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Sleep problems and mental health difficulties in older adults who endorse high autistic traits.

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Abstract

Background: Sleep problems and mental health difficulties are common in autistic children and young adults. However, these problems have seldom been studied in older autistic adults, or in older adults with elevated autistic traits.

Method: Cross-sectional data was examined from 13,897 adults aged 50-81 years taking part in the PROTECT study, who reported whether they experienced persistent socio-communicative autistic traits. Approximately 1%, 187 individuals, were identified as endorsing high autistic traits in childhood and currently, henceforth 'Autism Spectrum Trait' (AST) group. An age- and gender-matched comparison group was formed of 6,740 individuals who endorsed no autistic traits, henceforth 'Control Older Adults' (COA) group. Differences between AST and COA groups were explored in self-reported sleep behaviors, and in depression and anxiety symptoms.

Results: AST and COA groups reported similar sleep duration and depth, and nighttime waking frequency. However, the AST group reported significantly more problems with falling asleep, morning drowsiness, and lower sleep quality/satisfaction than COA. More AST adults reported sleep problems past cut-off, as well as clinical levels of depression and anxiety, compared to COA. Adults in both groups who met criteria for high sleep problems experienced more mental health difficulties than those with few sleep problems. However, even amongst those without depression/anxiety, the AST group reported more sleep problems than the COA.

Conclusions: These associations suggest that older adults with high autistic traits, like diagnosed autistic children/young adults, may experience poorer sleep and more mental health difficulties than those with low autistic traits. Further work is needed to see whether these results extend to older individuals meeting diagnostic criteria for autism.

Key Words: Autistic Traits, ASD, Aging, Older Adults, Sleep, Mental Health, Depression, Anxiety

INTRODUCTION

Autism Spectrum Disorder (ASD) is a lifelong neurodevelopmental condition that is characterized by impairments in social communication, and rigid and repetitive behaviors and interests (American Psychiatric Association, 2013). Social communication skills or difficulties are found to be distributed among the general population, with ASD being construed as lying at the end of this spectrum (Bralten et al., 2018; Colvert et al., 2015; Robinson et al., 2016). Much research has taken a dimensional approach to the study of ASD; this is done by studying the presence of traits across the general population. By doing this we consider the wider autism spectrum, including individuals with elevated autistic traits who nonetheless fall below the diagnostic threshold for ASD (Bralten et al., 2018). This dimensional approach may be particularly useful for examining the experiences and outcomes of under-researched (and possibly under-diagnosed) populations, such as older adults (Stuart-Hamilton, Griffith, & Totsika, 2010).

One function that is known to be impacted by ASD is sleep (Carmassi et al., 2019; Morgan, Nageye, Masi, & Cortese, 2020). Sleep disorders and sub-clinical sleep problems are a common comorbidity in ASD, often presenting as reduced sleep duration, delayed sleep onset, increased nighttime waking and sleeplessness, and overall lower sleep quality and efficiency (see Carmassi et al. (2019) and Schreck and Richdale (2020) for recent reviews). However, sleep in ASD (or autistic traits more broadly) in middle-age or later life has seldom been explored. A few recent studies have examined sleep disorders across the adult lifespan in ASD. In a study of private insurance healthcare records from Kaiser Permanente in Northern California (USA), Croen et al. (2015) reported that autistic adults aged 19-79 (total n = 1507, age 50-79 n = 143) had elevated diagnoses of sleep-related disorders (e.g. insomnia, dyssomnia) compared to a sex and age matched non-autistic comparison group (17.5% vs. 9.6%; OR=1.9). A later study by Hand, Angell, Harris, and Carpenter (2019) examined Medicare healthcare records of over 4,000 older autistic adults in the USA aged 65 years and older. This study reported significantly elevated rates of sleep disorders in older autistic adults when compared to a non-autistic comparison group (1.4% vs 0.7%, OR=2.2). Additionally, Jovevska et al. (2020) examined cross-sectional data from two Australian longitudinal cohorts (the Study of Australian School Leavers with Autism and the Australian Longitudinal Study of Adults with Autism). This study reported elevated rates of problematic sleep among their autistic participants (age 15-80 n = 324); however, these differences were not observed among those aged 60 years and older.

Furthermore, additional analyses of this data from Lawson et al. (2020) found associations between sleep and quality of life across the lifespan among their autistic participants. These studies also report elevated rates of mental health difficulties, suggesting that autistic individuals are vulnerable to poor sleep and poor mental health throughout adulthood, although the relationship between these variables has not been directly explored (Croen et al., 2015; Hand et al., 2019).

Sub-clinical sleep problems (as distinct from sleep disorders) have also been found to be highly prevalent in autistic populations across the lifespan. Systematic and clinical reviews have established that parent-reported sleep problems have a prevalence rate of 50-80% in autistic children compared to 9-50% in non-autistic children (Richdale & Schreck, 2009). Sleep problems are also observed in late adolescence and young adulthood, and have been documented to affect approximately 80% of autistic young adults (Oyane & Bjorvatn, 2005), compared to 4-26% of young adults in the general population (see Ohayon (2011) for an overview of sleep problems in the general population). These problems are also found in adulthood. Baker and Richdale (2015) utilized a multi-method approach to examine sleep problems in a sample of autistic adults aged 21-44 years. The authors reported that autistic adults experienced longer sleep onset and more fragmented sleep through actigraphy (a device that objectively measures sleep/wake patterns through movement recordings), and more sleep disturbances, lower sleep quality, and poorer sleep efficiency through self-report measures with moderate-to-large effect when compared to an age and gender matched comparison group. Furthermore, significant differences were observed in sleep duration measured via actigraphy, with autistic adults sleeping for shorter durations than the comparison group; however, this difference was not observed in self-report measures. Additionally, through compiling data from both actigraphy and self-report measures, 28% of the autistic group met probable criteria for insomnia compared to 6% of the comparison group. In an updated analysis of this sample, Baker and Richdale (2017) report that the autistic group experienced elevated rates of depression and anxiety compared to their comparison group, which may influence overall sleep patterns (see Schreck and Richdale (2020) for sleep problems and psychopathology interplay review). While few studies have examined the prevalence rate of sleep problems in mid-life and older adulthood, Jovevska et al. (2020) report that problematic sleep was more common for autistic individuals (64%) across the lifespan than their comparison group (46%). Furthermore, elevated symptoms have been reported by autistic (with large effect sizes) compared to comparison adults (age 19-79 years, mean age = 47 years) on a self-report

scale (Lever & Geurts, 2016). However, in both autistic and non-autistic adults, sleep problems were not found to be correlated with age. Studies that have examined sleep problems and mental health difficulties in autistic populations have reported that they commonly co-occur, with mental health problems being a significant predictor of poor sleep (Jovevska et al., 2020). Furthermore, results from non-autistic populations also suggest strong associations between sleep and mental health, although the direction of these associations is complex; sleep problems can have a robust negative impact on mental health, but sleep problems are also often a symptom of mental health difficulties (see Palmer and Alfano (2017) for a clinical review of sleep and mental health interplay).

