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Theory of Mind Performance in Younger and Older Adults with Elevated Autistic Traits.

Running title: Age, Theory of Mind and Autistic Traits

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Lay Summary

The behaviours and characteristics commonly found in autism spectrum disorders (ASD) have been linked to differences in understanding social situations. Similar difficulties have also been found in older age. We assessed social understanding in younger and older adults from the general population. Both younger and older adults who report more autism-like characteristics experience more difficulties with social understanding. However, few differences were found between younger and older adults.

Abstract

Little is known about the impact of aging with Autism Spectrum Disorder on theory of mind (ToM). While ToM difficulties appear to abate with age in older autistic populations, this has yet to be explored in the Broad Autism Phenotype (BAP). The current study examined ToM performance among younger (n=49, aged 18-46) and older adults (n=47, aged 60-91) who were classified as on the BAP (younger n=18; older n=21) or not (younger n=31; older n=26) using the BAP Questionnaire. ToM was assessed using the ecologically-valid Strange Stories Film Task (SSFT) and the dynamic Happé-Frith Triangle Animations task (TA). A 2x2 ANOVA examined the effects of autistic traits (BAP vs. non-BAP) and age (young vs. old). For both SSFT and TA, results showed autistic trait main effects on task performance (non-BAP > BAP). Age main effects were observed for some but not all metrics on TA (younger better than older), with no differences in SSFT. An interaction of autistic traits and age was observed in TA Intentionality, with Younger non-BAP and Younger BAP performing similarly but Older non-BAP performing better than Older BAP. Results show that younger and older adults with elevated autistic traits show poorer ToM performance. Despite ToM difficulties being common in later-life in the general population, this effect was not observed when using a ToM task designed to reflect real-world scenarios. However, results suggest that autistic traits and age could interact to increase risk for poor ToM performance in older adults who endorse elevated autistic traits.

Keywords: theory of mind, aging, broad autism phenotype, autism, adulthood

Introduction

The Broad Autism Phenotype (BAP) describes a set of subclinical behaviours and characteristics that are qualitatively similar to the dyad of impairment found in Autism Spectrum Disorder (American Psychiatric Association, 2013), henceforth referred to as autism (Bolton et al., 1994; Constantino & Todd, 2003; Losh & Piven, 2007). Autism is a lifelong heterogenous neurodevelopmental condition characterised by early onset difficulties in social-communication and restrictive and repetitive patterns of behaviours and interests (American Psychological Association, 2013). Deficits in theory of mind understanding are also a core feature of socio-cognitive ability in autism. Theory of mind refers to the capacity to attribute mental states (i.e., beliefs, intents, desires, emotions, knowledge, etc.) to others, and to understand that these may differ from our own (Happé, 2015). Throughout early development, theory of mind deficits are evident in children who go on to receive an autism diagnosis. Social functioning difficulties, such as poorer social orienting and reciprocity, lower attention to social stimuli, reduced imitation, lower social interest and social smiling, and atypical eye contact, are reported within the first 3 years of life (Zwaigenbaum et al., 2005). As the child reaches school age, further difficulties become apparent, such as tracking other's mental states and making friends. These difficulties are found to persist throughout childhood into adolescence and adulthood. While studies have found that autism symptom severity is associated with greater theory of mind difficulties (Happé & Frith, 2014), some studies have also reported that interoceptive difficulties caused by alexithymia, a condition commonly experienced by autistic people, may influence theory of mind difficulties (Bird & Cook, 2013). Despite various possible influences, theory of mind ability is thought to be stable throughout adulthood in autistic individuals, nevertheless few studies have examined it across the lifespan and into later life (Chung, Barch, & Strube, 2014). One study exploring theory of mind ability in autistic adults across the lifespan reported that difficulties observed on the Faux Pas task (Stone, Baron-

Cohen, & Knight, 1998) were less apparent in older age, with older autistic adults performing comparably to older non-autistic adults (Lever & Geurts, 2016).

However, it may be important to consider task characteristics and other cognitive factors when interpreting age-related differences in the performance on these tasks. One suggestion for this pattern of age-related change is that autistic individuals often utilise compensatory strategies, e.g., relying on other cognitive processes to circumvent theory of mind difficulties to arrive at an appropriate response, such as verbal ability and cognitive flexibility (Gökçen, Frederickson, & Petrides, 2016; Hughes & Leekam, 2004). Many theory of mind tasks, such as the Faux Pas (Stone, Baron-Cohen, & Knight, 1998; Baron-Cohen, O'Riordan, Stone, Jones, & Plaisted, 1999) and Strange Stories (Happé, 1994) tasks allow the individual as much time as they require to read and process the statement in order to complete the task, thus limiting their ecological validity. Therefore, while autistic adults may 'pass' some theory of mind tasks, they still experience difficulties in real-world social interactions (Frith & Happé, 1994; Scheeren, De Rosnay, Koot, & Begeer, 2013). This has led to a call for more ecologically-valid measures of theory of mind that mimic the naturalistic pace of real-world social interactions (Dziobek, 2012). However, age-related differences in ecologically-valid theory of mind tasks (such as the Strange Stories Film Task; Murray et al., 2017) have been previously documented in non-autistic adult populations. Results demonstrate that older adults perform more poorly than younger adults; this pattern may be due to age-related changes in executive functioning rather than theory of mind per se (Gökçen, Frederickson and Petrides, 2016; Jones et al., 2018; Nolaker et al., 2018). As executive functions are implicated in cognitive aging, this may drive age-related differences in theory of mind understanding. Theory of mind underlies successful social interactions, therefore a decline in this ability in later life may impact social functioning. This may lead to a rise in other social problems prevalent in older adults, such as isolation and loneliness which are risk factors for age-related cognitive

