal Distress.

ToM Measures: ToM was measured using the Reading the Mind in the Eyes Test (RMET) – Revised (Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001), the Frith-Happé Triangles Test (Abell, Happé, & Frith, 2000), the Strange Situations Film Task (Murray et al., 2017), and the new ToM Cartoon Stories Task (ToM-CSt) (Zıvralı Yarar, 2016).

In the RMET (Baron-Cohen et al., 2001), participants choose one of four words to describe what the person is thinking or feeling in 36 black-and-white photographs of eye region. Each correct answer is awarded 1 point (range 0-36).

The Frith-Happé Triangles Test (Abell et al., 2000) includes four short videos of two triangles interacting, after each clip participants explain what happened. Each clip is scored on appropriateness of the answers and mental state language used (ranging from 0-2 for each) leading to a total score of 0-8 for each.

The Strange Situations Film Task (Murray et al., 2017) consists of 15 short video clips: three practice, 12 mental state, and three control clips, in which two characters interact. Three questions are asked at the end of each clip: an intention question (e.g., "Why did character X say that?"), an interaction question (e.g., "If you were in character Y's situation what would you say next?"), and a memory question about a factual element of the clip (e.g., "How long was character X going away for?"). Accuracy and mental state language scores are allocated for the intention question, while scores are rated based on accuracy only for the interaction and the memory questions (ranging from 0-2 for each). Total intention, interaction and mental state language scores range from 0-24 for experimental and 0-6 for control clips, while total memory scores range from 0-6 and 0-3, respectively.

In the present analysis, to maximize sensitivity to individual differences, the mental state language scores for the Frith-Happé Triangles Test (Abell et al., 2000) and the Strange Situations Film Task (Murray et al., 2017) were extended from 0-2 points to 0-3 points, with 3-point scores given to answers that included second-order (e.g., "She thinks he knows X") or higher mental state attributions. Inter-rater reliability analysis based on ToM scores for 20%

of participants in each age-by-study group (i.e., younger ASD, older ASD, younger TD and older TD) showed that there was good agreement between two independent raters blind to group for both task scores (Kw=.88-1.00 and .83-1.00, respectively). Extended mental state language scores showed substantial relationship with each other in the ASD and TD group (r=.45, p<.001 and r=.43, p<.01, respectively) indicating adequate convergent validity. The internal consistency value was low for the extended mental state language score of the Strange Situations Film Task (Cronbach's α=.62), yet still higher than the original value (Cronbach's α=.42) reported by the authors (Murray et al., 2017). Satisfactory internal consistency value was found for the extended mental state language score of the Frith-Happé Triangles Test despite the small number of items (Cronbach's α=.72).

The ToM-CSt (Zıvralı Yarar, 2016) is a novel picture-sequencing task modelled on Baron-Cohen's Picture Sequencing Test (Baron-Cohen, Leslie, & Frith, 1986) to assess ToM ability while making minimal demands on memory. Five pictures (14 x 9.5cm) for each of ten ToM and five control cartoon stories are presented to the participant in a jumbled order; the participant arranges the pictures so that the story makes sense and explain the main point in the story. Performance was evaluated on: accuracy of sequencing stories (1 point for each correctly sequenced picture, leading to a total score of 0-5 for each story), identification of the main theme (scores range from 0-2 for each story), and use of mental state language in the explanation of the story (scores range from 0-3 for each story). Total sequence, accuracy and mental state language scores range from 0-50, 0-20 and 0-30, respectively, for experimental, and 0-25, 0-10 and 0-15 for control cartoons. The Kappa statistic based on ToM-CSt scores for 20% of participants in each sub-group (i.e., younger ASD, older ASD, younger TD and older TD) showed that there was good agreement between two independent raters who were blind to group (Kw=.86-1.00). Satisfactory internal consistency was achieved for ToM-CSt scores (Cronbach's α=.71-.78). Convergent validity was tested by investigating associations between the novel task and established social cognition tasks (as stated above). All three ToM-CSt scores were significantly correlated with all the other social cognition test scores (r=.26-.61), with the sole exception of a nonsignificant correlation between RMET and ToM-CSt mental state language score (r=.15); see Supplementary Table 2.

ToM measures were collected as part of a wider assessment lasting approximately three hours per session including breaks. Since an order effect was not expected, ToM tasks were not counterbalanced, but were administered at the beginning of a session. For practical reasons, testing sessions took place across two days for seven adults with ASD and 14 control participants. Information sheets were provided to all participants and written consent was taken before the study took place. All participants were thanked and reimbursed for their time and travel costs.

Statistical Analysis

Data were analyzed with SPSS version 24. Homogeneity of variance and homogeneity of regression slopes were measured using Levine's test and using a customized model, respectively. Normality of data distribution was checked using the Nonparametric Kolmogorov-Smirnov test, the Nonparametric Shapiro-Wilk test, histograms, Q-Q plots, and examination of skewness and kurtosis scores. Bootstrap analysis was performed to test whether the results were robust against deviations from parametric assumptions (Chong & Choo, 2011), when indicators suggested deviation from the normal distribution. All bootstrap tests were based on 1000 samples. Parametric tests were employed for statistical analysis where applicable.