Sleep problems have also been found to be common in children and adolescents with high autistic traits. A longitudinal study conducted by Uren, Richdale, Cotton and Whitehouse (2019) examined the associations between sleep problems, anxiety, and autistic traits (measured by the Childhood Behavior Checklist) in children at ages two and eight years. This study highlighted the inter-relatedness of sleep problems, anxiety, and autistic traits, with autistic traits at age 2 being a significant predictor of sleep problems (1.1% of variance) and anxiety (5.6% of variance) at age 8. Furthermore, a longitudinal study conducted by Verhoeff et al. (2018) examined whether sleep problems, ASD, and autistic traits (measured by the Childhood Behavior Checklist) are associated across childhood. Initial testing occurred at 1.5 years, with follow up at age 3, 6, and 9 years. This study notes that the trajectory of sleep problems differs between autistic and non-autistic children across childhood, with autistic children experiencing more sleep problems throughout childhood, while non-autistic children experience a decrease with age. Additionally, sleep problems were not found to precede or worsen autistic behavior but co-occurred with autistic traits. Another longitudinal study, conducted by Sivertsen, Posserud, Gillberg, Lundervold and Hysing (2012), examined the association between sleep problems and autistic traits (measured by the Autism Spectrum Screening Questionnaire) in children aged 7-9 and again at age 11-13 years. Children with high autistic traits were found to develop more sleep problems across childhood compared to those with low traits (OR=2.1 to 6.4). These problems were also more persistent over time in the high traits group, with a remission rate of 8.3% for those with high autistic traits compared to 52.4% in the comparison group. Even controlling for mental health problems, those with high autistic traits had a threefold increase in sleep problems.

Associations between sleep problems, poor mental health, and autistic traits have also been documented during older adolescence. Salmela, Kuula, Merikanto, Räikkönen, and Pesonen (2019) reported that high levels of autistic traits (measured by the Autism Quotient) were significantly associated with shorter sleep duration in 157 individuals from a Swedish birth cohort at age 16 years. Furthermore, autistic traits were an independent predictor of short sleep duration after controlling for depression and anxiety symptoms, with each 1-point increase in the AQ score representing an OR increase of 1.14 for shorter sleep duration. The findings of these studies suggest that sleep problems, mental health difficulties, and autistic traits are interrelated and should be studied concurrently. While autistic traits and genetic predisposition to autism have been associated with poor mental health in adult populations (Howlin, Moss, Savage, Bolton, & Rutter, 2015; Stewart, Charlton, & Wallace, 2018; Stewart et al., 2020), to the authors' knowledge, no studies have examined the relation between autistic traits and sleep problems beyond adolescence.

While some studies have explored sleep in older autistic populations (Croen et al., 2015; Hand et al., 2019; Lever & Geurts, 2016), it is currently unknown whether sleep problems are elevated in adults growing older with sub-clinical autistic traits. In the general population, it is well documented that the pattern and characteristics of sleep change throughout the life course, with total sleep duration decreasing with age (see Ohayon, Carskadon, Guilleminault and Vitiello (2004) for a meta-analysis of sleep behaviours from childhood to old age in the general population). Therefore, given these age-related changes and the well-documented sleep problems experienced by autistic people in younger life, it could be expected that older autistic adults (and those with high autistic traits more broadly) may be particularly vulnerable to poorer sleep compared to non-autistic or low trait older adults. Furthermore, given the previous associations between sleep and mental health, those who experience poor sleep may also experience more symptoms of poor mental health in older age.

The current study explores the profile of sleep behaviors and experiences in a sample of adults aged 50 years and older who endorsed persistent high socio-communicative autistic traits, compared to a control group who did not report any childhood or current autistic traits. The study further investigates whether those who endorse high autistic traits experience more sleep problems and mental health difficulties when compared to the control group. It is predicted that older adults with high autistic traits

will (1) report more current sleep problems, and (2) report more current symptoms of poor mental health, when compared to the control group. It is also predicted that (3) those who experience above cut-off sleep problems will experience more current symptoms of poor mental health. The results from this study could contribute to our understanding of sleep, mental health and autistic traits, and highlight potential differences in support and care needs of older adults on the wider autism spectrum.

METHODS

Study Design and Participants

This study uses cross-sectional baseline data from the ongoing PROTECT study (www.protectstudy.org.uk). Inclusion criteria for the PROTECT study are: adults over the age of 50 years, who live in the UK, have a good working understanding of English, and can use a computer with internet access. Participants who have an established diagnosis of dementia are excluded. Recruitment for the PROTECT study was advertised through Alzheimer's Society UK, the UK Medical Research Council, press coverage by the British Broadcasting Corporation (BBC), and on social media, e.g. Twitter. Participants register online and are required to review the study information sheet and to provide consent via an approved online platform. The PROTECT study received ethical approval from the UK London Bridge National Research Ethics Committee (Ref: 13/LO/1578).

From a current total sample of 20,220 PROTECT participants, 13,897 participants (female n = 10,520, 75.6%) completed measures of sleep quality, with 187 (1.3%) meeting our cut-off criteria for the Autism Spectrum Traits (AST) group, see Measures section below for inclusion criteria. To create a Control Older Adults (COA) group, from the remaining 13,710 participants, 2,768 participants were excluded for endorsing any autism spectrum traits. To ensure a broad age range is represented and to account for the high proportion of females within the sample, the AST and COA groups were matched on mean age and age range and gender ratio. For this matching a further 4,202 participants were excluded using random participant selection methods, resulting in 6,740 participants in the COA group. See Table 1 for demographic characteristics.

