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# Sensory processing and alcohol use in adults with autism spectrum disorder

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ABSTRACT

The association between substance use and autism spectrum disorder (ASD) is complex. Although sensory processing difficulties are highly prevalent in individuals with ASD, data on the association between sensory processing and substance use in ASD are limited. This study aimed to investigate the association between sensory processing patterns and alcohol use in adults with ASD. Kruskal–Wallis tests were performed on questionnaire data (Adolescent/Adult Sensory Profile and Alcohol Use Disorders Identification Test – Consumption) of 101 adults with ASD. Sensory processing difficulties are associated with alcohol use in adults with ASD. Differences in sensory processing between alcohol-based subgroups vary per specific sensory processing pattern: drinkers reported 6.5 to 8 points higher levels of low registration [$\chi^2(2) = 12.408$, $p = .002$, 99 % CI (.002.002)], non-hazardous drinkers reported 9 points higher levels of sensory sensitivity [$\chi^2(2) = 6.868$, $p = .031$, 99 % CI (.031, .032)], and hazardous drinkers reported 7.5 points higher levels of sensory seeking [$\chi^2(2) = 6.698$, $p = .034$, 99 % CI (.034, .035)], all in comparison with non-drinkers on scales ranging from 15 to 75. Our proof-of-concept study indicates that vulnerability in some individuals with ASD for substance use disorders might be explained by sensory processing difficulties. Whether alcohol is used as 'self-medication' or is associated with other neurobiological vulnerabilities needs further investigation in larger follow-up studies.



## Introduction

Autism spectrum disorder (ASD) is characterized by differences in social interaction and social communication, as well as restricted, repetitive patterns of behavior. In addition, sensory processing difficulties are highly prevalent in individuals with ASD. In fact, several studies demonstrated how sensory processing patterns differ from neurotypically developing controls in the vast majority of individuals with ASD (Crane, Goddard, & Pring, 2009; Kern et al., 2006; Tomchek & Dunn, 2007), with over 90 percent of children and adults with ASD experiencing sensory processing difficulties (Crane et al., 2009; Leekam, Nieto, Libby, Wing, & Gould, 2007). Therefore, sensory processing difficulties were added to the diagnostic criteria for ASD presented in the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (American Psychiatric Association, 2013). One of the leading models explaining the mechanisms underlying human sensory processing is the Model of Sensory Processing (Dunn, 1997). This model presents the interaction of a neurological threshold continuum (low to high) and a behavioral response continuum (passive to active), resulting in four quadrants known as the patterns of sensory processing: low registration, sensory seeking, sensory sensitivity, and sensory avoiding. Low registration concerns a more passive behavioral response to a higher neurological threshold, sensory seeking concerns a more active response to a higher neurological threshold, sensory sensitivity concerns a more passive response to a lower neurological threshold, and sensory avoiding concerns a more active response to a lower neurological threshold (Brown, Tollefson,

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Dunn, Cromwell, & Filion, 2001; Dunn, 1997). These concepts can be measured directly by means of the Adolescent/Adult Sensory Profile (AASP) questionnaire (Brown & Dunn, 2002), the most frequently used instrument for these purposes in adolescents and adults (DuBois, Lymer, Gibson, Desarkar, & Nalder, 2017), further introduced in the Material and Methods section.