Two-way ANOVA was used to investigate the effect of study group (ASD vs. TD) and age group (younger vs. older) on demographic information (age, total years of education and income level) and intelligence. Gender ratio of the groups was tested using a log-linear analysis. Performance on social cognition was tested using an ANCOVA analysis with the study group and age group as fixed factors and FSIQ as a covariate. Significant interactions were followed up with analysis of adjusted simple main effects. To reduce the number of statistical tests, a composite score was created for ToM performance using principal component analysis (PCA). Associations among social cognition scores were examined by calculating either Pearson's or Spearman's correlation coefficients. Association between empathy and alexithymia was investigated with an independent *t*-test between groups scoring below and above the alexithymia cut-off, and additional ANCOVA including alexithymia as a second covariate.

Results

Demographic Information

Two-way ANOVA and log-linear analysis results showed that study groups were matched on demographic information (see Table 1 for full results). Reflecting the grouping strategy, age was significantly different between the younger and older groups (p<.001), but the effect of study group (ASD versus TD) was non-significant (p>.05). No differences between study groups were observed for total years of education or income level. There was a significant main effect of age group for total years of education; younger adults (M=17.16, SD=2.85) had slightly more years of education than older adults (M=15.63, SD=4.04). No significant age group by study group interactions were detected on any of the demographic measures (Table 1). Similarly, the three-way log-linear analysis produced a final model that retained none of the effects including the interaction effect. The likelihood ratio of this model was $\chi^2(3)=3.77$, *p*=.29, indicating that age groups and study groups were not significantly different in terms of male:female ratio.

Intelligence

Two-way ANOVA analysis suggested there were no significant differences in intellectual level (verbal IQ: VIQ, performance IQ: PIQ and full-Scale IQ: FSIQ) between the groups; no significant effects of study or age group or interactions were found (Table 1).

Composite ToM Score

Since several ToM measures were used to assess ToM ability (see Supplementary Table 1), to reduce multiple testing and type one error, a composite score for ToM was created by using principal component analysis (PCA) performed on the whole sample. All ToM scores were examined for their inter-correlation in the whole sample. These were generally good; 30 of the 32 correlations between ToM variables were significant, with only the correlation between RMET and mental state language scores of SSFt and ToM-CSt not reaching significance (See Supplementary Table 2). The Kaiser-Meyer-Olkin measure verified the sampling adequacy for the analysis, KMO=.79, and all KMO values for individual scores were >.73, which is above the acceptable limit of .5 (Field, 2013). Bartlett's test of sphericity $\chi^2(36)=386.56$, $p<.001$, indicated that correlations were sufficiently large for PCA. The scree plot justified retaining one component explaining 47.68% of the variance. Supplementary Table 3 shows the factor loadings after extraction. Although we did not expect an order effect, factor loadings were examined against the order of administration (i.e., the RMET first, followed by the Strange Situations Film Task, the Frith-Happé Triangles Test, and finally the ToM-CSt). No practice or fatigue effects on the observed loadings were apparent.

Group- and Age-related Effects on Social Understanding

Separate two-way ANCOVAs were performed to test effects of study and age groups on the composite ToM, alexithymia and empathy scores covarying for full-scale IQ (see Table 2).

ToM: The covariate, FSIQ, was significantly related to ToM. A significant study group effect indicated that ToM performance was poorer in ASD than TD group. A significant age group effect showed that younger adults performed better than older adults. The interaction between study and age group was significant: age groups differed in the control group ($F(1,36)=12.57$, $p<.01$, $\eta_p^2=.26$), but not in the ASD group ($F(1,55)=.09$, $p=.77$, $\eta_p^2=.002$). Similarly, while younger TD adults significantly outperformed younger ASD adults ($F(1,46)=14.60$, $p<.001$, $\eta_p^2=.24$), older adults from the TD and ASD groups did not differ significantly in their ToM scores ($F(1,45)=.08$, $p=.78$, $\eta_p^2=.002$) (see Table 2 and Figure 1).

Alexithymia: The covariate, FSIQ, was not significantly related to total alexithymia score. A significant study group effect showed that adults with ASD self-reported more problems with understanding their own emotions than did TD controls (see Table 2). None of the adults in the TD group had a score above the suggested cut-off for alexithymia, whereas 65.5% of the younger ASD and 51.7% of the older ASD adults did. Age group effect and the interaction between study group and age group were not significant (see Table 2).

Empathy: On the self-report empathy questionnaire the covariate, FSIQ, was significantly related to Perspective Taking subscale score only. There was a significant effect of study group on subscale scores except for Fantasy; adults with ASD reported that they were poorer at Perspective Taking, felt less Empathic Concern for others and felt more Personal Distress compared to TD controls. Neither a significant age group effect nor an interaction of age group with study group was found (see Table 2).