To ensure the age- and gender-matched COA group, who endorsed no autism traits, were not atypical or unrepresentative of the whole PROTECT sample, analyses were repeated comparing the AST group to all other PROTECT participants (n=13,897). A similar pattern of results was observed, therefore, the results reported henceforth compare the AST and matched COA groups described above.

Very few participants in the PROTECT cohort report having an ASD diagnosis; there are 21 individuals who meet criteria on the Autism Trait measure and are included in the AST group who also reported an ASD diagnosis. No participant included in the COA group reported an ASD diagnosis.

TABLE 1 / DEMOGRAPHICS TABLE HERE

Measures

Autism Spectrum traits – Constraints on the number of items in the PROTECT battery of questionnaires required the construction of a very short, 5-item measure to assess childhood and current socio-communicative traits characteristic of autism. Using a yes/no format, the participant was asked if as a child they had "struggled compared to [their] peers (socially or at school) with: (1) knowing how to get along with other children; (2) understanding other kids' jokes, sarcasm or deception". Further questions asked if the participant "currently find[s] it more difficult than other people to: (1) make and keep friends; (2) understand other people's perspectives; (3) recognize if someone means something different from what they are saying". A stringent cut-off was used, with those included in the AST group endorsing both the childhood traits plus at least two of the three current traits (total scores=4-5/5), while those included in COA group did not endorse any past or current traits.

To validate this bespoke measure, an additional study was conducted to examine associations between the PROTECT Autism Traits measure and the Autism Quotient (AQ-10; Allison, Auyeung, & Baron-Cohen, 2012) and Ritvo Autism and Asperger's Diagnostic Screen (RAADS-14; Eriksson, Andersen, & Bejerot, 2013). In the separate validation sample (autistic individuals with a diagnosis n=101; non-autistic individuals n=133; see Supplementary Table 1 for full demographics), moderate to strong positive associations were observed between the PROTECT measure and the AQ-10 (autistic r=.51, p<.001; non-autistic r=.66, p<.001), and the RAADS-14 (autistic r=.56, p<.001; non-autistic

r=.73, *p*<.001). On the PROTECT measure 82.2% of the autistic group and 6.0% of the non-autistic group passed the cut-off described above. This overall sensitivity and specificity was as good as for the established measures; on the AQ-10 77.2% of autistic and 18.0% of non-autistic group passed cut-off, and on RAADS-14, 97.0% of autistic and 33.1% of non-autistic group passed cut-off (see Supplementary Table 2 for more details). Good to excellent internal consistency were demonstrated in the validation sample for the PROTECT measure (Cronbach's *a*=.82), AQ-10 (Cronbach's *a*=.80), and RAADS-14 (Cronbach's *a*=.93).

Demographic information – PROTECT participants completed an online demographic information questionnaire, including age, gender, marital status, education history, and employment status.

Self-report questionnaire measures – Sleep behaviors and experiences were measured using an adapted version of the St. Mary's Hospital Sleep questionnaire (SMH-SQ; Ellis et al., 1981). The SMH-SQ has 8-items which ask the participant about different aspects of their sleep over the last month. These questions include: 1) how long they typically sleep for at night (hours/mins), 2) how long they typically sleep for during the daytime (hours/mins), 3) their depth of sleep (6-point scale, very light to very deep), 4) how alert/drowsy they feel when waking (6-point scale, very alert to very drowsy), 5) how many times they wake up at night (8-point scale, none to seven or more times), 6) the experience of any difficulties falling asleep (4-point scale, none to extreme), 7) their overall perceived sleep quality (6-point scale, very bad to very good), and 8) their overall sleep satisfaction (5-point scale, very unsatisfied to very satisfied). To identify those with high sleep problems, a bespoke composite score of questions 5-8 was created with questions 7 and 8 being reverse scored. The distribution of this composite score was observed across the whole sample. A mean of 6.4 and median of 6 was reported, with a cut-off score being placed at the 90th percentile. With a maximum score of 19, those with a score ≥11 were identified as having above cut-off sleep problems, with those who meet criteria experiencing sleep problems across multiple domains.

Symptoms of depression were measured using the Patient Health Questionnaire (PHQ-9; Kroenke, Spitzer, & Williams, 2001). The PHQ-9 is a nine-item questionnaire with a 4-point scale which ask the participant to report whether they have been bothered by a range of problems over the past two

weeks. Using the conventional cut-off score of ≥10, the PHQ-9 has a sensitivity of 88% and a specificity of 88% for major depressive disorder.

Symptoms of anxiety were measured using the General Anxiety Disorder questionnaire (GAD-7; Spitzer, Kroenke, Williams, & Löwe, 2006). The GAD-7 is a seven-item questionnaire with a 4-point scale which asks the participant to report whether they have been bothered by a range of problems over the past two weeks. Using the conventional cut-off score of ≥10, the GAD-7 has a sensitivity of 89% and a specificity of 82% for generalized anxiety disorder.

Statistical Analyses

All statistical analyses were performed on IBM SPSS Statistics (version 25.0; IBM Corp., 2017). Group differences in demographic variables were analyzed using independent sample t-tests, $\chi 2$, and analysis of variance (ANOVA). $\chi 2$ and ANOVA were also used to evaluate differences in sleep behaviours and experiences between Trait (AST vs. COA) and Sleep (Low Problems vs. High Problems) groups. Pearson correlations were also used to measure associations between age, sleep, and mental health difficulties. Multiple comparisons were controlled for using the False Discovery Rate (Benjamini & Hochberg, 1995), with an α of 0.05 being used.

RESULTS

Demographics

Table 1 shows demographic characteristics by group. Age, gender ratio, education history and employment status did not differ between the AST and COA groups. Differences between the AST and COA groups were observed in marital status: the AST were more often divorced, co-habiting, or single compared to the COA group.

Gender differences were observed in marital status in AST and COA, and in education history and employment status in COA. For marital status, AST and COA females were more often widowed, divorced, separated or single, while males were more often married. For education history, COA males more often reported having postgraduate degrees, while females more often reported having school to 18 qualifications or undergraduate degrees. For employment status, COA females were more often employed, while males were more often retired.

The only significant interaction of group (AST vs. COA) with gender was observed for age. AST males and females were on average closer in age than COA males and females: mean (SD) male AST = 64.50 years (7.86 years); female AST = 62.28 years (6.53 years); male COA = 66.53 years (6.93 years); female COA = 61.30 years (6.04 years), $F(1,6927)=8.15$, $p=.004$.

