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The moderating effect of cognitive abilities on the association between sensory processing and emotional and behavioural problems and social participation in autistic individuals

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ABSTRACT

Background: Atypical sensory processing often impairs the emotional and behavioural functioning and social participation of autistic individuals. However, evidence lacks on the effect of cognitive abilities. Therefore, the aim of this study was to examine the moderating effect of cognitive abilities on both associations.

Method: We studied 241 individuals with Autism Spectrum Disorder (ASD) with varying cognitive abilities (mean age: 15.1 years, range: 5.1 to 54.1; IQ < 40 to > 130), using standardized questionnaires on sensory, emotional and behavioural functioning and social participation. Multiple linear regression analyses were performed to investigate the moderation effects.

Results: Individuals with higher cognitive abilities showed relatively more emotional and behavioural problems when reporting more sensory processing problems compared to autistic individuals having lower cognitive abilities (beta = -.29, $p = .004$). No significant effect occurred for social participation.

Conclusions: Cognitive abilities moderated the association of atypical sensory processing with emotional and behavioural problems, but not with social participation. In particular, higher cognitive abilities were associated with more problems. This may imply that cognitive abilities should be accounted for in the provision of care to autistic individuals.

1. Introduction

For many individuals with an Autism Spectrum Disorder (ASD), currently also referred to as autistic individuals, atypical sensory

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processing hinders emotional and behavioural functioning and social participation (e.g. Glod, Riby, Honey, & Rodgers, 2015; Ismael, Lawson, & Hartwell, 2018). Sensory processing refers to the reception, modulation, integration, and organization of sensory stimuli, and behavioural responses to sensory input (Miller & Lane, 2000). Atypical sensory processing is highly prevalent in autistic individuals, with rates up to 90% (Baker, Lane, Angley, & Young, 2008; Baranek, David, Poe, Stone, & Watson, 2006; Leekam, Nieto, Libby, Wing, & Gould, 2007; Tomchek & Dunn, 2007), and has been linked to emotional and behavioural problems such as anxiety (e.g., Ben-Sasson et al., 2008; Lane, Reynolds, & Dumenci, 2012; Wigham, Rodgers, South, McConachie, & Freeston, 2015), depression (Bitsika, Sharpley, & Mills, 2016), and stereotyped movements (e.g. Gal, Dyck, & Passmore, 2002). While atypical sensory processing may generally be associated with lower levels of social participation in ASD (LaVesser & Berg, 2011), specific sensory processing patterns may support as well as restrict social participation in ASD (Ismael et al., 2018). For instance, leisure activities that fit with the sensory needs of autistic individuals could support participation (Hochhauser & Engel-Yeger, 2010), whereas obligatory activities in school that do not match with the (extreme) sensory pattern of an autistic individual were associated with restrictions in the social participation (e.g. Ashburner, Ziviani, & Rodger, 2008; Watson et al., 2011). While social participation entails several domains such as self-care, community, and social involvement (World Health Organization, 2001), previous studies primarily focused on educational (e.g. Ashburner et al., 2008) and leisure participation (e.g., Hochhauser & Engel-Yeger, 2010), neglecting other domains of participation in ASD, i.e. the broader community participation (Ismael et al., 2018). As society primarily judges individuals based on their community functioning (Law et al., 2004), more research on the link between sensory processing and social participation is needed.

Autistic individuals vary in cognitive abilities. Baio et al. (2014) have estimated that up to 31% has an intellectual disability. The level of cognitive abilities has been uniquely associated with sensory problems (Engel-Yeger, Hardal-Nasser, & Gal, 2011). However, contradictory findings exist regarding the effect of cognitive abilities on the association between atypical sensory processing and emotional and behavioural outcomes within the ASD population. For instance, Ausderau et al. (2016) concluded that cognitive abilities were associated with specific sensory subtypes and associated outcomes, such as *hyporesponsiveness* and *sensory seeking with less adaptive functioning*. In contrast, Nadon, Feldman, Dunn, and Gisel (2011) and Gabriels et al. (2008) found no effect of cognitive abilities on the association between sensory processing in general and respectively eating problems, and restricted and repetitive behaviours. Previous research has been limited by various factors including small sample sizes; restriction to child-only samples (Glod et al., 2015); narrow focus on ASD related emotional or behavioural outcomes such as stereotyped movements or repetitive behaviours (Gabriels et al., 2008; Gal et al., 2002); and the use of a variety of methods and instruments hindering comparability (e.g. Ausderau et al., 2016; Lane, Young, Baker, & Angley, 2010). Research on the effect of cognitive abilities for the association between sensory processing and social participation is lacking. Moreover, other factors could be of influence when researching the effect of cognitive abilities. ASD severity might influence the association between sensory processing problems and emotional and behavioural problems and restrict social participation (Suarez, 2012). Age may also play a role, as sensory processing problems peak in children aged around 6-9 years, and generally decrease as they get older (Ben-Sasson et al., 2009; Schauder & Bennetto, 2016).

The aims of this study are to examine whether cognitive abilities moderate the association between sensory processing and (1) emotional and behavioural problems, and (2) social participation in autistic individuals, controlling for ASD severity and age.