Alexithymia-empathy association: The association between self-reported alexithymia and empathy was examined by comparing the empathy scores of individuals with ASD who scored above and below the cutoff for alexithymia (note, no TD participant scored above the cut-off). ASD adults who scored above the cutoff for alexithymia reported lower level of Empathic Concern for others ($t(54.47)=2.25$, $p<.05$, $d=.57$), but similar scores on the Perspective Taking ($t(56)=1.13$, $p=.28$, $d=.30$), Fantasy ($t(56)=1.20$, $p=.24$, $d=.32$), and Personal Distress sub-scales ($t(56)=-0.85$, $p=.40$, $d=.23$) A further ANCOVA was performed to examine whether study group differences in empathy between ASD and TD remained significant when self-reported alexithymia score was controlled for. Including alexithymia as a covariate, study group effects on Empathic Concern and Personal Distress scores no longer reached significance, whereas Perspective Taking scores remained significantly lower in ASD than TD groups. Study group effect on Fantasy score remained non-significant (see Supplementary Table 4).

Discussion

This study examined age-related effects on social cognition in younger and older adults with ASD compared to TD controls. As predicted, the ASD group showed poorer ToM performance, lower self-rated empathy and more alexithymia than the TD adults. However, there was a significant interaction between study group and age group on ToM, showing a different age-related pattern between adults with and without ASD. Younger and older adults in the ASD group did not differ in their ToM performance whereas in the control group older adults demonstrated poorer performance than younger adults. This pattern of no age-related decline in ToM in the ASD group is in keeping with the “safeguard hypothesis” (Geurts & Vissers, 2012), and might be interpreted as a “protective” effect in ASD. This does not mean that social cognition gets better, but it seems that it does not decline as in typical aging. Results are in line with the only study of ToM and aging in ASD to date (Lever & Geurts, 2016), which also showed no age-related decline in ToM in ASD. However, where Lever and Geurts (2016) focused on one single measure of ToM, the present study measured ToM in much more depth using a wide range of social cognitive measures. Results are also parallel with the wider literature demonstrating reduced ToM performance with age in TD adults (Beadle & Christine, 2019; Phillips et al., 2002). In the present study, IQ was related to ToM performance but did not explain age effects, perhaps reflecting the use of a range of ToM tasks including one designed to have low memory demands.

One explanation for preserved performance among ASD older adults could be poor performance by younger ASD adults leading to a floor effect; however, this was not the case in the current study (see scores in Supplementary Table 1). An alternative hypothesis might involve genuine differences in brain maturation, with the brain networks supporting ToM in ASD developing and declining at a different rate compared with TD adults, although this has yet to be tested. Findings may also reflect compensation, with ASD adults showing improved social skills over time. The alternative strategies that some ASD adults have described using in order to help them work out what other people may be thinking (Livingston, Shah, & Happé, 2019) may continue to be effective into older age or serve as “brain training” and protect against cognitive decline.

Empathy results showed the same pattern as previous findings from younger adult ASD groups (Mathersul et al., 2013). Compared to TD controls, ASD adults reported feeling less empathic concern and being less successful in taking others' perspectives, but experiencing higher levels of personal distress in tense social settings. There was no significant age effect nor interaction effect between age and study groups on any subscale of empathy. Results were in line with previous report of no age-related effect on self-reported empathy in adulthood with ASD (Lever & Geurts, 2018) and partly support previous findings from TD aging research showing similar self-reported empathic concern in younger and older groups (Beadle & Christine, 2019). The current study did not identify age-effects on the empathy sub-scale of self-reported Perspective Taking, which is contrary to some previous findings (Beadle & Christine, 2019; Sun et al., 2018). In the current study Perspective Taking was correlated with IQ, as in other studies that have found a reduced or absent age effect on empathy when level of education/intelligence were considered (Phillips et al., 2002; Schieman & Van Gundy, 2000).

Higher levels of alexithymia were found in the younger and older ASD adults compared to controls, with more than half passing TAS-20 cut-off, as previously reported for younger ASD groups (Kinnaird et al., 2019). Contrary to our prediction, there was no significant age effect for self-reported alexithymia. Several studies of typical aging have found higher levels of alexithymia with increasing age (Onor et al., 2010), although one study did not find this pattern (Santorelli & Ready, 2015).

The impact of alexithymia on empathy was also examined. Adults with ASD who scored above the TAS-20 cut-off (no control participant did so) self-reported poorer Empathic Concern, and covarying for alexithymia scores removed the ASD-TD group difference in Empathic Concern and Personal Distress. These results are in line with Bird and Cook's (2013) findings that comorbid alexithymia, rather than ASD, underlies emotion processing and empathy difficulties. However, the study group difference in Perspective Taking score was still significant, contrary to our hypothesis. Perspective Taking items measure a mixture of affective (understanding others' emotions) and cognitive ToM (understanding others' thoughts), whereas Empathic Concern and Personal Distress scores measure affective empathy, possibly explaining the different pattern of results particularly in study group by age group interactions. If replicated, this finding, and suggested interpretation, warrant further investigation in future studies.