decline (Shankar et al., 2013). Therefore, theory of mind ability may be particularly important for older autistic adults.

With current prevalence estimates of autism being around 1% (Lai, Lombardo, & Baron-Cohen, 2014), and an older adult population that is steadily increasing, it can be estimated that there are 240,000 autistic adults aged over 50 years old in the UK (Office for National Statistics, 2018a, 2018b). However, despite a growing population of both autistic and non-autistic older adults, our understanding of aging in relation to autism and subclinical autistic traits is limited (Mukaetova-Ladinska, Perry, Baron, & Povey, 2012). Previous studies have struggled to recruit older autistic adults, so sample sizes tend to be small (Howlin & Taylor, 2015). Furthermore, older autistic adults participating in studies may not be representative of the population not least because, depending on when they were diagnosed, different clinical criteria may have placed greater emphasis on intellectual disabilities or developmental delay. As such, older adults now receiving an autism diagnosis in later-life often have average intellectual abilities (Stuart-Hamilton, Griffith, & Totsika, 2010). Therefore, examining those who endorse elevated autistic traits (i.e. the BAP) in older age bypasses the potentially confounding influence of changes in diagnostic criteria and intellectual disability comorbidities.

The BAP may be assessed in different ways. Some researchers opt to use a family history of autism diagnoses to identity those who are likely to also endorse subclinical autistic traits. However, as autism is a polygenic disorder (Colvert et al., 2015) using a trait-based approach to quantify the BAP is more sensitive to identifying those who experience autism-like traits and may reduce the risk of false negatives (Hurley, Losh, Parlier, Reznick, & Piven, 2007). To date, the BAP traits have been explored in later life in relation to cognitive differences in executive function and memory (Stewart, Charlton, & Wallace, 2018; Wallace, Budgett, & Charlton, 2016). Results suggest that elevated BAP traits confer additional risk to

cognitive function for older adults. While other domains, such as theory of mind and social cognition, have not been directly explored in relation to aging in the BAP, they have been explored in relation to autistic traits (e.g. Baksh, Abrahams, Auyeung, & MacPherson, 2018; Gökçen et al., 2016). Previous studies have documented that both elevated autistic traits (measured by the Autism Quotient (AQ); Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001) and older age predict poorer theory of mind task performance in the general population (Baksh et al., 2018). However, the AQ demonstrates differing sensitivities in its psychometric properties between autistic and non-autistic individuals (Agelink van Rentergem, Lever, & Geurts, 2019). Therefore, while the AQ may be an effective tool for discriminating autistic and non-autistic individuals, measures designed to detect BAP traits may be more appropriate when examining the influence of subclinical autistic traits in non-autistic individuals. Thus, further exploration of theory of mind ability is warranted in older adult populations who endorse elevated BAP traits.

This study investigates performance on two measures of theory of mind varying in ecological validity across the adult lifespan (aged 18-91 years). Participants were divided based on age (Younger vs. Older), and on autistic trait endorsement as below or above the cut-off on the Broad Autism Phenotype Questionnaire (BAPQ; Hurley, Losh, Parlier, Reznick, & Piven, 2007) (non-BAP vs. BAP). Previous research indicates that older age and elevated autistic traits are associated with decrements in theory of mind performance (Baksh et al., 2018). Therefore, we predict that older adults will demonstrate poorer theory of mind performance than younger adults. Additionally, those who meet criteria for the BAP will also demonstrate poorer theory of mind performance than those in the non-BAP group. Finally, older adults who meet criteria for the BAP will experience an elevated risk to their theory of mind performance when compared to all other groups.

METHODS

Participants

To explore age related differences between young and older adults, 96 native English-speaking adults from London and the South-East of England were recruited for this study (younger adult age range 18-46, older adult age range 60-91 years, see Table 1 for demographic details). Participants were recruited through local community groups (e.g., Bowling Clubs, Women's Groups, Golf Clubs, Retirement Communities) and the Goldsmiths University Participant Recruitment scheme. As individuals with an autistic relative often endorse autistic traits, online advertisements (e.g., Research Autism, National Autistic Society) were used to target family members with a first- or second-degree autistic relative. All participants had normal or corrected-to-normal vision and hearing.