2. Methods

2.1. Participants

The current study was embedded within the Netherlands Autism Register (NAR) (https://www.nederlandsautismeregister.nl). The NAR is a longitudinal online database of individuals with a Diagnostic and Statistical Manual of Mental Disorders (DSM)-IV-TR or DSM-5 ASD diagnosis in the Netherlands. In that database, individuals registered themselves voluntary (more than 2800 records), and completed a general demographic questionnaire, followed by annual online questionnaires. Information was gathered on a variety of domains including diagnosis, cognitive functioning, comorbidity, treatment, relationships, sensory processing, emotional and behavioural problems, participation, and overall wellbeing.

For the current study, autistic children with and without an intellectual disability and autistic adults (all adults also diagnosed with an intellectual disability) were included, to compare autistic individuals having a wide range of cognitive abilities. In total, 399 participants filled out one annual questionnaire, of whom 90 participants had more than 10% missing items on at least both a section score and the total score of the Short Sensory Profile *(SSP)* and were therefore excluded. For individuals with 0 to 10% missing data, missing values were substituted with the average for the subscale, in accordance with Green, Chandler, Charman, Simonoff, and Baird

Table 1
Characteristics of the participants: background characteristics, and best estimate cognitive abilities, sensory processing, emotional and behavioural problems, and social participation (n = 241).

Male	191	79.3
Age	15.1	5.1 to 54.1, 6.7
CBCL	14.81	2 to 28, 6.10
Best estimate cognitive abilities	3.45	1 to 7, 1.53
SSP total	96.59	40 to 177, 26.61
SDQ total	17.01	1 to 31, 6.17
WHO-DAS total	16.36	0 to 46, 9.71

For male; number of participants (percentage). For all other measures: mean; range, standard deviation.

(2016). Further, 68 participants were excluded due to lack of official IQ test score records, resulting in a final sample of n = 241 participants. All participants were diagnosed using the DSM-IV-TR or DSM-5 criteria by licenced psychologists or psychiatrists working independently from the current study.

In Table 1, the sample characteristics of the 241 participants are presented (79.3% males). The mean age of the participants was 15.1 years of age (range: 5.1 to 54.1).

2.2. Materials

Parents of the autistic children (<16 years) and legal representatives of autistic adults filled in the questionnaire. Proxy measurements were used since not all autistic individuals were able to fill in the questionnaire by themselves due to limited cognitive abilities. Since there are hardly any valid instruments for autistic individuals having lower cognitive abilities, measurements were selected based on discussions with experts, both from clinical and research fields to assess our variables: sensory processing, emotional and behavioural problems, and social participation. We made an overview of different standardized questionnaires. Next, all items of the different versions of the standardized questionnaires below were analysed. The selected versions were suitable versions for ASD individuals with and without an intellectual disability, based on consensus between the experts.

Sensory processing was measured using the Dutch version (Rietman, 2013) of the proxy questionnaire SSP (Dunn, 1999). The SSP consisted of 38 items of sensory dysfunction rated on a 5-point Likert scale ranging from 'always = 1' to 'never = 5' (McIntosh, Miller, Shyu, & Hagerman, 1999). All items were recoded ('always = 5' to 'never = 1') for uniformity with the other questionnaires, in accordance with Tavassoli et al. (2019). A total score was computed from the 38 items, and was used in the analyses to get the frequency of sensory processing problems, with higher scores reflecting more problems. Internal reliability ranged between 0.70 and 0.90, the inter-correlations ranged between 0.25 and 0.76 (Dunn, 1999). Chronbach's alpha was calculated for the SSP total score, and the internal consistency was excellent (α = 0.922).

Emotional and behavioural problems were measured using the total difficulty score of the Dutch version (Van Widenfelt, Goedhart, Treffers, & Goodman, 2003) of the 18+ Strengths and Difficulties Questionnaire (SDQ) (Goodman, 1997), filled in by proxies. The SDQ addressed emotional and behavioural problems in four domains: emotional symptoms, conduct problems, hyperactivity/inattention, peer relationship problems, and one prosocial subscale. All 25 items were scored on a 3-point scale: 0 = not true, 1 = somewhat true, and 2 = certainly true. The total difficulties score regards the sum of the scores on the difficulties scores for these four domains, with higher scores reflecting more problems. The SDQ has shown to be a reliable instrument (Achenbach et al., 2008; Vostanis, 2006). Chronbach's alpha was calculated for the SDQ total difficulty score, and the internal consistency was acceptable (α = 0.771).

Social participation was measured using the Dutch 12-item proxy version (Van Hoeken, 2014) of the World Health Organization Disability Assessment Schedule 2.0 (WHO-DAS 2.0) (World Health Organization (WHO), 2010), assessing the magnitude of the disability during the previous 30-days on e.g. communication, self-care, life activities, and social participation on a 0-4 scale (0 = none, 4 = extreme/cannot do). A total score was calculated by aggregating the scores (ranging from zero to 48), with a higher score reflecting more problems. The WHO-DAS 2.0 has shown to have an internal consistency of > .85 (Üstün et al., 2010). Chronbach's alpha was calculated for the WHO-DAS total score, and the internal consistency was good (α = 0.883).