Some limitations deserve note. Few studies have compared well-matched groups of older and younger ASD and TD adults, as we do here, but larger sample sizes would have increased our power to detect smaller effects and allowed us to examine, for example, gender differences. Since small samples may result in both false-positives and false-negatives, our results should be considered with caution until they can be replicated in future studies and larger samples. The cross-sectional design used in this study may introduce cohort effects due to changes in ASD diagnostic criteria over time; longitudinal studies of ASD aging are needed. Our results could reflect a selection effect. Studies of aging in TD and other groups face a challenge to avoid "survivor" effects; those elderly people volunteering for research at an advanced age are necessarily those functioning relatively well. Without using epidemiological sampling it is hard to avoid such biases, although we tried to avoid selection effects by recruiting younger and older adults from similar sources. We note that our samples were matched for general intelligence, but selection effects on other dimensions (e.g., interest in taking part, physical health) cannot be entirely ruled out. Selection and survivor effects will apply to both study groups meaning that results are based on group differences between "healthiest" individuals and, as such, are less likely to explain study group effects or study group by age group interactions. However, since mortality rates in autism have been shown to be higher than in general population at all ages (Hwang, Srasuebkul, Foley, Arnold, & Trollor, 2019), further exploration of survivor effects in autism research is needed. We did not measure existing physical health conditions that could impact cognition (e.g., hypertension, previous stroke etc.). However, the overall test battery was challenging, taking three hours to complete and requiring attendance at a university setting, meaning that participants were generally healthy. Since IQ was covaried in the analyses, our significant effects are unlikely to be confounded by age-related general cognitive differences, but we did not measure overall executive function. Age-related ToM profiles in elderly ASD adults should be explored in relation to executive functions in future studies.

Conclusion

The present results suggest different age-related trajectories for distinct aspects of social processing in TD and autistic adults. If our finding of reduced age-related ToM decline in ASD is replicated, this may give important insights into biological/social effects on older age functioning in autism, and warrant neuroimaging and other investigation. This study contributes to our understanding of ASD across the lifespan, and highlights the urgent need to know more about the increasing elderly population with ASD.

References

Abell, F., Happé, F., & Frith, U. (2000). Do triangles play tricks? Attribution of mental states to animated shapes in normal and abnormal development. *Cognitive Development, 15*(1), 1-16.

Bagby, R. M., Parker, J. D., & Taylor, G. J. (1994). The twenty-item Toronto Alexithymia Scale—I. Item selection and cross-validation of the factor structure. *Journal of Psychosomatic Research, 38*(1), 23-32.

Baron-Cohen, S., Leslie, A. M., & Frith, U. (1986). Mechanical, behavioural and intentional understanding of picture stories in autistic children. *British Journal of developmental psychology*, *4*(2), 113-125.

Baron-Cohen, S., Wheelwright, S., Hill, J., Raste, Y., & Plumb, I. (2001). The "Reading the Mind in the Eyes" test revised version: A study with normal adults, and adults with Asperger syndrome or high-functioning autism. *Journal of Child Psychology and Psychiatry*, *42*(2), 241-251.

Beadle, J. N., & Christine, E. (2019). Impact of aging on empathy: Review of psychological and neural mechanisms. *Frontiers in Psychiatry, 10*, 331.

Beecham, J. & Knapp, M. (1992). Costing psychiatric interventions. In G. Thornicroft, C. Brewin, & J. K. Wing (Eds.), *Measuring mental health needs*. London: Gaskell.

Bernhardt, B. C., Valk, S. L., Silani, G., Bird, G., Frith, U., & Singer, T. (2013). Selective disruption of sociocognitive structural brain networks in autism and alexithymia. *Cerebral Cortex*, *24*(12), 3258-3267.

Bird, G., & Cook, R. (2013). Mixed emotions: The contribution of alexithymia to the emotional symptoms of autism. *Translational Psychiatry, 3*(7), e285.

Chong, S. F., & Choo, R. (2011). Introduction to bootstrap. *Proceedings of Singapore Healthcare, 20*(3), 236–240.

Davis, M. H. (1983). Measuring individual differences in empathy: Evidence for a multidimensional approach. *Journal of Personality and Social Psychology, 44*(1), 113-126.

Field, A. (2013). *Discovering statistics using SPSS* (4th ed.). London: Sage.

Geurts, H. M., & Vissers, M. E. (2012). Elderly with autism: Executive functions and memory. *Journal of Autism and Developmental Disorders*, *42*(5), 665-675.

Gurera, J. W., & Isaacowitz, D. M. (2019). Emotion regulation and emotion perception in aging: A perspective on age-related differences and similarities. *Progress in Brain Research*, *247*, 329-351.

Happé, F. (2015). Autism as a neurodevelopmental disorder of mind-reading. *Journal of the British Academy*, *3*, 197-209.

Happé, F., Cook, J. L., & Bird, G. (2017). The structure of social cognition: In (ter) dependence of sociocognitive processes. *Annual Review of Psychology*, *68*, 243-267.

Harms, M. B., Martin, A., & Wallace, G. L. (2010). Facial emotion recognition in autism spectrum disorders: A review of behavioral and neuroimaging studies. *Neuropsychology Review*, *20*(3), 290-322.

Hwang, Y. I., Srasuebkul, P., Foley, K. R., Arnold, S., & Trollor, J. N. (2019). Mortality and cause of death of Australians on the autism spectrum. *Autism Research, 12*(5), 806-815.