This study received ethical approval from the Goldsmiths University Ethics Committee. All participants gave written informed consent prior to participation and all research was carried out per the Declaration of Helsinki. Participants were offered research participation credits if enrolled as a student at Goldsmiths University, with non-students being offered £5 for their participation in the study and up to £10 for travel expenses.

TABLE 1 HERE

Measures

Self-report measures – The Broad Autism Phenotype Questionnaire (BAPQ; Hurley, Losh, Parlier, Reznick, & Piven, 2007) was used to assess presence of subclinical autistic traits. The BAPQ has 36-items and utilises a 6-point Likert-type scale from "very rarely" to "very often". BAPQ average scores range from 1 to 6, with higher scores representing greater BAP traits. Using the recommended cut off score, individuals with an average score =>3.15 were classified as BAP group, with those below threshold as non-BAP group. The BAPQ has acceptable inter-item reliability (Cronbach's a = .95) and did not differ between males and females or those with or without autistic relatives.

The Bernard-Vorst Alexithymia Questionnaire (BVAQ; Vorst & Bermond, 2001) was used to assess the presence of behaviours related to alexithymia, i.e. difficulty reflecting on and describing one's emotions. The BVAQ has 20-items and utilises a 5-point Likert-type scale from "strongly disagree" to "strongly agree". BVAQ total scores range from 20 to 100, with higher scores representing greater alexithymia traits. The BVAQ has acceptable inter-item reliability (Cronbach's a = .85) and did not differ between males and females.

Questionnaires were administered prior to the in-person assessment and were completed either on paper distributed via post or online using Qualtrics Software (www.qualtrics.com).

Neuropsychological assessments – An in-person neuropsychological screening assessment was administered by a trained research assistant in a quiet room in the participant's home or in a laboratory at Goldsmiths University. All participants completed the Wechsler Test of Adult Reading (WTAR; Wechsler, 2001), which is a reliable measure of premorbid intelligence (Bright & van der Linde, 2018). The WTAR was adjusted for age and sex to estimate full-scale IQ (FSIQ). WTAR FSIQ scores of 100 represent an average IQ.

All participants over 60 years of age completed the Mini Mental State Exam (MMSE; Folstein, Folstein, & McHugh, 1975) as a screener for possible dementia or other cognitive impairments. MMSE total scores range from 0 to 30, with scores ≥24 indicating normal cognitive functioning. Below this, scores can indicate severe (≤9 points), moderate (10 to 18 points) or mild (19 to 23 points) cognitive impairment. All participants in the current study scored 26 or above.

Strange Stories Film Task (SSFT; Murray et al., 2017) – The SSFT was used as an ecologically-valid measure of theory of mind and social processing. Prior to the task, participants are informed about the nature of the task, i.e., they can see each video once, the clips are short, each is an isolated scenario, and all responses will be transcribed. Participants are also given background information of the characters' relationship, i.e., the character names, the characters are boyfriend and girlfriend, and they live and work together. Participants are instructed that some of the questions have no right or wrong answer, and that we are interested in what they think is happening in each scenario. The SSFT involves a series of 15 self-contained short video clips acted by two semi-professional actors based on the original Strange Stories task (Happé, 1994). Twelve scenarios involved a mental state component (henceforth referred to as SSFT ToM scenarios), such as a double bluff, a white lie, detecting irony or a joke. The remaining three scenarios did not contain a mental state component (henceforth referred to as SSFT Control scenarios). The 15 scenarios all followed the same format, with a third-person perspective displaying the context of the social exchange, followed by the actors speaking directly into the camera to mimic real-world interactions from a first-person perspective. Following each scenario three questions were asked, examining Intentionality (i.e., Why did the character say that?), Interaction (i.e., If you were in the other characters situation, what would you say next?), and a memory question to check for attention and gross memory difficulties (e.g., Where was the character?). Intentionality questions were scored 0-2 (ToM

scenario max total = 24) based on accuracy and appropriateness. An additional Mental State Speech score of 0-2 (ToM scenario max total = 24) was rated for the presence of metacognitive language or complex mental state description in the Intentionality response, e.g. "she wanted him to feel guilty" or "she felt both curious and squeamish at the same time". Interaction questions were scored between 0-2 (ToM scenario max total = 24) based on accuracy and appropriateness. Memory questions scored 0-1 (ToM scenario max total = 12) based on accuracy. The Intentionality question was designed to measure theory of mind, whereas the Interaction and Mental State Speech responses were intended to measure social cognition more broadly. While participants completed all 15 test scenarios, this study only analysed differences in the 12 ToM scenarios. All questions were scored following guidelines outlined in Murray et al. (2017) by a single rater. To assess consistency of scoring, inter-rater reliability of 10 randomly selected scripts was calculated. Responses from two trained research assistants were assessed with an experienced coder (RAC) using two-way random model intra-class correlations (absolute values) in IBM SPSS Statistics (version 25.0; IBM Corp., 2017), with all values being deemed good; ToM-Intentionality, r = .962; ToM-Mental State Speech, r = .871, ToM-Memory, r = .969; Control-Intentionality, r = .894; Control-Mental State Speech, r = .907; Control-Interaction, r = .724; Control-Memory, $r = 1$, no differences were observed on rater scores.