Best estimate cognitive abilities were obtained based on proxy reported IQ test scores. First, proxies reported whether the individual had previously done an IQ test, independently of the current study, administered by a professional. Next, only participants for whom this IQ test information was available were included. IQ level was categorized on a 7-point rating of IQ: 1 = above 130, 2 = 116 to 130, 3 = 86 to 115, 4 = 71 to 85, 5 = 56 to 70, 6 = 40 to 55, and 7 = below 40. To check for validity, this was correlated with the Daily Living subscale of the Vineland Screener 0-12 years proxy version (Van Duijn, Dijkxhoorn, Noens, Scholte, & van Berckelaer-Onnes, 2009) for the intellectual disability group (autistic individuals with an IQ < 70) (n = 61). Results showed a strong correlation of, -.71, in line with our hypothesis of less adaptive functioning associated with a lower IQ.

ASD severity was measured using the Pervasive Developmental Problems and Withdrawn subscales of the Dutch version (Verhulst & Van der Ende, 1997) of the Child Behavior Checklist (CBCL) 1.5-5 years (Achenbach & Rescorla, 2000). These comprised 16 items, rated on a three-point scale (0 = not true, 1 = somewhat or sometimes true, and 2 = very true or often true). A total score was obtained by adding the items, with higher scores reflecting more severe ASD. These scales differentiated well between young children with and without ASD (Rescorla et al., 2019). We validated this questionnaire for our sample by correlating the total CBCL score with the total score of the Dutch short version of the Autism spectrum Quotient (AQ-NL) (Hoekstra et al., 2011), a translation of the AQ questionnaire (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001), which gives an indication of the existence of ASD, filled in by 134 participants. This association was .48. Chronbach's alpha was calculated for the CBCL score, and the internal consistency was good (α = 0.853). We further measured *chronological age.*

2.3. Procedure

Standardized questionnaires for each variable and relevant background characteristics were assessed, including their ASD diagnosis, comorbidities, treatment, employment, and cognitive functioning (299 items). Participants received a link to complete the online annual assessment. The Medical Ethical Committee of the Vrije Universiteit Amsterdam approved this research (E1321MW, VCWE-2020-041). Active informed consent was obtained.

2.4. Statistical analysis

The sociodemographic characteristics of the participants were described. Next, we assessed the moderation effect of best estimate cognitive abilities on the association between sensory processing and the outcomes: emotional and behavioural problems (SDQ-total difficulty score), and social participation (WHO-DAS 2.0). First, we assessed the main effects: the association between sensory processing and the outcomes, and between best estimate cognitive abilities and the outcomes using multiple linear regression analyses. Second, we repeated these analyses, controlled for our co variates ASD severity and age. Third, we added the interaction term to our model to assess whether best estimate cognitive abilities moderated the association between sensory processing and the outcomes, controlled for ASD severity and age using multiple linear regression analyses with an interaction term. In text, the outcomes of these three-step analyses are presented per outcome. For the analyses, all continuous independent variables were centred at its mean, except for best estimate cognitive abilities, which was centred at category 1 (highest IQ) for a clearer interpretation since this variable was based on 7 categories. For the interpretation of the interaction effect, we analysed the intercepts of sensory processing, best estimate cognitive abilities, and the interaction term, controlled for the centred means of ASD severity and age. Lastly, we repeated all analyses without outliers (sensitivity analyses) to validate our findings. To assess the moderation effect of best estimate cognitive abilities we used the linear multiple regression analyses module in SPSS, version 25. Per outcome (i.e. 1. emotional and behavioural problems and 2. social participation) the multiple regression analyses were performed using the enter method, a procedure in which all variables in a block are entered in a single step. By performing the previous three stage regression analyses, we could investigate the main effects and the additional contribution of the interaction effect to these main effects.

3. Results

3.1. The moderation effect of best estimate cognitive abilities on the association between sensory processing and emotional and behavioural problems

More sensory processing problems (beta = .58, p <.001) and lower best estimate cognitive abilities (beta = .23, p < .001) were significantly associated with more emotional and behavioural problems. For sensory processing problems this association also was found when controlled for ASD severity and age (beta = .32, p < .001). Best estimate cognitive abilities significantly moderated the association between sensory processing problems and emotional and behavioural problems showing a cross-over interaction (beta = -.29, p = .004), i.e., individuals with lower best estimate cognitive abilities showed more emotional and behavioural problems in case of less sensory processing problems, whereas individuals with higher best estimate cognitive abilities had more emotional and behavioural problems in case of more sensory processing problems. In Fig. 1, the cross-over interaction is presented. In Table 2, results for both aim 1 and aim 2 are presented.

3.2. The moderation effect of best estimate cognitive abilities on the association between sensory processing and social participation

More sensory processing problems (beta = .69, p < .001) and lower best estimate cognitive abilities (beta = .38, p < .001) were significantly associated with more restrictions in social participation, also when controlled for ASD severity and age (beta = .40, p < .001; beta = .13, p = .018). Best estimate cognitive abilities did not significantly moderate the association between sensory processing and social participation (beta = .08, p = .337).