Kinnaird, E., Stewart, C., & Tchanturia, K. (2019). Investigating alexithymia in autism: A systematic review and meta-analysis. *European Psychiatry*, *55*, 80-89.

Lever, A. G., & Geurts, H. M. (2016). Age-related differences in cognition across the adult lifespan in autism spectrum disorder. *Autism Research*, *9*(6), 666-676.

Lever, A. G., & Geurts, H. M. (2018). Is older age associated with higher self-and other-rated ASD characteristics?. *Journal of Autism and Developmental Disorders*, *48*(6), 2038-2051.

Li, X., Wang, K., Wang, F., Tao, Q., Xie, Y., & Cheng, Q. (2013). Aging of theory of mind: The influence of educational level and cognitive processing. *International Journal of Psychology: Journal International de Psychologie*, *48*(4), 715-727.

Livingston, L. A., Shah, P., & Happé, F. (2019). Compensatory strategies below the behavioural surface in autism: A qualitative study. *The Lancet Psychiatry*, *6*(9), 766-777.

Lombardo, M. V., Barnes, J. L., Wheelwright, S. J., & Baron-Cohen, S. (2007). Self-referential cognition and empathy in autism. *PloS One*, *2*(9), e883.

Lord, C., Rutter, M., DiLavore, P., Risi, S., Gotham, K., & Bishop, S. (2012). *Autism diagnostic observation schedule – 2nd edition (ADOS-2).* Los Angeles, CA: Western Psychological Corporation.

Mathersul, D., McDonald, S., & Rushby, J. A. (2013). Understanding advanced theory of mind and empathy in high-functioning adults with autism spectrum disorder. *Journal of Clinical and Experimental Neuropsychology*, *35*(6), 655-668.

Mul, C. L., Stagg, S. D., Herbelin, B., & Aspell, J. E. (2018). The feeling of me feeling for you: Interoception, alexithymia and empathy in autism. *Journal of Autism and Developmental Disorders*,*48*(9), 2953-2967.

Murray, K., Johnston, K., Cunnane, H., Kerr, C., Spain, D., Gillan, N., ... & Happé, F. (2017). A new test of advanced theory of mind: The “Strange Stories Film Task” captures social processing differences in adults with autism spectrum disorders. *Autism Research*, *10*(6), 1120-1132.

Nemiah, J. C., Freyberger, H., & Sifneos, P. E. (1976). Alexithymia: A view of the psychosomatic process. *Modern Trends in Psychosomatic Medicine, 3*, 430-439.

Onor, M., Trevisiol, M., Spano, M., Aguglia, E., & Paradiso, S. (2010). Alexithymia and aging: A neuropsychological perspective. *The Journal of Nervous and Mental Disease*, *198*(12), 891-895.

Phillips, L. H., Bull, R., Allen, R., Insch, P., Burr, K., & Ogg, W. (2011). Lifespan aging and belief reasoning: Influences of executive function and social cue decoding. *Cognition, 120*(2), 236–247.

Phillips, L. H., MacLean, R. D. J., & Allen, R. (2002). Age and the understanding of emotions: Neuropsychological and sociocognitive perspectives. *The Journals of Gerontology*. *Series B, Psychological Sciences and Social Sciences, 57*(6), 526-530.

Roestorf, A., Bowler, D. M., Deserno, M. K., Howlin, P., Klinger, L., McConachie, H., ... & Geurts, H. M. (2019). “Older adults with ASD: The consequences of aging.” Insights from a series of special interest group meetings held at the International Society for Autism Research 2016–2017. Research in Autism Spectrum Disorders, 63, 3-12.

Rogers, K., Dziobek, I., Hassenstab, J., Wolf, O. T., & Convit, A. (2007). Who cares? Revisiting empathy in Asperger syndrome. *Journal of Autism and Developmental Disorders, 37*(4), 709-715.

Santorelli, G. D., & Ready, R. E. (2015). Alexithymia and executive function in younger and older adults. *The Clinical Neuropsychologist*, *29*(7), 938-955.

Schieman, S., & Van Gundy, K. (2000). The personal and social links between age and self-reported empathy. *Social Psychology Quarterly*, 152-174.

Sebastian, C. L., Fontaine, N. M., Bird, G., Blakemore, S. J., De Brito, S. A., McCrory, E. J., & Viding, E. (2011). Neural processing associated with cognitive and affective theory of mind in adolescents and adults. *Social Cognitive and Affective Neuroscience, 7*(1), 53-63.

Sun, B., Luo, Z., Zhang, W., Li, W., & Li, X. (2018). Age-related differences in affective and cognitive empathy: Self-report and performance-based evidence. *Aging, Neuropsychology, and Cognition*, *25*(5), 655-672.

Wechsler, D. (2011). *Wechsler abbreviated scale of intelligence, second edition*. San Antonio, TX: NCS Pearson.

Zıvralı Yarar, E. (2016). *Ageing in autism spectrum disorder* (Unpublished PhD thesis). King's College London, London, UK.