Sleep behaviors and experiences

Table 2 shows self-reported sleep behaviors and experiences by group. No difference was observed in the total duration of nighttime sleep between those in the AST and COA groups, however, the AST group reported slightly longer daytime sleep than COA. No differences were observed in the depth of sleep or in frequency of nighttime waking between AST and COA groups. The AST group reported more difficulty with falling asleep and with feeling drowsier when waking than COA. Finally, the AST group reported poorer overall sleep quality and satisfaction than COA.

Gender differences in sleep behaviors and experiences

Supplementary Table 3 shows self-reported sleep behaviors and experiences by group and gender. Females in the COA group reported slightly shorter nighttime sleep duration, lighter depth sleep, more

frequent nighttime waking, more difficulty with falling asleep, feeling drowsier when waking, and poorer overall sleep quality and satisfaction when compared to COA males. No gender differences were observed in the AST group.

Associations between age and sleep duration

For the COA group, small but significant positive associations were found between age and nighttime sleep duration (r=.06, p <.001) and daytime sleep duration (r=.06, p <.001). For the AST group, no significant associations were found between age and sleep duration.

TABLE 2 / SLEEP TABLE HERE

Frequency of above cut-off sleep problems

Table 3 shows frequencies of above cut-off sleep problems by group. Those in the AST group reported higher scores in the sleep problems composite than COA. When applying a cut-off to identify those with high sleep problems, 21.4% of the AST group met criteria, compared to 10.3% in the COA group; OR=2.36.

Gender differences in above cut-off sleep problems

Supplementary Table 4 shows frequencies of above cut-off sleep problems by group and gender. Females in the COA group reported higher scores in the sleep problems composite than COA males. When applying a cut-off to identify those with high sleep problems, more COA females met criteria then COA males (11.7% vs. 7.0%; OR=1.75). No gender differences in sleep problems composite or above cut-off score frequency were observed in the AST group.

TABLE 3 / CUT-OFF TABLE HERE

Poor sleep and mental health problems

Table 4 shows self-reported mental health symptom scores by trait group and sleep problems group. Sleep problems were found to be moderately positively correlated with depression (COA: r=.38, p<.001; AST: r=.32, p<.001) and anxiety (COA: r=.24, p<.001; AST: r=.25, p<.001). Furthermore, depression and anxiety were found to be strongly correlated (COA: r=.63, p<.001; AST: r=.66, p<.001). The strength and direction of these associations were found to be similar when groups were split by gender.

A 2x2 ANOVA was used to examine the effect of autistic traits and poor sleep on mental health problems. A main effect of trait group (AST vs. COA) was observed for current depression and anxiety symptoms, with those in the AST group reporting more current symptoms than those in the COA group. Furthermore, a main effect of sleep problems (High vs. Low) was also observed for current depression and anxiety symptoms, with those with High sleep problems reporting more symptoms than those with Low sleep problems.

An interaction of trait group and sleep problems group was observed in current depression and anxiety symptoms; however, while statistically significant the effect sizes were small (η^2ps=.001-.002).

When examining the overlap of those meeting sleep problems, depression and anxiety cut-off criteria, a higher proportion of the AST than COA group met cut-off for all three (4.3% vs. 0.2%). See Figure 1 for proportional Venn diagram of cut-off overlap.

FIGURE 1 HERE

TABLE 4 / SLEEP x MH TABLE HERE

Post-hoc analyses for poor sleep and mental health problems

As a significantly higher proportion of the AST vs COA group report above cut-off symptoms of current depression (20.9% vs. 2.5%) and anxiety (11.8% vs. 1.1%), post-hoc analyses examined whether group differences in sleep simply reflected the higher rates of mental ill health in the AST group. With those reporting above cut-off symptoms of current depression and/or anxiety removed from the analyses, significant group differences between AST and COA remained, with AST reporting more sleep problems and more above cut-off sleep scores than COA (see Supplementary Table 5).

DISCUSSION

For the first time, this study documents the sleep behaviors and experiences of older adults with high autistic traits. As predicted, and in-keeping with findings from autistic children and young adults, older adults with high autistic traits experienced significantly more sleep problems compared to an age- and gender-matched control group (selected for low autistic traits). In both groups, significant positive associations were found between sleep problems and mental health difficulties, and more individuals with high autistic traits met cut-off criteria for sleep problems and mental health difficulties, compared to the control group. In both groups, those who met criteria for high sleep problems reported more symptoms of mental health difficulties. An interaction between trait group and sleep problems group was also observed for these mental health difficulties; however, the effect size of this interaction was very small. Importantly, the higher rate of sleep problems in the autism trait group was not merely a reflection of poor mental health; even amongst those without anxiety or depression, sleep problems were more common in the high autism trait group versus controls. These results taken together suggest that those with high autistic traits may experience more sleep problems in old age.

The sleep problems reported in the AST group covered a broad range of difficulties including longer daytime napping, more difficulty with falling asleep, feeling drowsier when waking, and lower overall sleep quality and satisfaction when compared to COA. Those in the AST group had a twofold increased likelihood of meeting cut-off criteria for sleep problems (in the 90th percentile) compared to COA. By contrast, no differences were observed between AST and COA for nighttime sleep duration, depth of sleep, or the number of times waking during the night. For age-related differences, very small associations were found, with sleep duration increasing with age in COA but not AST group. When contextualizing these results, some similarities are found with the previous literature for sleep problems in young autistic adults (Carmassi et al., 2019; Morgan et al., 2020) and adolescents with high autistic traits (Salmela et al., 2019). Similar to the findings of the current study, autistic adults have been reported to experience difficulty with falling asleep, lower sleep efficiency, daytime sleepiness, and lower satisfaction with the quality of their sleep than non-autistic populations. However, autistic adults also often report more fragmented sleep and lower sleep duration than non-autistic populations, which we did not find in the current study.