3.3. Sensitivity analyses

In total, five participants had an age > 3 standard deviations off the mean and three participants had mild outliers on the WHO-

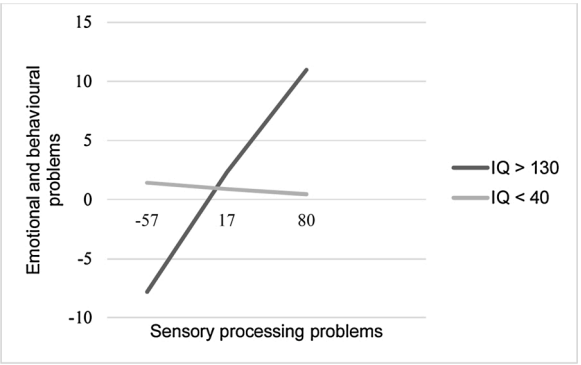

Fig. 1. Visualization of the cross-over interaction of best estimate cognitive abilities on the association between sensory processing and emotional and behavioural problems. As an illustration, the highest IQ score (IQ > 130) and lowest IQ score (IQ < 40) are plotted.
Regarding sensory processing; -57: minimum centred SSP, 80: maximum centred SSP.

Table 2
N = 241. Moderation effect of best estimate cognitive abilities on the association between sensory processing and (1) emotional and behavioural problems, and (2) social participation for ASD individuals: results of multiple linear regression analyses leading to betas.

	Emotional and behavioural problems			Social participation		
	Beta	p-value	Adjusted r2	Beta	p-value	Adjusted r2
Model 1a			.33			.48
Sensory processing	.58	<.001*		.69	<.001*	
Model 1b			.05			.14
Best estimate cognitive abilities	.23	<.001*		.38	<.001*	
Model 2a			.41			.60
Sensory processing	.32	<.001*		.40	<.001*	
ASD severity	.38	<.001*		.45	<.001*	
Age	-.06	.210		-.01	.804	
Model 2b			.35			.52
Best estimate cognitive abilities	.01	.851		.13	.018*	
ASD severity	.58	<.001*		.66	<.001*	
Age	-.13	.018*		-.12	.010*	
Model 3			.43			.61
Sensory processing	.59	<.001*		.33	<.001*	
Best estimate cognitive abilities	.04	.474		.12	.011*	
Sensory processing x best estimate cognitive abilities	-.29	.004*		.08	.337	
ASD severity	.35	<.001*		.41	<.001*	
Age	-.09	.097		-.04	.360	

Note: reported values: beta and p-value per variable per model, adjusted r2 per model. * indicates $p < .05$.

DAS. When we excluded these participants from the analyses (leading to N = 236 and N = 238, respectively), two minor changes occurred: age was non-significant in model 2b for social participation for the N = 236, and best estimate cognitive abilities was significant in model 2b for social participation for the N = 238. No changes occurred in the final model.

4. Discussion

The aims of the current study were to assess whether cognitive abilities moderate the association between sensory processing and (1) emotional and behavioural problems and (2) social participation in autistic individuals. We found in our study that best estimate cognitive abilities moderated the association of sensory processing and emotional and behavioural problems, but not the association between sensory processing and social participation for autistic individuals.

Best estimate cognitive abilities moderated the association between sensory processing and emotional and behavioural problems. In particular, for autistic individuals with higher best estimate cognitive abilities, sensory problems showed stronger associations with emotional and behavioural problems compared to those with lower best estimate cognitive abilities in case of more sensory processing problems. This is in line with findings of previous studies that autistic individuals with higher cognitive abilities have an increased risk for emotional and behavioural problems (Bauminger, Solomon, & Rogers, 2010) and parents more likely report anxiety and depression for autistic individuals with higher compared to lower cognitive abilities (Mazurek & Kanne, 2010). Our specific findings can be explained in three ways. First, individuals with higher cognitive abilities may have more self-knowledge and may be more aware of their own (sensory) difficulties, leading to more challenges compared to autistic individuals with lower cognitive abilities (Mazurek & Kanne, 2010). Second, higher expectations may be placed on autistic individuals with higher compared to lower cognitive abilities (Manjiviona, 2003), which could lead to overestimating their capabilities by e.g., parents, teachers, employers, and health professionals. Third, most of the measurements were filled in by proxies (parents, caregivers). However, proxies may not adequately recognize or observe behaviour in autistic individuals with lower cognitive abilities or make false attributions of observed behaviour to different concepts, since the same observed behaviour could be the expression of different concepts (Gillberg, 2010). For instance, parents of autistic individuals often report sensory processing problems when they observe emotional or behavioural problems (Gourley, Wind, Henninger, & Chinitz, 2013). Therefore, the current findings should be seen under the consideration that data was gathered from the parents' perspectives. In our study, autistic individuals who show higher cognitive abilities experience more problems in case of more sensory processing problems.