Tables

Table 1. Demographics and intelligence scores by age group in the ASD and TD groups: Mean (SD)

	ASD		TD		$F^{\dagger}$	*p*-value	effect size: η_p^2
	Younger n=29	Older n=29	Younger n=20	Older n=19			
Age (years)	29.48 (8.51) range:19-48	61.32 (6.18) range:50-71	29.40 (7.54) range:20-44	57.83 (6.33) range:52-71	1.28^{dx} 400.48^{age***} 1.41^{agexdx}	$.26^{dx}$ $<.001^{age}$ $.24^{agexdx}$	$.01^{dx}$ $.81^{age}$ $.02^{agexdx}$
Gender ratio (M:F)	22:7	22:7	11:9	11:8	-	-	-
FSIQ	111.83 (14.99)	111.03 (17.05)	114.75 (11.01)	107.58 (13.80)	0.01^{dx} 1.71^{age} 1.09^{agexdx}	$.93^{dx}$ $.20^{age}$ $.30^{agexdx}$	$.000^{dx}$ $.02^{age}$ $.01^{agexdx}$
Total years of education	16.55 (3.11)	15.31 (3.83)	18.05 (2.21)	16.11 (4.4)	2.54^{dx} 4.90^{age*} 0.24^{agexdx}	$.11^{dx}$ $.03^{age}$ $.63^{agexdx}$	$.03^{dx}$ $.05^{age}$ $.003^{agexdx}$
Level of income	2.83 (1.71)	3.17 (1.56)	3.65 (1.42)	3.37 (1.50)	2.45^{dx} 0.01^{age} 0.93^{agexdx}	$.12^{dx}$ $.92^{age}$ $.34^{agexdx}$	$.03^{dx}$ $.000^{age}$ $.01^{agexdx}$

ASD: ASD group; TD: control group; M: male; F: female; FSIQ: full-scale intelligence; †all df_Ms=1 and df_Rs=93; ^{dx}main effect of study group (ASD vs. TD); ^{age}main effect of age group (Younger vs. Older); ^{agexdx}interaction effect of age group by study group; *p<.05, ***p<.001

Table 2. Composite ToM, alexithymia (TAS-20) and empathy (IRI) scores by age group in ASD and TD groups: Mean (SD)

		ASD		TD		$F^{\dagger}$	*p*-value	effect size: η_p^2
		Younger n=29	**Older n=29**	**Younger n=20**	**Older n=19**			
Composite ToM		-0.15 (1.07)	-0.24 (0.85)	0.83 (0.42)	-0.28 (1.13)	$25.65^{FSIQ***}$ 7.83^{dx**} 8.08^{age**} $6.05^{agexdx*}$	$< .001^{FSIQ}$ $.006^{dx}$ $.006^{age}$ $.02^{agexdx}$	$.22^{FSIQ}$ $.08^{dx}$ $.08^{age}$ $.06^{agexdx}$
Alexithymia-total (max=100)		60.69 (12.12)	58.14 (14.21)	38.75 (9.53)	35.58 (8.69)	0.08^{FSIQ} 82.73^{dx***} 1.44^{age} 0.03^{agexdx}	$.77^{FSIQ}$ $< .001^{dx}$ $.23^{age}$ $.88^{agexdx}$	$.001^{FSIQ}$ $.47^{dx}$ $.02^{age}$ $< .001^{agexdx}$
Empathy	**Perspective Taking (max=28)**	12.21 (4.40)	12.97 (5.49)	19.00 (4.82)	20.00 (5.38)	5.05^{FSIQ*} 45.82^{dx***} 0.31^{age} 0.02^{agexdx}	$.03^{FSIQ}$ $< .001^{dx}$ $.58^{age}$ $.90^{agexdx}$	$.05^{FSIQ}$ $.33^{dx}$ $.003^{age}$ $< .001^{agexdx}$
	Fantasy (max=28)	13.41 (7.21)	13.76 (5.75)	16.15 (6.78)	12.79 (5.78)	1.79^{FSIQ} 0.43^{dx} 1.70^{age} 2.34^{agexdx}	$.19^{FSIQ}$ $.52^{dx}$ $.20^{age}$ $.13^{agexdx}$	$.02^{FSIQ}$ $.01^{dx}$ $.02^{age}$ $.03^{agexdx}$
	Empathic Concern (max=28)	16.10 (6.64)	19.38 (4.54)	21.15 (4.28)	22.26 (4.07)	2.66^{FSIQ} 14.02^{dx***} 3.40^{age} 1.43^{agexdx}	$.11^{FSIQ}$ $< .001^{dx}$ $.07^{age}$ $.24^{agexdx}$	$.03^{FSIQ}$ $.13^{dx}$ $.04^{age}$ $.02^{agexdx}$
	Personal Distress (max=28)	13.55 (4.69)	13.59 (6.32)	8.25 (6.21)	9.47 (4.68)	0.13^{FSIQ} 16.61^{dx***} 0.35^{age} 0.30^{agexdx}	$.72^{FSIQ}$ $< .001^{dx}$ $.56^{age}$ $.58^{agexdx}$	$.001^{FSIQ}$ $.15^{dx}$ $.004^{age}$ $.003^{agexdx}$

ASD: ASD group; TD: control group; TAS-20: 20-Item Toronto Alexithymia Scale; IRI: Interpersonal Reactivity Index; †all df_Ms=1 and df_Rs=92; ^{FSIQ}effect of covariate: full-scale IQ; ^{dx}main effect of study group (ASD vs. TD) controlled for full-scale IQ; ^{age}main effect of age group (Younger vs. Older) controlled for full-scale IQ; ^{agexdx}interaction effect of age group by study group controlled for full-scale IQ; **p*<.05, ***p*<.01, ****p*<.001.