ASD is considered to be a risk factor for substance abuse, with a 6 times higher risk of substance abuse in persons with ASD in comparison with persons without autistic traits (Lundström et al., 2011). Conditions such as attention deficit hyperactivity disorder (ADHD) and intellectual disability commonly co-occur with autism and are positively associated with substance use problems (Butwicka et al., 2017). Previous studies have also found positive associations between familial risk for substance use and substance use in persons with ASD (Butwicka et al., 2017; Lundström, 2011). Moreover, apart from ASD diagnosis, positive associations with substance abuse were also found for higher levels of autistic traits (De Alwis et al., 2014; Lundström, 2011). Risk factors for substance use, such as familial history, adverse family events or psychological distress, are found to be equally relevant for individuals with ASD as for individuals without ASD but might be more prevalent in individuals with ASD (Kendler, Prescott, Myers, & Neale, 2003). Additionally, social impairment and less sensation-seeking behavior might be specific risk factors for individuals with ASD (Ressel et al., 2020). Motivations for substance use are often found in the social difficulties that are part of ASD symptomatology. Substances are used, for instance, to cope with social events (Lalanne, Weiner, Trojak, Berna, & Bertschy, 2015) or with experiencing social insecurity, i.e., not being able to easily join in with others (Kronenberg, Slager-Visscher, Goossens, van den Brink, & van Achterberg, 2014). Differences in executive functioning and psychological distress are important motives for substance use in ASD as well (Kronenberg et al., 2014). Hypothesized etiological and pathophysiological mechanisms for substance use are often focused on the social effects of substance use in relation to social challenges (Brown, Christiansen, & Goldman, 1987) or on substance use as a form of self-medication for mental health problems and psychological distress (Khantzian, 1997). Recent qualitative research has further identified underlying motivations for substance use in individuals with ASD, and findings support the use of substances to manage behavior and reduce mental health symptoms and distress (Weir, Allison, & Baron-Cohen, 2021).

Although the association between autism spectrum disorder and substance use has been extensively researched, this is not the case for the possible association between sensory processing difficulties and substance use. Data on the association between sensory processing and (the broader concept of) substance use within the ASD population are limited. Previous studies on substance use in ASD have not included measurements of sensory processing or have only implicitly assessed them as part of more generic instruments for the assessment of ASD. As a result, recent overviews on the topic lack information and are not able to provide suggestions for clinical practice (Ressel et al., 2020). Only one study has found evidence for a positive association between sensory processing difficulties and substance use disorders (Kelly, Meredith, Taylor, Morphett, & Wilson, 2021). The present study aims to fill this gap and investigates the possible association between sensory processing patterns and alcohol use in adults with ASD.

## Material and methods

### *Participants*

The present study is part of the Sensory Processing and Aggressive Behavior in Autism Spectrum Disorder (SPAA) Study, an observational study in a clinical population (van den Boogert et al., 2021). The project was approved by the institutional review board of the Dimence Group under study identification code CWO-042018FB. Between April 2018 and April 2019, data were collected at outpatient and inpatient locations of the Center for Developmental Disorders of Dimence Mental Health Care Institution in the Netherlands. The eligible population consisted of adult persons in treatment at one of these outpatient or inpatient facilities for clinically diagnosed ASD who were willing to provide written informed consent for participation in the study. The local protocol for the assessment of ASD in adults follows the national guidelines for ASD in adults (Kan, Geurts, & Sizoo, 2013), incorporating extensive diagnostic interviews by experienced clinicians. Predefined exclusion criteria were insufficient knowledge of the Dutch language or other difficulties to understand the provided information. A total of 101 adults with ASD ($M_{Age} = 32.9$, $SD_{Age} = 12.4$; $N_{Male}/N_{Female} = 53/48$) participated in the study. Written informed consent was provided by all participants. Participation was on a voluntary basis, and the participants received no benefit or compensation.

### *Procedure*

The following procedure was applied in order to form the described study sample. The procedure is also described in detail in van den Boogert et al. (2021). All therapists at the outpatient and inpatient locations of the Center for Developmental Disorders were extensively informed about the study and requested to select potential participants from their individual caseloads by applying the described inclusion and exclusion criteria. Next, all selected patients were informed about the study and provided with the study's information sheet by their own therapist. The patients were asked, after sufficient reflection time, to consider participating in the study and to fill out the informed consent form. Only after providing written informed consent were patients contacted by a research employee to schedule an appointment for completing the survey. During the appointment, availability of a research employee was ensured at all times to provide brief verbal instructions and to answer questions. As a result, 101 participants were able to complete all parts of the survey.

### *Materials*

We used the Dutch version of the Adolescent/Adult Sensory Profile (AASP; Brown & Dunn, 2002), a 60-item, self-report questionnaire to obtain information on responsiveness to various sensory stimuli and to identify difficulties in the sensory systems that may inhibit the individual from participating in daily activities. The AASP produces four continuous raw quadrant scores ranging from 15 to 75, representing the four quadrants of Dunn's Model of Sensory Processing (Dunn, 1997): low registration (i.e., under-registration of sensory stimuli), sensory seeking, sensory sensitivity, and sensory avoiding. Each quadrant is constructed of 15 items, rated on a 5-point Likert scale from never (1) to always (5). The values of the alpha coefficients for the quadrant scores range from .64 to .78, which is satisfactory (Pearson, 2019; Tavakol & Dennick, 2011).