We found that best estimate cognitive abilities did not moderate the association between sensory processing and social participation. No previous study has assessed the effect of cognitive abilities on this association in autistic individuals. However, cognitive abilities have previously been found to be associated with both sensory processing problems (Engel-Yeger et al., 2011) and restrictions in social participation (Magiati, Tay, & Howlin, 2014) in autistic individuals, which is in line with our findings. The absent moderation effect may be explained in two ways. First, characteristics of an ASD diagnosis may lead to restrictions in social participation, including adaptive functioning and language ability (Orsmond, Shattuck, Cooper, Sterzing, & Anderson, 2013; Shattuck, Orsmond, Wagner, & Cooper, 2011). Specifically, atypical sensory processing of autistic individuals may lead to the inability to interact, explore, and communicate with the environment (Ashburner et al., 2008; Baranek et al., 2002; Cosbey, Johnston, & Dunn, 2010). Second, recent studies support a cascade effect of atypical sensory processing resulting in participation restrictions later in life (Baranek et al., 2018; Williams et al., 2018). Regardless of their cognitive abilities, autistic individuals seem to experience social participation problems that could be due to their sensory processing problems.

Based on total scores we found that autistic individuals have participation restrictions due to their sensory processing, with parents report of autistic individuals with higher best estimate cognitive abilities having more emotional and behavioural problems in case of more sensory processing problems compared to those with lower best estimate cognitive abilities. A wide range of autistic individuals were included in our study, from a severe intellectual disability to above average cognitive abilities, which strengthen our finding. This contrasts with findings that in general, autistic individuals with lower cognitive abilities experience more problems (Matson & Shoemaker, 2009). However, this is partly in line with the conflicting findings about the effect of cognitive abilities on sensory processing (Hazen, Stornelli, O'Rourke, Koesterer, & McDougle, 2014). Our findings may be explained in two ways. First, more knowledge about the concept sensory processing in autistic individuals is needed, i.e., regarding individual differences and moderating factors (Uljarevic et al., 2017). Second, in autistic individuals, both delay and a distortion in their development is present (Boucher, 2012). This makes the role of cognitive abilities even more complicated. Overall, based on the findings of the current study, proxies report that autistic individuals have daily life restrictions due to their sensory processing regardless of their cognitive abilities, whereas autistic individuals with higher cognitive abilities may have more problems in case of more sensory processing problems.

4.1. Strengths and limitations

This study has several strengths. First, we included autistic individuals with a wide range of cognitive abilities in our sample ($IQ < 40$ to $IQ > 130$). Second, data was gathered from a large national database of autistic individuals in the Netherlands (NAR database). Third, we controlled for two major factors that could be of influence: ASD severity and age.

There are also some limitations. First, the use of proxy measurements may have resulted in bias, e.g. regarding underreporting existing behaviour of the autistic individual or false attributions of behaviour to different concepts. This holds in particular for autistic individuals having lower cognitive abilities. Therefore, we have to be cautious regarding statements and inferences. In line with this, we recommend gathering data from autistic individuals themselves or by observations made by trained clinicians. In particular, cognitive abilities of autistic individuals was based on the best estimate cognitive abilities. Therefore, this study could be repeated using uniform standardized intelligence measurements. Second, all effects were cross sectional; therefore no statements about the causality could be made. Third, the overlap between our concepts may be a problem in assessing the concepts as measured. However, prior to the analyses we therefore assessed the correlations between all concepts.

4.2. Implications for clinical practice and research

First, in the current study parents report that in autistic individuals with higher cognitive abilities, higher levels of sensory processing problems are associated with higher levels of emotional and behavioural problems. Therefore, we recommend that cognitive abilities are accounted for in the provision of care to autistic individuals. In addition, objective measures could be added as part of a (clinical) assessment, to get more insight into the actual competencies of the autistic individuals, in particular regarding intelligence scores. Second, since autistic individuals seem to experience social participation restrictions due to their sensory processing regardless of cognitive abilities, attention should be paid to organize their daily life activities in different settings e.g., in their home, school, and work environment and in clinical settings, in collaboration with their context. Third, in this study many autistic individuals face daily life obstacles due to their sensory processing problems but individuals with higher cognitive abilities might notice more problems in case of more sensory processing problems. Therefore, the network of autistic individuals including parents, teachers, employers, health professionals, and clinicians should be alert regarding early detection of sensory problems and offer support to optimize the daily life of all autistic individuals.

First, further research is needed in which other methods are used to assess the moderation effect of cognitive abilities. This research should include direct assessments of sensory processing, and emotional and behavioural problems, especially since there is overlap in the concepts, in particular for autistic individuals with lower cognitive abilities (Gillberg, 2010). In addition, self-report data could be used from autistic individuals without an intellectual disability. Second, further research is needed to specify the impact of cognitive abilities on the association between sensory processing and emotional and behavioural problems and social participation in autistic individuals, in particular with adults without an intellectual disability, which were not included in the current study. Third, subgroup analyses of autistic individuals with comparable cognitive abilities should be performed to assess within group differences, e.g., autistic individuals with and without an intellectual disability may differ in functioning in certain emotional and behavioural problems or social participation domains.

4.3. Conclusion

The findings of this study showed a moderation effect of cognitive abilities on the association between sensory processing and emotional and behavioural problems. No moderation effect of cognitive abilities was found for the association between sensory processing and social participation. Therefore, we can conclude that according to parents, many autistic individuals experience problems in their daily life functioning due to their sensory processing problems regardless of their cognitive abilities, whereas individuals with higher cognitive abilities notice them more in case of more sensory processing problems.