To the author's knowledge, no study has yet documented the sleep behaviors and experiences of older autistic adults or those with high autistic traits. The current study examines those with high autistic traits, rather than those who have a confirmed ASD diagnosis. This could suggest that trait severity may impact sleep, with autistic individuals experiencing poorer sleep than those with subclinical autistic traits. However, this causal inference goes beyond the scope of the current cross-sectional study and should be examined in future longitudinal research. Furthermore, age-related differences may be influencing the pattern of results found in the current study. As previously mentioned from the non-autistic literature, older adults (age 60 years+) typically require a shorter nighttime sleep duration than younger adults (Ohayon et al., 2004), with medical comorbidities (e.g. physical pain, increased need for the bathroom, etc.) being associated with the frequency of nighttime waking in older age (Foley et al., 1995; Vitiello, Moe, & Prinz, 2002). Another possible explanation for the differences within the current study could be that the developmental trajectory of sleep, from young adulthood into older age, is less sensitive to age-related changes in those with high autistic traits. Those with low autistic traits may experience more change to sleep duration with age, while those with high autistic traits (who are more likely to experience shorter sleep across the lifespan) may remain more stable with age. While no difference was observed in nighttime sleep duration or nighttime waking between AST and COA groups, the subjective complaints documented in younger age for autistic/trait populations related to poorer sleep quality appear to persist into older age. Therefore, older adults with high autistic traits may not be disproportionately impacted by age-related changes to some aspects of sleep, e.g. nighttime sleep duration and frequency of nighttime waking, when compared to non-autistic populations.

Another finding from the current study was that both AST and COA groups report similar significant positive associations between more sleep problems and increased symptoms of depression and anxiety. This suggests that the association of sleep problems and mental health difficulties are not disproportionately experienced by those with high autistic traits. However, when considering the overlap of these problems, 10% of the AST group were above cut-off criteria for poor sleep and high depression and/or anxiety compared to only 1% of the COA group, highlighting a tenfold increase to experiencing poor sleep and mental health difficulties together. When examining the effect of high vs. low sleep problems on COA and AST, those who experienced high sleep problems reported higher

rates of depression and anxiety. While a statistically significant interaction was observed between the trait and sleep problems groups, the effect size was very small and is likely due to the large statistical group differences observed.

To the author's knowledge, no study has documented the associations between sleep problems and mental health in relation to the wider autism spectrum in older age. However, the complex link between sleep problems and poor mental health has been widely discussed in relation to the general population (Palmer & Alfano, 2017), and in diagnosed autism (Schreck & Richdale, 2020). One suggested explanation for this association is that hyperarousal (often associated with elevated anxiety in autistic populations) may relate to symptoms of insomnia, increasing sensory awareness and leading to problems with falling asleep and more fragmented sleep (Schreck & Richdale, 2020). While the current study is able to establish these associations in older adults with high autistic traits, future (e.g. longitudinal) studies designed to establish the direction of associations between sleep problems and mental health difficulties are needed to gain a better understanding of the mechanisms that influence the experience and outcomes of older adults on the wider autism spectrum.

It is important to consider the strengths and limitations when interpreting the results of the current study. A strength of the PROTECT study is that it utilizes an online platform which allows large scale recruitment from a wide geographic spread across the UK. However, use of self-report alone is a limitation, and collecting objective measures would be important for future work. This may be a particularly important point for sleep problems, given the well-documented discrepancy between subjective and objective sleep measures. Those with sleep problems are often inaccurate at subjectively recalling the duration of their sleep when compared to objective measures (e.g. actigraphy), including overestimating how long it takes them to fall asleep while underestimating total sleep time (Perlis, Giles, Mendelson, Bootzin, & Wyatt, 1997). Therefore, future studies utilizing a multi-method approach may be more insightful in disentangling whether sleep problems experienced by those on the wider autism spectrum are subjective difficulties or objectively verified. Additionally, the PROTECT study does not have data related to whether participants are taking medication for sleep problems, or other medications that might affect sleep, which is a limitation of the present study. Another point to consider within the PROTECT study is that older adults who engage in medical research are typically physically well and mentally able, which may lead to sampling biases and poor

generalizability of findings (Golomb et al., 2012). The PROTECT sample is predominately female and well-educated, which may further limit the generalizability of findings. This may be particularly important as large population studies have shown that 2-3 times more males than females are autistic (see Loomes, Hull and Mandy (2017) for a systematic review and meta-analysis concerning ASD gender prevalence), which is not reflected in the percentage of males meeting our grouping criteria. Furthermore, while PROTECT data will be acquired longitudinally, this study is based on cross-sectional data, therefore we cannot infer the direction of associations between self-reported socio-communicative autism traits, poor sleep, and mental health difficulties. Future research would ideally utilize longitudinal designs with both self-report and objective measures of sleep, which may be able to identify mechanisms that lead to poor sleep and mental health difficulties in those on the wider autism spectrum. Such studies may be able to identify whether there are different patterns in self-reported complaints and objective difficulties and disentangle the direction of the associations between poor sleep and mental health difficulties. Finally, the criteria used to identify the AST group relied upon a bespoke set of brief questions rather than a standardized measure. However, this measure was found to be comparable with other well validated measures (e.g. the AQ-10 and RAADS-14) and had good specificity and sensitivity for identifying those with an autism diagnosis – although that validation sample was not large enough to support factor analysis. Future research should utilize other well-established measures of autistic traits to replicate the findings of the current study. Whilst these factors may limit the overall generalizability of the findings, the results still provide important new information about sleep behaviors and experiences and their link with mental health difficulties in a large population of older adults. Results are a first step towards greater understanding of aging for those with poor socio-communicative functioning.

In conclusion, our study exploring the sleep and mental health experiences of older adults suggests that those who self-report high autistic social-communication traits in childhood and adulthood also report more sleep problems and mental health difficulties in older age, compared to those without autistic traits. These older adults with high autistic traits were also more likely to meet criteria for above cut-off sleep problems, depression and anxiety. When controlling for elevated rates of depression and anxiety, those with high autistic traits still experienced high rates of sleep problems compared to the control group. The findings of the current study highlight that sleep and mental health

difficulties are common (and often co-occurring) in those with high autistic traits in older age. There is a need for mental health support for those on the wider autism spectrum, including those with high traits who may not have a diagnosis or meet current criteria, to ensure that they receive appropriate support to address these high rates of sleep problems and mental health difficulties in older age.