The Alcohol Use Disorders Identification Test – Consumption (Bush, Kivlahan, McDonell, Fihn, & Bradley, 1998) is a 3-item brief screener for hazardous alcohol use. The three items encompass frequency of drinking in the past year, typical quantity of drinks, and frequency of heavy drinking. Items are answered on a 5-point scale, with possible scores ranging from 0 to 4. As a result, the total score ranges from 0 to 12. Items 2 and 3 were only completed by participants who confirmed alcohol consumption in the past year on the first question. In line with Bowri et al. (2021), we used the

AUDIT-C to identify three subgroups: non-drinkers, non-hazardous drinkers, and hazardous drinkers. We used item 1 to identify non-drinkers and applied cut-offs ≥4 for men and ≥3 for women (Reinert & Allen, 2007) to label drinkers as hazardous drinkers or non-hazardous drinkers.

### *Analysis*

For all statistical analyses, we used IBM SPSS version 25.0. First, we compared non-drinkers, non-hazardous drinkers, and hazardous drinkers on demographic variables using chi-square tests. Next, assumptions for a Multivariate Analysis of Variance (MANOVA) were tested. Due to the non-normal distribution of sensory processing quadrant scores, we used Kruskal–Wallis H tests to investigate the association between the AASP raw quadrant scores of sensory processing and the three subgroups of alcohol use. All statistical tests were two-sided and used a significance level of $p < .05$. The $p$ values of the Kruskal–Wallis H tests were calculated using the Monte Carlo method with 99 % confidence intervals based on 1 000 000 samples. Effect size for each Kruskal–Wallis H test was calculated and expressed in epsilon-squared. *Post hoc* analyses were done by performing Dunn–Bonferroni tests for pairwise comparisons and corrected for multiple comparisons.

## Results

General sample characteristics are presented in Table 1. Differences between non-drinkers ($N = 37$), non-hazardous drinkers ($N = 38$), and hazardous drinkers ($N = 26$) were not statistically significant on all demographic variables, except for treatment setting [$\chi^2(2) = 6.010$, $p = .050$]. Outpatients were more often hazardous drinkers and less often non-drinkers than inpatients, with borderline significance.

Fig. 1 presents sample characteristics based on the AUDIT-C. A relatively high proportion of participants (37 %) reported no alcohol consumption at all, over the past year. Almost one-third reported drinking alcohol monthly or less frequently. A total of 15 % of the sample reported drinking on more than one occasion per week. Within the drinking group, almost two-thirds reported drinking 1 or 2 units on a typical occasion. Binge drinking (≥6 drinks) was reported by 39 % of the drinkers.

Main results of the Kruskal–Wallis H tests are presented in Table 2. Median values on low registration were 34.0 for non-drinkers, 40.5 for non-hazardous drinkers, and 42.0 for hazardous drinkers. The difference in low registration between non-drinkers, non-hazardous drinkers, and hazardous drinkers was statistically significant [$\chi^2(2) = 12.408$, $p = .002$, 99 % CI (.002, .002)]. *Post hoc* analysis revealed that the mean rank scores on low registration of both non-hazardous drinkers [$\chi^2(1) = -17.658$, $p = .027$] and hazardous drinkers [$\chi^2(1) = -24.692$, $p = .003$] were higher than the mean rank score of non-drinkers. We found no indication for a statistically significant difference between non-hazardous and hazardous drinkers on low registration [$\chi^2(1) = -7.034$, $p = 1.00$].