Declaration of Competing Interest

The authors report no declarations of interest.

CRediT authorship contribution statement

M.F. Werkman: Conceptualization, Data curation, Formal analysis, Methodology, Writing - original draft, Writing - review & editing. **S. Brouwer:** Conceptualization, Formal analysis, Methodology, Writing - original draft, Writing - review & editing. **Y.M. Dijkxhoorn:** Conceptualization, Writing - review & editing. **I.A. van Berckelaer-Onnes:** Conceptualization, Writing - review & editing. **S.A. Reijneveld:** Conceptualization, Formal analysis, Methodology, Writing - original draft, Writing - review & editing. **J.A. Landsman:** Conceptualization, Formal analysis, Methodology, Writing - original draft, Writing - review & editing. **S. Begeer:** Conceptualization, Formal analysis, Methodology, Writing - original draft, Writing - review & editing.

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References

Achenbach, T., & Rescorla, L. (2000). *Manual for the ASEBA Preschool Forms and Profiles*. Burlington, VT: University of Vermont.

Achenbach, T. M., Becker, A., Döpfner, M., Heiervang, E., Roessner, V., Steinhausen, H., … Rothenberger, A. (2008). Multicultural assessment of child and adolescent psychopathology with ASEBA and SDQ instruments: Research findings, applications, and future directions. *Journal of Child Psychology & Psychiatry, 49*(3), 251–275. https://doi.org/10.1111/j.1469-7610.2007.01867.x.

Ashburner, J., Ziviani, J., & Rodger, S. (2008). Sensory processing and classroom emotional, behavioral, and educational outcomes in children with autism spectrum disorder. *American Journal of Occupational Therapy, 62*(5), 564–573. https://doi.org/10.5014/ajot.62.5.564.

Ausderau, K. K., Sideris, J., Little, L. M., Furlong, M., Bulluck, J. C., & Baranek, G. T. (2016). Sensory subtypes and associated outcomes in children with autism spectrum disorders. *Autism Research, 9*(12), 1316–1327. https://doi.org/10.1002/aur.1626.

Baio, J., Wiggins, L., Christensen, D. L., Maenner, M. J., Daniels, J., Warren, Z., & Dowling, N. F. (2014). Prevalence of autism spectrum disorder among children aged 8 years - autism and developmental disabilities monitoring network, 11 sites, united states, 2014. *Morbidity and Mortality Weekly Report.Surveillance Summaries (Washington, D.C.: 2002), 67*(6), 1–23. https://doi.org/10.15585/mmwr.ss6706a1.

Baker, A. E. Z., Lane, A., Angley, M. T., & Young, R. L. (2008). The relationship between sensory processing patterns and behavioural responsiveness in autistic disorder: A pilot study. *Journal of Autism & Developmental Disorders, 38*(5), 867–875. https://doi.org/10.1007/s10803-007-0459-0.

Baranek, G. T., Chin, Y. H., Hess, L. M. G., Yankee, J. G., Hatton, D. D., & Hooper, S. R. (2002). Sensory processing correlates of occupational performance in children with fragile X syndrome: Preliminary findings. *American Journal of Occupational Therapy, 56*(5), 538–546. https://doi.org/10.5014/ajot.56.5.538.

Baranek, G. T., David, F. J., Poe, M. D., Stone, W. L., & Watson, L. R. (2006). Sensory experiences questionnaire: Discriminating sensory features in young children with autism, developmental delays, and typical development. *Journal of Child Psychology and Psychiatry, 47*(6), 591–601. https://doi.org/10.1111/j.1469-7610.2005.01546.x.

Baranek, G. T., Woynaroski, T. G., Nowell, S., Turner-Brown, L., DuBay, M., Crais, E. R., … Watson, L. R. (2018). Cascading effects of attention disengagement and sensory seeking on social symptoms in a community sample of infants at-risk for a future diagnosis of autism spectrum disorder. *Developmental Cognitive Neuroscience, 29*, 30–40. https://doi.org/10.1016/j.dcn.2017.08.006.

Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., & Clubley, E. (2001). The autism-spectrum quotient (AQ): Evidence from asperger syndrome/high-functioning autism, males and females, scientists and mathematicians. *Journal of Autism and Developmental Disorders, 31*(1), 5–17. https://doi.org/10.1023/A:1005653411471.

Bauminger, N., Solomon, M., & Rogers, S. J. (2010). Externalizing and internalizing behaviors in ASD. *Autism Research, 3*(3), 101–112. https://doi.org/10.1002/aur.131.

Ben-Sasson, A., Cermak, S. A., Orsmond, G. I., Tager-Flusberg, H., Kadlec, M. B., & Carter, A. S. (2008). Sensory clusters of toddlers with autism spectrum disorders: Differences in affective symptoms. *Journal of Child Psychology and Psychiatry, 49*(8), 817–825. https://doi.org/10.1111/j.1469-7610.2008.01899.x.