Reference List

Allison, C., Auyeung, B., & Baron-Cohen, S. (2012). Toward brief “red flags” for autism screening: The short Autism Spectrum Quotient and the short Quantitative Checklist in 1,000 cases and 3,000 controls. *Journal of the American Academy of Child & Adolescent Psychiatry*, *51*(2), 202-212.e7. https://doi.org/10.1016/j.jaac.2011.11.003

American Psychiatric Association. (2013). *Diagnostic and Statistical Manual of Mental Disorders, 5th Edition*. American Psychiatric Publishing, Inc. https://doi.org/10.1176/appi.books.9780890425596.744053

Baker, E. K., & Richdale, A. L. (2015). Sleep Patterns in Adults with a Diagnosis of High-Functioning Autism Spectrum Disorder. *Sleep*, *38*(11), 1765–1774. https://doi.org/10.5665/sleep.5160

Baker, E. K., & Richdale, A. L. (2017). Examining the Behavioural Sleep-Wake Rhythm in Adults with Autism Spectrum Disorder and No Comorbid Intellectual Disability. *Journal of Autism and Developmental Disorders*, *47*(4), 1207–1222. https://doi.org/10.1007/s10803-017-3042-3

Benjamini, Y., & Hochberg, Y. (1995). Controlling the False Discovery Rate : A Practical and Powerful Approach to Multiple Testing. *Journal of the Royal Statistical Society*, *57*(1), 289–300.

Bralten, J., van Hulzen, K. J., Martens, M. B., Galesloot, T. E., Arias Vasquez, A., Kiemeney, L. A., … Poelmans, G. (2018). Autism spectrum disorders and autistic traits share genetics and biology. *Molecular Psychiatry*, *23*(5), 1205–1212. https://doi.org/10.1038/mp.2017.98

Carmassi, C., Palagini, L., Caruso, D., Masci, I., Nobili, L., Vita, A., & Dell’Osso, L. (2019). Systematic review of sleep disturbances and circadian sleep desynchronization in autism spectrum disorder: Toward an integrative model of a self-reinforcing loop. *Frontiers in Psychiatry*, *10*(JUN). https://doi.org/10.3389/fpsyt.2019.00366

Colvert, E., Tick, B., McEwen, F., Stewart, C., Curran, S., Woodhouse, E., … Bolton, P. (2015). Heritability of Autism Spectrum Disorder in a UK Population-Based Twin Sample. *JAMA Psychiatry*, *72*(5), 415–423. https://doi.org/10.1001/jamapsychiatry.2014.3028

Croen, L. A., Zerbo, O., Qian, Y., Massolo, M. L., Rich, S., Sidney, S., & Kripke, C. (2015). The health status of adults on the autism spectrum. *Autism*, *19*(7), 814–823. https://doi.org/10.1177/1362361315577517

Ellis, B. W., Johns, M. W., Lancaster, R., Raptopoulos, P., Angelopoulos, N., & Priest, R. G. (1981). The St. Mary’s Hospital sleep questionnaire: A study of reliability. *Sleep*, *4*(1), 93–97.

https://doi.org/10.1093/sleep/4.1.93

Eriksson, J. M., Andersen, L. M., & Bejerot, S. (2013). RAADS-14 Screen: validity of a screening tool for autism spectrum disorder in an adult psychiatric population. *Molecular Autism*, *4*(1), 49. https://doi.org/10.1186/2040-2392-4-49

Foley, D. J., Monjan, A. A., Brown, S. L., Simonsick, E. M., Wallace, R. B., & Blazer, D. G. (1995). Sleep complaints among elderly persons: An epidemiologic study of three communities. *Sleep*, *18*(6), 425–432. https://doi.org/10.1093/sleep/18.6.425

Golomb, B. A., Chan, V. T., Evans, M. A., Koperski, S., White, H. L., & Criqui, M. H. (2012). The older the better: Are elderly study participants more non-representative? A cross-sectional analysis of clinical trial and observational study samples. *BMJ Open*, *2*(6), 1–6. https://doi.org/10.1136/bmjopen-2012-000833

Hand, B. N., Angell, A. M., Harris, L., & Carpenter, L. A. (2019). Prevalence of physical and mental health conditions in Medicare-enrolled, autistic older adults. *Autism*, 136236131989079. https://doi.org/10.1177/1362361319890793

Howlin, P., Moss, P., Savage, S., Bolton, P., & Rutter, M. (2015). Outcomes in Adult Life Among Siblings of Individuals with Autism. *Journal of Autism and Developmental Disorders*, *45*(3), 707–718. https://doi.org/10.1007/s10803-014-2224-5

Jovevska, S., Richdale, A. L., Lawson, L. P., Uljarević, M., Arnold, S. R. C., & Trollor, J. N. (2020). Sleep Quality in Autism from Adolescence to Old Age. *Autism in Adulthood*, *00*(00), 1–11. https://doi.org/10.1089/aut.2019.0034

Kroenke, K., Spitzer, R. L., & Williams, J. B. W. (2001). The PHQ-9. *Journal of General Internal Medicine*, *16*(9), 606–613. https://doi.org/10.1046/j.1525-1497.2001.016009606.x

Lawson, L. P., Richdale, A. L., Haschek, A., Flower, R. L., Vartuli, J., Arnold, S. R. C., & Trollor, J. N. (2020). Cross-sectional and longitudinal predictors of quality of life in autistic individuals from adolescence to adulthood: The role of mental health and sleep quality. *Autism*. https://doi.org/10.1177/1362361320908107

Lever, A. G., & Geurts, H. M. (2016). Psychiatric Co-occurring Symptoms and Disorders in Young, Middle-Aged, and Older Adults with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, *46*(6), 1916–1930. https://doi.org/10.1007/s10803-016-2722-8

Loomes, R., Hull, L., & Mandy, W. P. L. (2017). What Is the Male-to-Female Ratio in Autism Spectrum

Disorder? A Systematic Review and Meta-Analysis. *Journal of the American Academy of Child and Adolescent Psychiatry*, *56*(6), 466–474. https://doi.org/10.1016/j.jaac.2017.03.013

Morgan, B., Nageye, F., Masi, G., & Cortese, S. (2020). Sleep in adults with Autism Spectrum Disorder: a systematic review and meta-analysis of subjective and objective studies. *Sleep Medicine*, *65*, 113–120. https://doi.org/10.1016/j.sleep.2019.07.019

Ohayon, M. M. (2011). Epidemiological Overview of sleep Disorders in the General Population. *Sleep Medicine Research*, *2*(1), 1–9. https://doi.org/10.17241/smr.2011.2.1.1

Ohayon, M. M., Carskadon, M. A., Guilleminault, C., & Vitiello, M. V. (2004). Meta-analysis of quantitative sleep parameters from childhood to old age in healthy individuals: Developing normative sleep values across the human lifespan. *Sleep*, *27*(7), 1255–1273. https://doi.org/10.1093/sleep/27.7.1255