Median values on sensory seeking were 37.0 for non-drinkers, 40.5 for non-hazardous drinkers, and 44.5 for hazardous drinkers. The difference in sensory seeking between non-drinkers, non-hazardous drinkers, and hazardous drinkers was statistically significant [$\chi^2(2) = 6.698$, $p = .034$, 99 % CI (.034, .035)]. *Post hoc* analysis showed that the mean rank score on sensory seeking of hazardous drinkers was higher than the mean rank score of non-drinkers [$\chi^2(1) = -19.389$, $p = .029$]. We found no indication that mean rank scores of non-hazardous drinkers differed from non-drinkers [$\chi^2(1) = -8.213$, $p = .674$] or from hazardous drinkers [$\chi^2(1) = -11.176$, $p = .401$].

Median values on sensory sensitivity were 42.0 for non-drinkers, 51.0 for non-hazardous drinkers, and 51.0 for hazardous drinkers. Difference in sensory sensitivity between non-drinkers, non-hazardous drinkers, and hazardous drinkers was statistically significant [$\chi^2(2) = 6.868$, $p = .031$, 99 % CI (.031, .032)]. *Post hoc* analysis showed that the mean rank score on sensory sensitivity of non-hazardous drinkers was higher than the mean rank score of non-drinkers [$\chi^2(1) = -17.153$, $p = .034$]. Mean rank scores of hazardous drinkers did not differ from non-drinkers [$\chi^2(1) = -13.094$, $p = .242$] or from non-hazardous drinkers [$\chi^2(1) = 4.060$, $p = 1.00$.].

Median values on sensory avoiding were 45.0 for non-drinkers, 52.0 for non-hazardous drinkers, and 48.0 for hazardous drinkers. Differences in sensory avoiding between non-drinkers, non-hazardous drinkers, and hazardous drinkers was not statistically significant [$\chi^2(2) = 1.197$, $p = .386$, 99 % CI (.385, .387)].

## Discussion

Our results demonstrate that sensory processing difficulties are associated with alcohol use in adults with ASD, and that differences in sensory processing between alcohol-based subgroups vary per specific sensory processing pattern. Drinkers (both hazardous and non-hazardous) reported higher levels of low registration compared to non-drinkers. Moreover, non-hazardous drinkers reported higher levels of sensory sensitivity compared to non-drinkers, whereas hazardous drinkers reported higher levels of

**Table 1**
General sample characteristics for the total sample and for alcohol consumption based subgroups.

| Descriptive | | Total $N = 101$ | Non-drinkers $N = 37$ | Non-hazardous drinkers $N = 38$ | Hazardous drinkers $N = 26$ | Sig.[a] |
|---|---|---|---|---|---|---|
| Age (*M*, *SD*) | | 32.9, 12.4 | 32.7, 11.9 | 32.5, 12.5 | 33.7, 13.3 | $p = .929$ |
| Male/Female (%) | | 52.5/47.5 | 62.2/37.8 | 47.4/52.6 | 46.2/53.8 | $p = .332$ |
| Outpatient/Inpatient (%) | | 70.3/29.7 | 56.8/43.2 | 73.7/26.3 | 84.6/15.4 | $p = .050$ |
| Dutch nationality (%) | | 97.0 | 97.3 | 94.7 | 100.0 | $p = .473$ |
| Educational level | Lower (%) | 34.7 | 45.9 | 28.9 | 26.9 | $p = .467$ |
| | Middle (%) | 49.5 | 43.2 | 52.6 | 53.8 | |
| | Higher (%) | 15.8 | 10.8 | 18.4 | 19.2 | |
| Paid work (%) | | 21.8 | 18.9 | 21.1 | 26.9 | $p = .743$ |
| Partner (%) | | 22.8 | 13.5 | 26.3 | 30.8 | $p = .221$ |
| Children (%) | | 17.8 | 16.2 | 15.8 | 23.1 | $p = .718$ |
| Comorbidity | Depressive/anxiety disorder (%) | 36.6 | 27.0 | 50.0 | 30.8 | $p = .092$ |
| | ADHD (%) | 13.9 | 10.8 | 15.8 | 15.4 | $p = .796$ |
| | Other (%) | 30.7 | 32.4 | 31.6 | 26.9 | $p = .887$ |

[a] Significance level of appropriate statistical test for data type.