Frith-Happé Triangles Animations (TA; Abell, Happé, & Frith, 2000; Castelli, Frith, Happé, & Frith, 2002) – The TA task is a silent dynamic theory of mind task, which involves a series of six short animated videos showing one large red and one small blue triangle moving freely around a framed white background. Prior to the task, participants are informed about the nature of the task, i.e. the triangles will be doing certain actions (such as chasing, running, and some other interesting things), and we want to know what they think is happening. Participants are

also told that they can see each video once, the clips are short, and all responses will be transcribed. The TA task was selected to be similar in presentation (visual, moving stimuli) and response mode to the SSFT. Four of the animated videos were ToM focused, where one triangle responds to the mental state of the other (henceforth referred to as TA ToM scenarios). The ToM scenarios involve the triangles coaxing, surprising, mocking, and seducing. The remaining two animated videos were goal-directed, and involved the triangles fighting and chasing (henceforth referred to as TA Control scenarios). While the ToM scenarios were designed for the participant to interpret the mental states of the triangles, the control scenarios are more likely to evoke direct descriptions of the interactions taking place.

Responses to the video scenarios were scored for Appropriateness, Intentionality and whether Mental States were described. Appropriateness was scored between 0–2 (ToM scenario max total = 8) based on response accuracy which described in part or whole the intended meaning of the animation sequence. Intentionality was scored between 0–5 (ToM scenario max total = 20) based on the complexity of how the scenario was described; for example, describing a simple movement (e.g., rotating/spinning) would result in a low score, while describing deliberate actions that aim to influence another's mental state (e.g., surprising/mocking) would result in a high score. The Mental State Speech coding was between 0-1 (ToM scenario max total = 4) based on the presence of any explicit psychological or mental state terms (e.g., tricking). While participants completed all six test scenarios, this study only analysed differences in the four ToM scenarios.

All questions were scored by a single rater. To assess consistency of scoring, inter-rater reliability was calculated in 22 randomly selected scripts from the GoldAge Lab ToM project collected 2016-2018. Responses from two trained research assistants were assessed with an experienced coder (RAC) using two-way random model intra-class correlations (absolute values) in IBM SPSS Statistics (version 25.0; IBM Corp., 2017) with all values being deemed

good; ToM-Appropriateness, r = .969; ToM-Intentionality, r = .939, ToM-Mental State, r = .955; Goal Directed-Appropriateness, r = 1, no differences were observed on rater scores; Goal Directed-Intentionality, r = .914; Goal Directed-Mental State, r = 1, no differences were observed on rater scores.

Statistical Analyses

All statistical analyses were performed in IBM SPSS Statistics (version 25.0; IBM Corp., 2017). Group differences in demographic variables were analysed using independent sample t-tests, χ^2, and analysis of variance (ANOVA). ANOVA was also used to evaluate differences and interactions between BAP (non-BAP vs. BAP) and Age (Younger Adult vs. Older Adult) on SSFT and TA task performance. These analyses were rerun using analysis of covariance (ANCOVA) with WTAR scores entered as a covariate to confirm that any group differences were not attributable to the influence of IQ. Pearson correlations were also used to measure associations between BVAQ and both SSFT and TA task performance. Multiple comparisons were controlled for using the False Discovery Rate (Benjamini & Hochberg, 1995), with an alpha of 0.05 being used.

RESULTS

Participants were classified according to cut-off score on the BAPQ as being either non-BAP or BAP. Participants were also divided into groups by age: Younger Adult group, aged 18-46 years and Older Adult group aged 60-91, see Table 1.

Group differences – Demographics

Age did not differ between the non-BAP and BAP groups (see Table 1 for full demographic characteristics).

Differences in sex ratio were observed between YA and OA groups, with fewer males in the YA than OA group, but not between the BAP groups.

Similarly, highest level of education differed between YA and OA groups, but not between BAP groups. The YA group was comprised predominantly of current undergraduate students, with 93.8% having University Entry Level/School to 18 qualifications. The OA group had a broader range of qualifications levels, from no formal qualifications to postgraduate degrees, see Table 1 for full breakdown of highest level of education qualifications.

No group differences in MMSE or estimated FSIQ score were observed between the two age or BAP groups.

Group differences – Self-report measures

A main effect of BAP group on BVAQ ratings was observed. The BAP individuals were found to rate themselves as experiencing more alexithymia traits compared to non-BAP individuals. There was no main effect of age group, and no interaction between BAP and age groups.