Oyane, N. M. F., & Bjorvatn, B. (2005). Sleep disturbances in adolescents and young adults with autism and Asperger syndrome. *Autism*, *9*(1), 83–94. https://doi.org/10.1177/1362361305049031

Palmer, C. A., & Alfano, C. A. (2017). Sleep and emotion regulation: An organizing, integrative review. *Sleep Medicine Reviews*, *31*, 6–16. https://doi.org/10.1016/j.smrv.2015.12.006

Perlis, M. L., Giles, D. E., Mendelson, W. B., Bootzin, R. R., & Wyatt, J. K. (1997). Psychophysiological insomnia: The behavioural model and a neurocognitive perspective. *Journal of Sleep Research*, *6*(3), 179–188. https://doi.org/10.1046/j.1365-2869.1997.00045.x

Richdale, A. L., & Schreck, K. A. (2009). Sleep problems in autism spectrum disorders: Prevalence, nature, & possible biopsychosocial aetiologies. *Sleep Medicine Reviews*, *13*(6), 403–411. https://doi.org/10.1016/j.smrv.2009.02.003

Robinson, E. B., St Pourcain, B., Anttila, V., Kosmicki, J. A., Bulik-Sullivan, B., Grove, J., … Daly, M. J. (2016). Genetic risk for autism spectrum disorders and neuropsychiatric variation in the general population. *Nature Genetics*, *48*(5), 552–555. https://doi.org/10.1038/ng.3529

Salmela, L., Kuula, L., Merikanto, I., Räikkönen, K., & Pesonen, A.-K. K. (2019). Autistic traits and sleep in typically developing adolescents. *Sleep Medicine*, *54*, 164–171. https://doi.org/10.1016/j.sleep.2018.09.028

Schreck, K. A., & Richdale, A. L. (2020). Sleep problems, behavior, and psychopathology in autism: inter-relationships across the lifespan. *Current Opinion in Psychology*, *34*, 105–111.

https://doi.org/10.1016/j.copsyc.2019.12.003

Sivertsen, B., Posserud, M. B., Gillberg, C., Lundervold, A. J., & Hysing, M. (2012). Sleep problems in children with autism spectrum problems: A longitudinal population-based study. *Autism*, *16*(2), 139–150. https://doi.org/10.1177/1362361311404255

Spitzer, R. L., Kroenke, K., Williams, J. W., & Löwe, B. (2006). A brief measure for assessing generalized anxiety disorder: The GAD-7. *Archives of Internal Medicine*, *166*(10), 1092–1097. https://doi.org/10.1001/archinte.166.10.1092

Stewart, G. R., Charlton, R. A., & Wallace, G. L. (2018). Aging with elevated autistic traits: Cognitive functioning among older adults with the broad autism phenotype. *Research in Autism Spectrum Disorders*, *54*(December 2017), 27–36. https://doi.org/10.1016/j.rasd.2018.06.009

Stewart, G. R., Corbett, A., Ballard, C., Creese, B., Aarsland, D., Hampshire, A., … Happé, F. (2020). The Mental and Physical Health of Older Adults With a Genetic Predisposition for Autism. *Autism Research*, 1–14. https://doi.org/10.1002/aur.2277

Stuart-Hamilton, I., Griffith, G., & Totsika, V. (2010). The circumstance and support needs of older people with autism. *Report for the Welsh Assembly Government*, (September). Retrieved from www.autism.org.uk/iexist

Uren, J., Richdale, A. L., Cotton, S. M., & Whitehouse, A. J. O. (2019). Sleep problems and anxiety from 2 to 8 years and the influence of autistic traits: a longitudinal study. *European Child and Adolescent Psychiatry*, *28*(8), 1117–1127. https://doi.org/10.1007/s00787-019-01275-y

Verhoeff, M. E., Blanken, L. M. E., Kocevska, D., Mileva-Seitz, V. R., Jaddoe, V. W. V., White, T., … Tiemeier, H. (2018). The bidirectional association between sleep problems and autism spectrum disorder: A population-based cohort study. *Molecular Autism*, *9*(1), 1–9. https://doi.org/10.1186/s13229-018-0194-8

Vitiello, M. V., Moe, K. E., & Prinz, P. N. (2002). Sleep complaints cosegregate with illness in older adults clinical research informed by and informing epidemiological studies of sleep. *Journal of Psychosomatic Research*, *53*(1), 555–559. https://doi.org/10.1016/S0022-3999(02)00435-X

Table 1. Demographic characteristics of the COA and AST groups.

		COA (n = 6,740)	AST (n = 187)	Trait Difference
Age	*M (SD)*	62.81 (6.75)	62.88 (6.96)	F(1,6925) = .02$^{n/s}$
	[95% CI]	[62.65-62.98]	[61.87-63.88]	
	Range	50 - 81	50 - 81	
Gender	*Male : Female*	1954 : 4786	50 : 137	$\chi 2$ = .50$^{n/s}$
	%	29.0% : 71.0%	26.7% : 73.3%	
Marital Status	*Married*	4909 (72.9%)	112 (59.9%)	$\chi 2$ = 25.49***
	Widowed	313 (4.6%)	7 (3.9%)	
	Separated	105 (1.6%)	2 (1.1%)	
	Divorced	587 (8.7%)	25 (13.4%)	
	Civil Partner	36 (0.5%)	1 (0.5%)	
	Co-Habiting	421 (6.2%)	18 (9.6%)	
	Single	367 (5.4%)	22 (11.8%)	
Education History	*School to 16*	822 (12.2%)	24 (12.8%)	$\chi 2$ = 1.76$^{n/s}$
	School to 18	2084 (30.9%)	50 (26.7%)	
	Undergraduate	2354 (34.9%)	72 (38.5%)	
	Postgraduate	1478 (21.9%)	41 (21.9%)	
Current Employment Status	*Employed*	3458 (51.3%)	89 (47.6%)	$\chi 2$ = 4.38$^{n/s}$
	Retired	3087 (45.8%)	88 (47.1%)	
	Unemployed	193 (2.9%)	10 (5.3%)	

Note: “School to 16” represents qualifications typically achieved at age 16 in UK education, i.e. GCSEs. “School to 18” represents qualifications typically achieved at age 18 in UK education, i.e. A-Levels, BTECs, and other vocational qualifications.
$^{n/s}$ not significant, * $p < .05$, ** $p < .01$, *** $p < .001$

Table 2. Sleep behaviours and experiences of the COA and AST groups.