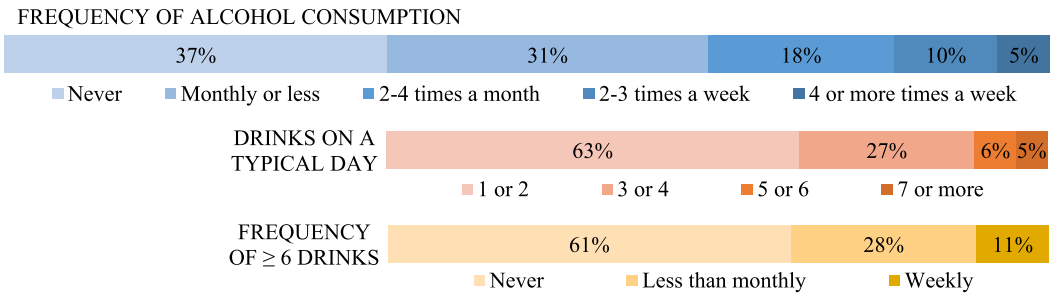


**Fig. 1.** General sample characteristics for alcohol consumption (AUDIT-C): frequency of alcohol consumption for the total sample and number of drinks on a typical day and frequency of binge drinking for drinkers.

sensory seeking compared to non-drinkers. We found no indication of differences in sensory avoiding.

Research on the association between alcohol use, or substance use in general, and sensory processing difficulties is scarce. Recently, Kelly et al. (2021) found comparable results among young people with substance use disorders, with elevated levels of low registration, sensory sensitivity, and sensory avoiding compared to the general population. Moreover, in neurotypical young adults, sensory sensitivity was associated with problematic substance use, although through elevated levels of distress (Meredith, Bailey, Strong, & Rappel, 2016). However, it is at present unknown whether sensory processing difficulties may result in substance use disorders, or the other way around – some sensory processing difficulties may be increased or caused by substance use. It is tempting to speculate that our study – in a clinical population of individuals with ASD, in which difficulties in sensory processing are a ubiquitous feature – points to a main causal direction from sensory processing difficulties to substance use disorder, but the temporal direction could not be distinguished due to our cross-sectional design.

In our study, we applied the same subgroup definitions as Bowri et al. (2021), identifying non-drinkers, non-hazardous drinkers, and hazardous drinkers. Bowri et al. (2021) found a U-shaped pattern among autistic adults, with higher levels of autistic traits among non-drinkers and hazardous drinkers in comparison with non-hazardous drinkers. We did not find such patterns for sensory processing difficulties. Lowest levels of sensory processing difficulties were found in non-drinkers, and elevated levels of sensory processing difficulties were found in both non-hazardous as well as hazardous drinkers. We propose two possible explanations. First, within the largely unknown underlying causal mechanism, the severity of sensory processing difficulties might differ from the amount and severity of (other) autistic traits. As Bowri et al. (2021) proposed, greater social communication difficulties may lead to either avoiding social events or more symptomatic distress during social events. Avoiding social events may be accompanied by less alcohol consumption and more prevalent abstinence, and by less sensory input. Engaging in social events might lead to elevated alcohol consumption for reasons of social enhancement or self-medication, and to more sensory input, which in itself also might invoke self-medication. Second, although alcohol use is usually considered as a form of self-medication, alcohol ingestion in itself may influence sensory experiences, such as the vestibular (Tianwu et al., 1995) or visual functions (Watten & Lie, 1996). Alcohol use may not induce the (inborn) vulnerability for sensory processing difficulties but may still impact on the neurological threshold or the atypical sensory-based behavior in individuals with ASD.

Our study has several strengths. This study is one of the first to specifically focus on the association between alcohol use and sensory processing difficulties. Moreover, the design of the SPAA Study enabled us to study this association while measuring sensory processing difficulties in detail using the AASP questionnaire within a population known for high prevalence rates of these difficulties: adults with ASD (Crane et al., 2009). As a result, we studied the association of alcohol use with different patterns of sensory processing, in order to further understand the underlying mechanisms. Some limitations need to be discussed as well. First, for statistical reasons, we were bound to non-parametric testing and were not able to control for potential confounding variables, such as age, educational level, and treatment setting. Also, because

**Table 2**
Main results of all Kruskal–Wallis H tests calculating differences on four AASP quadrants: low registration, sensory seeking, sensory sensitivity, and sensory avoiding over three alcohol consumption groups: non-drinkers, non-hazardous drinkers, and hazardous drinkers.