While BAPQ scores were not different between YA and OA groups, sex differences were observed with males (M = 3.28, SD = 0.58) rating themselves as demonstrating more BAP traits than females (M = 2.91, SD = 0.59), $t(94) = 2.72$, $p = .008$. Given the overall sample size of the current study and the small number of males in the younger age group, further analysis of sex effects were not conducted.

Group differences – Theory of Mind task performance

For SSFT scores, a main effect of BAP group was observed, with non-BAP individuals performing better than BAP individuals on Intentionality, Interaction, and Memory. No main effect of BAP group in SSFT Mental State Speech was observed after adjusting for multiple comparisons. A main effect of age group was also observed, with YA performing better than OA in Memory only. No further main effects of BAP or age group, nor an interaction between BAP and age groups were observed for SSFT scores, see Table 2 for ToM task group differences and interactions.

For TA scores, a main effect of BAP group was observed, with non-BAP individuals performing better than BAP in Intentionality; however, there were no main effects of BAP group in Appropriateness or Mental State Speech. A main effect of age group was also observed, with YA performing better than OA in Intentionality. No main effect of age group was observed in Appropriateness or Mental State Speech.

Finally, an interaction between BAP and age groups was observed in TA Intentionality. While no differences were observed between the YA non-BAP and BAP individuals, OA BAP individuals experienced more task difficulties than OA non-BAP individuals (see Figure 1).

FIGURE 1 HERE

No further interactions between BAP and age groups were observed for TA scores.

A follow-up ANCOVA controlling for FSIQ found the same pattern of results in SSFT and TA performance for both evaluation of group differences and interactions (results not shown).

TABLE 2 HERE

Correlation analyses – BVAQ with BAPQ and Theory of Mind task performance.

In the whole sample, a positive correlation was observed between alexithymia and BAP traits. No other significant associations were observed between BVAQ and either SSFT or TA task scores. See Table 3.

TABLE 3 HERE

DISCUSSION

For the first time, the current study explored the influence of subclinical autistic (BAP) traits on theory of mind ability in both younger and older adults. This study demonstrated significantly poorer performance on theory of mind tasks in individuals with high self-reported BAP traits in younger and older adults, and results were not explained by IQ. Two age-related differences in theory of mind performance were observed, with one interaction between BAP traits and age also being identified.

Individuals reporting high BAP traits demonstrated poorer theory of mind performance on most measures compared to those with low BAP traits. This effect was especially strong on measures from the ecologically-valid SSFT. Poorer theory of mind in the high BAP group was observed on measures of understanding intentions and interactions (SSFT and TA), and appropriateness of response to a scenario when adopting another's perspective (SSFT); however, differences in Mental State Speech did not survive multiple comparison correction. Although group differences were not observed on TA scores reflecting appropriateness of response to a scenario or mental state terms, this may reflect differences between the TA and SSFT tasks. The TA task uses dynamic silent animations of shapes, while the SSFT uses people enacting real-world scenarios. The increased ecological validity of the SSFT may be the source of its sensitivity in detecting more subtle differences in theory of mind performance. Previous studies in autistic and other neurodevelopmental populations have demonstrated discrepancies between real-world behaviour and lab-based task performance in theory of mind (Hutchins et al., 2016). Studies have shown that autistic individuals may pass theory of mind tasks despite exhibiting real-world problems (Castelli et al., 2002; Fitzpatrick et al., 2018; Frith & Happé, 1994; Scheeren, De Rosnay, Koot, & Begeer, 2013; Tager-Flusberg, 2007). Despite this, researchers

have struggled to design theory of mind tests that are ecologically-valid, have good reliability, and are not either too complex or time-consuming to administer. Therefore, as the SSFT has an ecologically-valid design and is sensitive to subtle differences in performance, it may be an effective tool for documenting socio-cognitive difficulties in both autism and lifespan research.

Our findings largely converge with previous literature exploring theory of mind performance in both autistic and BAP populations. Difficulties in theory of mind performance, in particular in relation to intention and belief inference have been well documented in younger and mid-life autistic adult populations (see Chung, Barch, & Strube, 2014 for meta-analysis). However, theory of mind has seldom been explored in autistic populations in older age. In one study that examined theory of mind using the Faux Pas task, no differences were observed between autistic older adults and neurotypical controls in later life. This could suggest that autism confers a protective stability to age-related changes in theory of mind ability (Lever & Geurts, 2016), although it is important to note that it may also reflect cohort effects. Similarly, theory of mind performance has rarely been examined in relation to the BAP across the lifespan. Within the limited literature, younger and mid-life adults who endorse elevated BAP traits (using the BAPQ; Hurley et al., 2007) or autistic traits more broadly (using the AQ; Baron-Cohen et al., 2001) demonstrate difficulties with theory of mind performance, social cognition and social understanding (Baksh et al., 2018; Sasson, Nowlin, & Pinkham, 2012). Within a young adult sample with elevated BAP traits (measured by the BAPQ), Sasson et al. (2012) report similar findings to the current study with not only poorer performance on theory of mind tasks but also poorer performance on a naturalistic conversation task. Results suggest that elevated BAP traits may have a widespread impact upon social understanding and interpersonal skills. Further studies have extended these findings into middle and older adulthood. Baksh et al. (2018) demonstrated comparable results to the current study. Utilising a novel theory of