		COA (n = 6,740)	AST (n = 187)	Trait Difference	Effect Size (*d*)
Night Sleep Duration	*M hours:mins (SD)*	6:47 (1:26)	6:39 (1:31)	F(1,6937)	0.08
	[95% CI]	[6:45-6:49]	[6:26-6:52]	= 1.45$^{n/s}$	[-0.05-0.23]
Day Sleep Duration	*M hours:mins (SD)*	0:17 (0:56)	0:28 (1:03)	F(1,6923)	0.19
	[95% CI]	[0:16-0:19]	[0:19-0:37]	= 6.92**	[0.05-0.34]
Depth of Sleep	*Very Light*	251 (3.7%)	12 (6.4%)		
	Light	552 (7.7%)	17 (9.1%)		
	Fairly Light	2063 (30.6%)	65 (34.8%)	χ2 =	0.11
	Fairly Deep	3009 (44.7%)	65 (34.8%)	10.78n/s	[0.03-0.26]
	Deep	796 (11.8%)	23 (12.3%)		
	Very Deep	98 (1.5%)	5 (2.7%)		
Nighttime waking	*Not at all*	278 (4.1%)	9 (4.8%)		
	Once	2143 (31.8%)	47 (25.1%)	χ2 =	0.15
	Twice	2274 (33.7%)	59 (31.6%)	6.98n/s	[0.01-0.29]
	Three or more	2045 (30.3%)	72 (38.5%)		
Difficulty Sleeping	*None or very little*	4530 (67.2%)	94 (50.3%)		
	Some	1864 (27.7%)	68 (36.4%)	χ2 =	0.49
	A lot	291 (4.3%)	14 (7.5%)	65.93***	[0.34-0.64]
	Extreme difficulty	55 (0.8%)	11 (5.9%)		
Waking Quality	*Very drowsy*	115 (1.7%)	19 (10.2%)		
	Moderately drowsy	608 (9.0%)	47 (25.1%)		
	Slightly drowsy	1692 (25.1%)	50 (26.7%)	χ2 =	0.68
	Fairly clear-headed	2803 (41.6%)	46 (24.6%)	137.06***	[0.54-0.83]
	Alert	1341 (19.9%)	22 (11.8%)		
	Very alert	181 (2.7%)	3 (1.6%)		
Sleep Quality^ *(max score = 6)*	*M (SD)*	3.93 (1.02)	3.52 (1.24)	F(1,6924)	0.39
	[95% CI]	[3.90-3.95]	[3.34-3.70]	= 28.22***	[0.24-0.53]
Sleep Satisfaction^ *(max score = 5)*	*M (SD)*	3.31 (1.09)	2.84 (1.18)	F(1,6924)	0.43
	[95% CI]	[3.29-3.34]	[2.67-3.01]	= 33.83***	[0.28-0.57]

Note: ^ Higher scores represent higher quality/satisfaction. $^{n/s}$ not significant, * $p < .05$, ** $p < .01$, *** $p < .001$

Table 3. Frequency of above cut-off sleep problems of the COA and AST groups.

		COA (n = 6,740)	AST (n = 187)	Trait Difference	Effect Size (*d*)	Odds Ratio
Sleep Problems *(max score = 19)*	*Mean (SD)* *95% CI*	6.31 (3.18) [6.24-6.39]	7.73 (3.73) [7.19-8.27]	F(1,6925) = 35.72***	0.44 [0.29-0.59]	-
Sleep Problems *(cut off ≥11)*	*Frequency (%)*	697 (10.3%)	40 (21.4%)	$\chi 2$ = 23.36***	0.47 [0.27-0.67]	2.36 [1.65-3.36]

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

Table 4. Depression and anxiety scores and cut-off frequency of AST and COA by Sleep Problem groups.

		Control Older Adults			Autism Spectrum Traits			Group Differences					
		Whole Group (n = 6,740)	**Low Sleep Problems (n = 6,043)**	**High Sleep Problems (n = 697)**	**Whole Group (n = 187)**	**Low Sleep Problems (n = 147)**	**High Sleep Problems (n = 40)**	**Trait Main Effect**	**Effect Size (*d*)**	**Sleep Main Effect**	**Effect Size (*d*)**	**Interaction**	***η^2p***
Depression *(max score = 27)*	*Mean (SD) 95% CI*	2.15 (2.70) [2.08-2.21]	1.90 (2.43) [1.75-1.87]	4.28 (3.77) [3.83-4.28]	6.19 (4.68) [5.51-6.86]	5.44 (4.38) [4.58-6.11]	8.93 (4.80) [6.89-9.43]	F(1,6925) = 281.28***	1.24 [1.09-1.39]	F(1,6926) = 144.60***	0.60 [0.52-0.68]	F(1,6926) = 5.06***	.001
Anxiety *(max score = 21)*	*Mean (SD) 95% CI*	1.27 (2.27) [1.21-1.32]	1.13 (2.09) [1.04-1.14]	2.44 (3.22) [2.07-2.46]	4.26 (4.40) [3.62-4.89]	3.66 (3.83) [2.95-4.30]	6.45 (5.58) [4.36-7.10]	F(1,6924) = 239.56***	1.15 [1.00-1.29]	F(1,6926) = 94.52***	0.38 [0.30-0.45]	F(1,6926) = 12.21***	.002
Depression *(cut off ≥10)*	*Frequency (%)*	169 (2.5%)	107 (1.8%)	62 (8.9%)	39 (20.9%)	22 (15.0%)	17 (42.5%)	$\chi 2$ = 210.27***	1.09 [0.94-1.23]	$\chi 2$ = 168.56***	0.95 [0.79-1.11]	-	
Anxiety *(cut off ≥10)*	*Frequency (%)*	77 (1.1%)	50 (0.8%)	27 (3.9%)	22 (11.8%)	12 (8.2%)	10 (25.0%)	$\chi 2$ = 145.68***	0.90 [0.76-1.05]	$\chi 2$ = 75.46***	0.91 [0.68-1.14]	-	

Note: Depression measured using PHQ-9; Anxiety measured using GAD-7.
* $p < .05$, ** $p < .01$, *** $p < .001$

Figure legend

Figure 1: Proprotional venn diagram of above cut-off sleep problems and mental health difficulties in COA and AST.