Figures

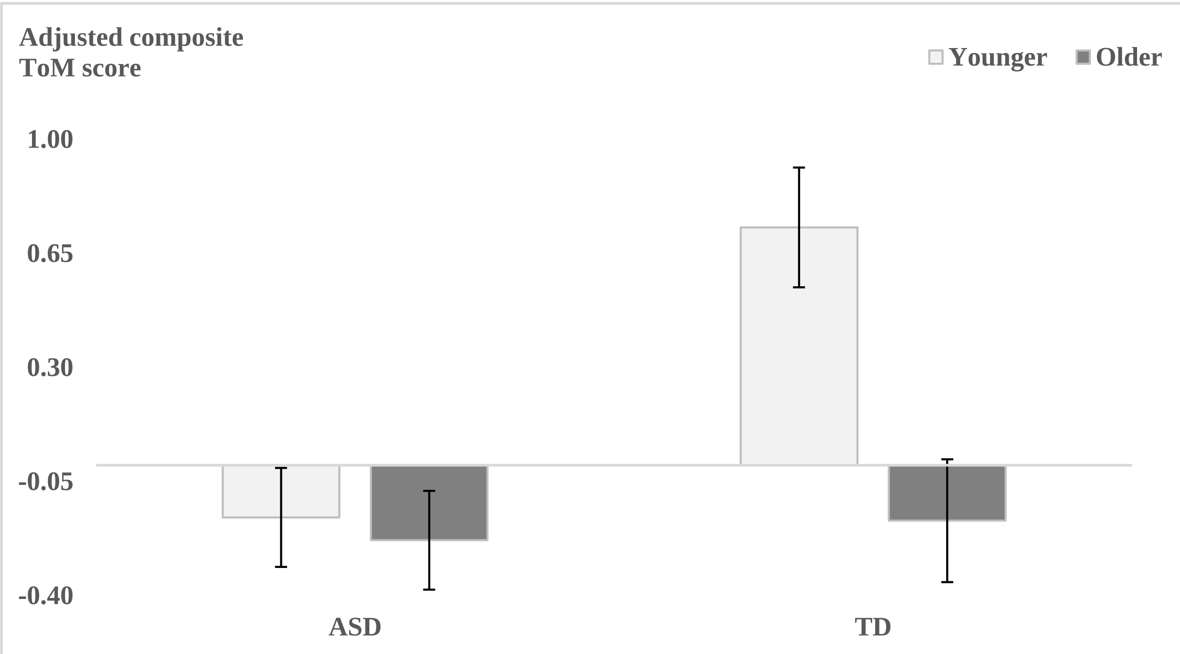

Figure 1. Full-scale IQ-adjusted composite ToM scores showing the interaction between study (ASD vs. TD) and age groups (Younger vs. Older). ASD: ASD group; TD: control group.

Supplementary Tables

Supplementary Table 1. ToM (F-HT, RMET, SSFt, and ToM-CSt) scores by age group in ASD and TD groups: Mean (SD)

			ASD		TD	
			Younger n=29	**Older n=29**	**Younger n=20**	**Older n=19**
ToM	**F-HT**	**Accuracy (max=8)**	4.97 (2.13)	3.69 (1.87)	5.90 (1.74)	3.95 (2.12)
		MSL[†] (max=12)	4.86 (2.59)	5.10 (2.47)	6.65 (1.69)	5.58 (2.50)
	RMET (max=36)		24.38 (5.44)	25.38 (4.70)	30.15 (2.64)	26.74 (3.89)
	SSFt	**Intention (max=24)**	16.00 (3.61)	15.00 (3.39)	19.15 (2.28)	15.37 (4.07)
		MSL[†] (max=36)	15.97 (5.31)	15.28 (3.87)	18.30 (3.10)	15.42 (4.68)
		Interaction (max=24)	10.97 (3.92)	12.28 (3.26)	15.40 (1.64)	13.84 (3.93)
	ToM-CSt	**Sequence (max=50)**	40.45 (8.76)	38.55 (9.29)	43.00 (4.22)	33.26 (10.12)
		Accuracy (max=20)	10.34 (4.97)	9.97 (4.76)	13.45 (2.89)	8.47 (4.98)
		MSL[†] (max=30)	16.41 (3.79)	17.17 (3.91)	17.50 (2.24)	15.63 (3.15)

ASD: ASD group; TD: control group; ToM: theory of mind; F-HT: Frith-Happé Triangles Test; RMET: Reading the Mind in the Eyes Test; SSFt: Strange Situations Film Task; ToM-CSt: Theory of Mind Cartoon Stories Task; [†]mental state language

Supplementary Table 2 Associations between ToM task scores in the whole study sample