mind task, they reported that poorer performance was associated with elevated autistic traits (measured by the AQ) and increased age in young, mid-life, and older adults. However, in the same sample these associations were not demonstrated on another well-established video measure, the Reading the Mind in the Films task (Golan, Baron-Cohen, Hill, & Golan, 2006). It is worth noting that some of these differences may be due to task specific difference. Therefore, while it was expected that individuals who endorse elevated BAP traits would demonstrate impaired theory of mind (Losh & Piven, 2007; Wainer, Ingersoll, & Hopwood, 2011), the inconsistencies in findings when using different measures suggests that task characteristics play an important role in being able to detect subtle differences in theory of mind ability.

Notably, few age-related differences in task performance were observed. Poorer performance in the older relative to the younger adult group was demonstrated on scores reflecting memory (SSFT) and on scores reflecting understanding intentions and interactions only on the TA task. While age-related differences in memory are expected, the other SSFT scores related to theory of mind (understanding intentions, interactions and attributing mental states) were not affected by age in the current study. Most studies in typical aging demonstrate poorer theory of mind performance in older adults compared to younger adults regardless of task domain, i.e. cognitive or affective, or modality, i.e. verbal or visual (see Henry, Phillips, Ruffman, & Bailey (2013) for meta-analyses of theory of mind and aging literature). Other than the age difference on the TA measure of understanding intentions, our current findings do not follow the prevailing pattern of results (although see the discussion of cognitive abilities in the next paragraph). Despite the literature in older age being limited for the specific measures used in this study, poorer task performance is associated with increased age in a range of theory of mind tasks including Happé's Strange Stories task on which the SSFT is based (Castelli et al.,

2010; Charlton, Barrick, Markus, & Morris, 2009; Maylor, Moulson, Muncer, & Taylor, 2002; Rakoczy, Harder-Kasten, & Sturm, 2012), the Faux Pas task (Slessor, Phillips, & Bull, 2007), and animated/cartoon tasks (Baksh et al., 2018; Duval, Piolino, Bejanin, Eustache, & Desgranges, 2011).

While age-related differences in theory of mind ability are often observed, many studies acknowledge the importance of considering domain general cognitive functions. A growing number of studies have shown that age-related differences in theory of mind performance are mediated by cognitive factors, such as IQ and executive functions (Charlton et al., 2009; Rakoczy, Wandt, Thomas, Nowak, & Kunzmann, 2018; Sullivan & Ruffman, 2004). Perhaps most pertinent to the current study, Nolaker et al. (2018) demonstrated theory of mind performance on the SSFT decreased with age across the adult lifespan (17-95 years), although this age-effect was explained by performance on executive function measures. We did not find age-effects on SSFT in our current study comparing younger and older adults (note that due to recruitment strategy age is not continuous with a gap in mid-life). It is possible that the sample of older adults in the current study were more cognitively able than those in the Nolaker et al. (2018) study, thus explaining the pattern of results; however, this is speculative as Nolaker et al. did not measure intelligence. What can be noted is that the older non-BAP sample included in the current study have estimated IQ scores of 108.92, reflecting abilities in the average range (for reference: average range = 90-109; high average range = 110-119). As such, age-related cognitive factors rather than age itself may be the key factor influencing theory of mind ability during aging. This highlights the importance of considering broader cognitive functioning when examining social cognition in later life. Other features that are common but not unique to autism such as alexithymia, may also impact theory of mind understanding. In the current study, high BAP individuals reported higher alexithymia scores, which is in keeping with other

studies (Berthoz, Lalanne, Crane, & Hill, 2013; Szatmari et al., 2008). However, unlike previous studies we did not find a significant association between alexithymia and theory of mind abilities (see Bird & Cook (2013) for review). This may reflect the nature of the tasks being used, as unlike emotion identification tasks (e.g. Reading the Mind in the Eyes (Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001)), neither the SSFT and TA place an emphasis on emotion identification or introspection.

An additional finding from the current study was that older adults who endorse elevated BAP traits were found to experience an increased risk to their understanding of intentions and interactions (TA) compared to older adults without elevated BAP traits. This interaction effect remained significant when IQ was taken into account. However, the same pattern of results was not observed on a similar measure in the ecologically-valid SSFT. This suggests that task characteristics may exacerbate difficulties in some aspects of theory of mind performance. Therefore, while the pattern of results is not consistent across all aspects of theory of mind, aging with elevated BAP traits could confer an elevated risk to some aspects theory of mind performance later in life. Future studies employing a longitudinal design that can control for individual differences in age-related change to non-social cognitive factors and theory of mind ability are best equipped to more stringently test this possibility.