Ben-Sasson, A., Hen, L., Fluss, R., Cermak, S. A., Engel-Yeger, B., & Gal, E. (2009). A meta-analysis of sensory modulation symptoms in individuals with autism spectrum disorders. *Journal of Autism and Developmental Disorders, 39*(1), 1–11. https://doi.org/10.1007/s10803-008-0593-3.

Bitsika, V., Sharpley, C. F., & Mills, R. (2016). Are sensory processing features associated with depressive symptoms in boys with an ASD? *Journal of Autism and Developmental Disorders, 46*(1), 242–252. https://doi.org/10.1007/s10803-015-2569-4.

Boucher, J. (2012). Research review: Structural language in autistic spectrum disorder - characteristics and causes. *Journal of Child Psychology & Psychiatry, 53*(3), 219–233. https://doi.org/10.1111/j.1469-7610.2011.02508.x.

Cosbey, J., Johnston, S. S., & Dunn, M. L. (2010). Sensory processing disorders and social participation. *American Journal of Occupational Therapy, 64*(3), 462–473. https://doi.org/10.5014/ajot.2010.09076.

Dunn, W. (1999). *Sensory profile user's manual*. San Antonio, TX: Harcourt Assessment.

Engel-Yeger, B., Hardal-Nasser, R., & Gal, E. (2011). Sensory processing dysfunctions as expressed among children with different severities of intellectual developmental disabilities. *Research in Developmental Disabilities: A Multidisciplinary Journal, 32*(5), 1770–1775. https://doi.org/10.1016/j.ridd.2011.03.005.

Gabriels, R. L., Agnew, J. A., Miller, L. J., Gralla, J., Pan, Z., Goldson, E., & Hooks, E. (2008). Is there a relationship between restricted, repetitive, stereotyped behaviors and interests and abnormal sensory response in children with autism spectrum disorders? *Research in Autism Spectrum Disorders, 2*(4), 660–670. https://doi.org/10.1016/j.rasd.2008.02.002.

Gal, E., Dyck, M., & Passmore, A. (2002). Sensory differences and stereotyped movements in children with autism. *Behaviour Change, 19*(4), 207–219. https://doi.org/10.1375/bech.19.4.207.

Gillberg, C. (2010). The ESSENCE in child psychiatry: Early symptomatic syndromes eliciting neurodevelopmental clinical examinations. *Research in Developmental Disabilities, 31*(6), 1543–1551. https://doi.org/10.1016/j.ridd.2010.06.002.

Glod, M., Riby, D. M., Honey, E., & Rodgers, J. (2015). Psychological Correlates of Sensory Processing Patterns in Individuals with Autism Spectrum Disorder: A Systematic Review. *Review Journal of Autism and Developmental Disorders, 2*(2), 199–221. https://doi.org/10.1007/s40489-015-0047-8.

Goodman, R. (1997). The strengths and difficulties questionnaire: A research note. *Child Psychology & Psychiatry & Allied Disciplines, 38*(5), 581–586. https://doi.org/10.1111/j.1469-7610.1997.tb01545.x.

Gourley, L., Wind, C., Henninger, E., & Chinitz, S. (2013). Sensory processing difficulties, behavioral problems, and parental stress in a clinical population of young children. *Journal of Child & Family Studies, 22*(7), 912–921. https://doi.org/10.1007/s10826-012-9650-9.

Green, D., Chandler, S., Charman, T., Simonoff, E., & Baird, G. (2016). Brief report: DSM-5 sensory behaviours in children with and without an autism spectrum disorder. *Journal of Autism and Developmental Disorders, 46*(11), 3597–3606. https://doi.org/10.1007/s10803-016-2881-7.

Hazen, E. P., Stornelli, J. L., O'Rourke, J. A., Koesterer, K., & McDougle, C. J. (2014). Sensory symptoms in autism spectrum disorders. *Harvard Review of Psychiatry, 22*(2), 112–124. https://doi.org/10.1097/01.HRP.0000445143.08773.58.

Hochhauser, M., & Engel-Yeger, B. (2010). Sensory processing abilities and their relation to participation in leisure activities among children with high-functioning autism spectrum disorder (HFASD). *Research in Autism Spectrum Disorders, 4*(4), 746–754. https://doi.org/10.1016/j.rasd.2010.01.015.

Hoekstra, R. A., Vinkhuyzen, A. A. E., Wheelwright, S., Bartels, M., Boomsma, D. I., Baron-Cohen, … van der Sluis, S. (2011). The construction and validation of an abridged version of the autism-spectrum quotient (AQ-short). *Journal of Autism and Developmental Disorders, 41*(5), 589–596. https://doi.org/10.1007/s10803-010-1073-0.

Ismael, N., Lawson, L. M., & Hartwell, J. (2018). Relationship between sensory processing and participation in daily occupations for children with autism spectrum disorder: A systematic review of studies that used dunn's sensory processing framework. *American Journal of Occupational Therapy, 72*(3), 1–9. https://doi.org/10.5014/ajot.2018.024075.

Lane, A. E., Young, R. L., Baker, A. E. Z., & Angley, M. T. (2010). Sensory processing subtypes in autism: Association with adaptive behavior. *Journal of Autism & Developmental Disorders, 40*(1), 112–122. https://doi.org/10.1007/s10803-009-0840-2.