		F-HT		RMET	SSFt			ToM-CSt		
		Accuracy	MSL†		Intention	MSL†	Interaction	Sequence	Accuracy	MSL†
F-HT	Accuracy	-	.58***‡	.38***‡	.51***	.35***	.28**	.38***‡	.44***	.27**‡
	MSL†	-	-	.26**‡	.43***‡	.48***‡	.36***‡	.27**‡	.39***‡	.47***‡
RMET		-	-	-	.38***‡	.16‡ (*p*=.12)	.34***‡	.38***‡	.41***‡	.15‡ (*p*=.15)
SSFt	Intention	-	-	-	-	.70***	.57***	.38***‡	.53***	.38***‡
	MSL†	-	-	-	-	-	.47***	.29**‡	.36***	.33***‡
	Interaction	-	-	-	-	-	-	.25*‡	.40***	.33***‡
ToM-CSt	Sequence	-	-	-	-	-	-	-	.68***‡	.37***‡
	Accuracy	-	-	-	-	-	-	-	-	.53***‡
	MSL†	-	-	-	-	-	-	-	-	-

ToM: theory of mind; F-HT: Frith-Happé Triangles Test; RMET: Reading the Mind in the Eyes Test; SSFt: Strange Situations Film Task; ToM-CSt: Theory of Mind Cartoon Stories Task; †mental state language; ‡Spearman's Rho; *p<.05, **p<.01, ***p<.001

Supplementary Table 3. Summary of principal component analysis results for ToM scores

	F-HT accuracy	F-HT msl†	RMET	SSFt intention	SSFt msl†	SSFt interaction	ToM-CSt sequence	ToM-CSt accuracy	ToM-CSt msl†
Factor loadings for ToM ability	.68	.68	.56	.81	.67	.65	.70	.80	.64

F-HT: Frith-Happé Triangles Test; RMET: Reading the Mind in the Eyes Test; SSFt: Strange Situations Film Task; ToM-CSt: Theory of Mind Cartoon Stories Task; †mental state language

Supplementary Table 4. ANCOVA results of empathy (IRI) scores by age group in the ASD and TD groups with alexithymia (TAS-20) score as an additional covariate

		ASD		TD		$F^{\dagger}$	p-value	effect size: η_p^2
		Younger n=29	Older n=29	Younger n=20	Older n=19			
Empathy	Perspective Taking (max=28)	12.21 (4.40)	12.97 (5.49)	19.00 (4.82)	20.00 (5.38)	5.53^{FSIQ*} $4.50^{alexithymia*}$ 12.56^{dx***} 0.09^{age} 0.03^{agexdx}	$.02^{FSIQ}$ $.04^{alexithymia}$ $< .001^{dx}$ $.77^{age}$ $.87^{agexdx}$	$.06^{FSIQ}$ $.05^{alexithymia}$ $.12^{dx}$ $.001^{age}$ $< .001^{agexdx}$
	Fantasy (max=28)	13.41 (7.21)	13.76 (5.75)	16.15 (6.78)	12.79 (5.78)	2.02^{FSIQ} $4.27^{alexithymia}$ 0.88^{dx} 2.47^{age} 2.53^{agexdx}	$.16^{FSIQ}$ $.04^{alexithymia}$ $.35^{dx}$ $.12^{age}$ $.12^{agexdx}$	$.02^{FSIQ}$ $.05^{alexithymia}$ $.01^{dx}$ $.03^{age}$ $.03^{agexdx}$
	Empathic Concern (max=28)	16.10 (6.64)	19.38 (4.54)	21.15 (4.28)	22.26 (4.07)	3.12^{FSIQ} $7.35^{alexithymia**}$ 0.89^{dx} 2.42^{age} 1.64^{agexdx}	$.08^{FSIQ}$ $<.01^{alexithymia}$ $.35^{dx}$ $.12^{age}$ $.20^{agexdx}$	$.03^{FSIQ}$ $.08^{alexithymia}$ $.01^{dx}$ $.03^{age}$ $.02^{agexdx}$
	Personal Distress (max=28)	13.55 (4.69)	13.59 (6.32)	8.25 (6.21)	9.47 (4.68)	0.21^{FSIQ} $7.20^{alexithymia**}$ 1.46^{dx} 0.88^{age} 0.38^{agexdx}	$.65^{FSIQ}$ $<.01^{alexithymia}$ $.23^{dx}$ $.35^{age}$ $.54^{agexdx}$	$.002^{FSIQ}$ $.07^{alexithymia}$ $.02^{dx}$ $.01^{age}$ $.004^{agexdx}$

ASD: ASD group; TD: control group; TAS-20: 20-Item Toronto Alexithymia Scale; IRI: Interpersonal Reactivity Index; †all df_Ms=1 and df_Rs=91; ^{FSIQ}effect of covariate: full-scale IQ; ^{alexitymia}effect of covariate: alexithymia; ^{dx}main effect of study group (ASD vs. TD) controlled for full-scale IQ and alexithymia; ^{age}main effect of age group (Younger vs. Older) controlled for full-scale IQ and alexithymia; ^{agexdx}interaction effect of age group by study group controlled for full-scale IQ and alexithymia; *p<.05, **p<.01, ***p<.001