It is important to consider limitations when contextualizing this research. The recruitment strategy differed for the younger and older adult populations and this may influence results. The younger adult group was predominantly composed of undergraduate Psychology students whereas the older adult group was recruited from various social or activity groups. Although there is potential for this to lead to sampling biases, it is unlikely that the same recruitment strategy would be effective in such diverse age-ranges. Furthermore, this study recruited a

younger and older adult sample; however, an alternate approach could have been to recruit across the entire adult lifespan to consider age as a continuous variable. The BAPQ also could be used as a continuous variable rather than dichotomizing into BAP and non-BAP groupings. Furthermore, while the BAP may form a bridge in the continuum from typical to atypical autistic traits, it is unknown whether these results extend to those meeting criteria for autism. A separate issue is the inconsistent pattern of results for the SSFT compared to TA. This could be partly attributed to task characteristics, such as real-world scenarios vs. animations, actors vs. shapes, or verbal vs. non-verbal presentation modality, rather than theory of mind ability per se. As the SSFT mimics acted real-world scenarios comparable to their everyday social encounters, this may be more familiar to older adults who can therefore interpret them more accurately. In contrast the TA uses dynamic animations, which are less likely to be regularly experienced and could be more challenging to interpret due to their abstract presentation. Of potential importance is the SSFT's reliance on two young adult actors in its scenarios, which could result in performance bias in the younger adult group due to same-age bias (Anastasi & Rhodes, 2006; Ebner & Johnson, 2009; Ruffman, Henry, Livingstone, & Phillips, 2008). Previous studies have demonstrated an own-age bias in recognition memory tasks, but the effect of this is less clear in other tasks (Harrison & Hole, 2009). However, it is important to note that age-effects were not observed on the SSFT. Future task development should expand the scenarios to include actors from a wider age range to allow for the examination of possible own-age biases in social cognition abilities. Furthermore, while the SSFT has been designed to be a more ecologically-valid measure of socio-cognitive abilities by tapping into scenarios which mimic real-world interactions, future studies should assess whether real-life understanding in social situations correlates with SSFT performance. Finally, studying executive functions alongside social cognition may be important to understanding the driving factors behind age-related changes in theory of mind understanding.

In summary, this study finds that the BAP detrimentally impacts performance on both a naturalistic and non-social theory of mind task in younger and older adults. Additionally, there was some evidence that aging with BAP traits confers an elevated risk to some aspects of theory of mind performance (e.g., perspective taking). This suggests that the trajectories of age-related change in theory of mind performance may differ in individuals with elevated BAP traits when compared to neurotypical individuals. As the BAP may form a bridge in the continuum from typical to atypical levels of autistic traits, these findings may provide insight into aging in autism. Therefore, older autistic adults may also be at greater risk for increased age-related declines in theory of mind ability in adulthood. Future longitudinal studies including individuals with both subclinical and clinical levels of autistic traits are needed to definitively assess the influence of autistic trait levels on trajectories of social cognition in adulthood.

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Tables

Table 1. Demographic characteristics of the Younger Adults and Older Adults groups, with non-BAP/BAP subgroupings

		Younger Adult (<46 years)		Older Adult (>60 years)		Group Difference			
		non-BAP (n=31)	**BAP (n=18)**	**non-BAP (n=26)**	**BAP (n=21)**	**BAP Main Effect**	**Effect Size**	**Age Main Effect**	**Effect Size**
Age, *years*	*M (SD)*	24.94 (8.73)	22.83 (7.54)	73.04 (7.13)	74.38 (8.49)	t(94) = -.68 p = .497	0.14	-	-
Sex	*male:female*	3:28 (9.7%:90.3%)	4:14 (22.2%:77.8%)	8:18 (30.8%:69.2%)	10:11 (47.6%:52.4%)	χ^2 = 3.31 p = .069	0.39	χ^2 = 7.18 p = .014*	0.57
Highest Education	*None* *School to 16* *School to 18* *Undergraduate* *Postgraduate*	0 1 (3.2%) 29 (93.5%) 0 1 (3.2%)	0 0 17 (94.4%) 0 1 (5.6%)	1 (3.8%) 6 (23.1%) 6 (23.1%) 5 (19.2%) 8 (30.8%)	1 (4.8%) 9 (42.9%) 4 (19.0%) 5 (23.8%) 2 (9.5%)	χ^2 = 8.76 p = .187	0.27	χ^2 = 53.23 p < .001***	0.19
WTAR FSIQ	*M (SD)*	107.23 (5.95)	106.72 (5.08)	108.92 (9.05)	106.81 (7.46)	F(1,91) = .77 p = .553	0.18	F(1,91) = .36 p = .553	0.13
MMSE, *total*	*M (SD)*	-	-	28.92 (.79)	28.71 (1.34)	t(47) = .50 p = .620	0.04	-	-
BAPQ, *mean*	*M (SD), Range*	2.62 (.32) 1.78 - 3.06	3.61 (.37) 3.19 - 4.51	2.62 (.53) 1.47 - 3.11	3.51 (.37) 3.15 - 4.53	-	-	t(94) = -.26 p = .794	0.07
BVAQ, *total*	*M (SD)* *Range*	45.95 (7.98)	54.94 (8.29)	48.00 (8.86)	50.00 (12.16)	F(1,92) = 7.92 p = .012**	0.56	F(1,92) = .56 p = .458	0.04