| Variable | Group | *N* | $M_{RANK}$ | Kruskal–Wallis H | Effect size | Sig. [99 % CI][a] |
|---|---|---|---|---|---|---|
| Low registration | Non-drinkers | 37 | 38.0 | 12.408 | $\varepsilon^2 = .124$ | .002 [.002, .002] |
| | Non-hazardous drinkers | 38 | 55.7 | | | |
| | Hazardous drinkers | 26 | 62.7 | | | |
| Sensory seeking | Non-drinkers | 37 | 42.9 | 6.698 | $\varepsilon^2 = .067$ | .034 [.034, .035] |
| | Non-hazardous drinkers | 38 | 51.5 | | | |
| | Hazardous drinkers | 26 | 62.3 | | | |
| Sensory sensitivity | Non-drinkers | 37 | 41.2 | 6.868 | $\varepsilon^2 = .069$ | .031 [.031, .032] |
| | Non-hazardous drinkers | 38 | 58.3 | | | |
| | Hazardous drinkers | 26 | 54.3 | | | |
| Sensory avoiding | Non-drinkers | 37 | 47.0 | 1.917 | | .386 [.385, .387] |
| | Non-hazardous drinkers | 38 | 56.1 | | | |
| | Hazardous drinkers | 26 | 49.4 | | | |

[a] All *p* values were calculated using the Monte Carlo method with 99 % confidence intervals based on 1 000 000 samples.

of the limited sample size, we were unable to perform stratified analyses. Second, our study lacked sufficient measurement of other autistic traits and their severity. Therefore, we were unable to investigate the association of autistic traits other than sensory processing difficulties and severity of these autistic traits on the one hand and alcohol use on the other hand in our study population. This would have enabled a broader comparison of our results to results of previous studies. In addition, the measurements used in our study are a limited reflection of the autism spectrum, resulting in limited generalizability to the population of persons with autism spectrum disorder. Third, because our study was conducted within a clinical population of adults with ASD, generalizability of our results is limited. Finally, we did not include a general population or clinical (i.e., ADHD) comparison group in our study design. Therefore, we are unable to determine whether the found effects are unique for the ASD population.

Our study demonstrates that sensory processing difficulties are associated with alcohol use in adults with ASD, and that differences in sensory processing between alcohol-based subgroups vary per specific sensory processing pattern. Our results indicate that vulnerability for substance use disorders in some individuals with autism spectrum disorder might be explained by sensory processing difficulties. Although our study design limits the possibility of causal inference, the assumption that sensory processing influences alcohol use suggests that detailed diagnostics for sensory processing difficulties should be considered in cases of problematic alcohol use in adults with ASD. Whether alcohol is used as 'self-medication' for sensory processing difficulties or is associated with other neurobiological vulnerabilities needs further investigation in larger follow-up studies. Moreover, since sensory processing difficulties are increasingly considered to be a transdiagnostic factor (van den Boogert et al., 2022), diagnostics on these difficulties in cases of alcohol abuse might be considered outside the ASD population as well. Finally, considering that sensory processing difficulties are highly prevalent in ASD, the question of how alcohol use perhaps influences sensory experiences should be considered in a therapeutic context regarding these difficulties.

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## Data statement

The datasets generated during and/or analyzed during the current study are not publicly available due to legal privacy restrictions but are available from the corresponding author on reasonable request.

## Author contributions

Frank van den Boogert: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Project administration; Resources; Software; Validation; Visualization; Roles/Writing – original draft; Writing – review and editing. Bram Sizoo: Conceptualization; Validation; Writing – review & editing. Yvonne H. A. Bouman: Conceptualization; Funding acquisition; Supervision; Validation; Writing – review and editing. Witte J. G. Hoogendijk: Conceptualization; Funding acquisition; Supervision; Validation; Visualization; Writing – review and editing. Sabine J. Roza: Conceptualization; Formal analysis; Funding acquisition; Investigation; Methodology; Resources; Supervision; Validation; Visualization; Roles/Writing – original draft; Writing – review and editing.

## Declaration of competing interest

None.

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