Note: BAP, Broad Autism Phenotype; WTAR FSIQ, Weschler Test of Adult Reading Full-scale IQ estimate controlled for sex and education; MMSE, Mini Mental State Exam (Range 0-30). BAPQ, Broad Autism Phenotype Questionnaire (Range 1-6); BVAQ, Bernard-Vorst Alexithymia Questionnaire (Range 20-100). Effect size = Cohen's d. No interactions are observed between autistic traits and age.
All statistics displayed are corrected for multiple comparisons. * p < .05, ** p < .01, *** p < .001

Table 2. Mean and Standard Deviations of Theory of Mind task performance of the Younger Adults and Older Adults groups, with non-BAP/BAP subgroupings

		Younger Adult (<46 years)		Older Adult (>60 years)		Group Difference				
		non-BAP (n=31)	BAP (n=18)	non-BAP (n=26)	BAP (n=21)	BAP Main Effect	Effect Size	Age Main Effect	Effect Size	Interaction
Strange Stories Film Task										
Intentionality	*Mean (SD)*	17.67 (3.02)	16.17 (3.00)	17.53 (3.79)	13.66 (5.23)	F(1,92) = 11.16 p < .001***	0.46	F(1,91) = 2.71 p = .137	0.33	F(1,91) = 2.17 p = .144
Mental State Speech		13.67 (3.84)	12.61 (3.50)	13.88 (5.14)	10.42 (5.14)	F(1,92) = 5.63 p = .060	0.51	F(1,92) = 1.07 p = .302	0.20	F(1,92) = 1.57 p = .302
Interaction		16.96 (2.99)	15.33 (3.34)	17.80 (4.34)	13.09 (4.83)	F(1,92) = 15.23 p < .001***	0.81	F(1,92) = .74 p = .784	0.16	F(1,92) = 3.58 p = .186
Memory		11.70 (.52)	11.44 (.92)	11.42 (1.13)	10.66 (1.49)	F(1,92) = 5.31 p = .042*	0.50	F(1,92) = 6.00 p = .042*	0.50	F(1,92) = 1.27 p = .348
Triangle Animations Task										
Appropriateness	*Mean (SD)*	4.3 (2.10)	4.44 (1.94)	4.76 (2.55)	3.85 (2.12)	F(1,92) = .77 p = .591	0.18	F(1,92) = .023 p = .879	0.00	F(1,92) = 1.26 p = .591
Intentionality		12.16 (3.58)	12.00 (3.49)	11.73 (3.35)	8.28 (4.40)	F(1,92) = 5.44 p = .044*	0.50	F(1,92) = 7.19 p = .036*	0.49	F(1,92) = 4.52 p = .048*
Mental State Speech		1.19 (1.01)	1.50 (.85)	1.76 (1.24)	1.47 (.98)	F(1,92) = .001 p = .976	0.03	F(1,92) = 1.59 p = .315	0.32	F(1,92) = 1.87 p = .315

Note: BAP, Broad Autism Phenotype; SSFT Intentionality, Mental State and Interaction max scores = 24, Memory max score = 12; TA Appropriateness max score = 8, Intentionality max score = 20, Mental State max score = 4. Effect size = Cohen's d.
All statistics displayed are corrected for multiple comparisons. * p < .05, ** p < .01, *** p < .001

Table 3. Correlations between BVAQ, Theory of Mind scores and BAPQ within the whole sample.

	SSFT Intentionality	***SSFT Mental State Speech***	***SSFT Interaction***	***SSFT Memory***	***TA Appropriateness***	***TA Intentionality***	***TA Mental State Speech***	***BAPQ average score***
BVAQ total score	-.01	.03	.07	-.06	-.05	-.08	-.14	.36**

Note: SSFT, Strange Stories Film Task; TA, Triangle Animations; BVAQ, Bernard-Vorst Alexithymia Questionnaire; BAPQ, Broad Autism Phenotype Questionnaire

* $p < .05$, ** $p < .01$, *** $p < .001$

Figure Legend:

Figure 1: BAP x Age group interaction on TA Intentionality score.