Lane, S. J., Reynolds, S., & Dumenci, L. (2012). Sensory overresponsivity and anxiety in typically developing children and children with autism and attention deficit hyperactivity disorder: Cause or coexistence? *American Journal of Occupational Therapy, 66*(5), 595–603. https://doi.org/10.5014/ajot.2012.004523.

LaVesser, P., & Berg, C. (2011). Participation patterns in preschool children with an autism spectrum disorder. *OTJR: Occupation, Participation and Health, 31*(1), 33–39. https://doi.org/10.3928/15394492-20100823-01.

Law, M., Finkelman, S., Hurley, P., Rosenbaum, P., King, S., King, G., & Hanna, S. (2004). Participation of children with physical disabilities: Relationships with diagnosis, physical function, and demographic variables. *Scandinavian Journal of Occupational Therapy, 11*(4), 156–162. https://doi.org/10.1080/11038120410020755.

Leekam, S. R., Nieto, C., Libby, S. J., Wing, L., & Gould, J. (2007). Describing the sensory abnormalities of children and adults with autism. *Journal of Autism and Developmental Disorders, 37*(5), 894–910. https://doi.org/10.1007/s10803-006-0218-7.

Magiati, I., Tay, X. W., & Howlin, P. (2014). Cognitive, language, social and behavioural outcomes in adults with autism spectrum disorders: A systematic review of longitudinal follow-up studies in adulthood. *Clinical Psychology Review, 34*(1), 73–86. https://doi.org/10.1016/j.cpr.2013.11.002.

Manjiviona, J. (2003). In M. Prior (Ed.), *Assessment of specific learning difficulties* (pp. 55–84). New York, NY: Guilford Press. Retrieved from http://web.a.ebscohost.com/ehost/detail/detail?vid=0&sid=a955f715-091d-4dbb-82e4-4a87ced64cf9%40sessionmgr4008&bdata=JnNpdGU9ZWhvc3QtbGl2ZSZzY29wZT1zaXRl#AN=2004-00019-003&db=psyh.

Matson, J. L., & Shoemaker, M. (2009). Intellectual disability and its relationship to autism spectrum disorders. *Research in Developmental Disabilities: A Multidisciplinary Journal, 30*(6), 1107–1114. https://doi.org/10.1016/j.ridd.2009.06.003.

Mazurek, M. O., & Kanne, S. M. (2010). Friendship and internalizing symptoms among children and adolescents with ASD. *Journal of Autism and Developmental Disorders, 40*(12), 1512–1520. https://doi.org/10.1007/s10803-010-1014-y.

McIntosh, D. N., Miller, L. J., Shyu, V., & Hagerman, R. J. (1999). Sensory-modulation disruption, electrodermal responses and functional behaviors. *Developmental Medicine & Child Neurology, 41*(9), 608–615. https://doi.org/10.1017/S0012162299001267.

Miller, L. J., & Lane, S. J. (2000). Toward a consensus in termonology [sic] in sensory integration theory and practice: Part 1: Taxonomy of neurophysiological processes. *Sensory Integration Special Interest Section Quarterly, 23*(1), 1–4.

Nadon, G., Feldman, D. E., Dunn, W., & Gisel, E. (2011). Association of sensory processing and eating problems in children with autism spectrum disorders. *Autism Research & Treatment*, 1–8. https://doi.org/10.1155/2011/541926.

Orsmond, G. I., Shattuck, P. T., Cooper, B. P., Sterzing, P. R., & Anderson, K. A. (2013). Social participation among young adults with an autism spectrum disorder. *Journal of Autism and Developmental Disorders, 43*(11), 2710–2719. https://doi.org/10.1007/s10803-013-1833-8.

Rescorla, L. A., Winder-Patel, B., Paterson, S. J., Pandey, J., Wolff, J. J., Schultz, R. T., … Piven, J. (2019). Autism spectrum disorder screening with the CBCL/1½–5: Findings for young children at high risk for autism spectrum disorder. *Autism: The International Journal of Research & Practice, 23*(1), 29–38. https://doi.org/10.1177/1362361317718482.

Rietman, A. (2013). *Sensory Profile-NL. Handleiding. Pearson Assessment and Information, Amsterdam*.

Schauder, K. B., & Bennetto, L. (2016). Toward an interdisciplinary understanding of sensory dysfunction in autism spectrum disorder: An integration of the neural and symptom literatures. *Frontiers in Neuroscience, 10*. https://doi.org/10.3389/fnins.2016.00268, 268–268.

Shattuck, P. T., Orsmond, G. I., Wagner, M., & Cooper, B. P. (2011). Participation in social activities among adolescents with an autism spectrum disorder. *PLoS ONE, 6*(11), 1–9. https://doi.org/10.1371/journal.pone.0027176.

Suarez, M. A. (2012). Sensory processing in children with autism spectrum disorders and impact on functioning. *Pediatric Clinics of North America, 59*(1), 203–214. https://doi.org/10.1016/j.pcl.2011.10.012.

Tavassoli, T., Brandes-Aitken, A., Chu, R., Porter, L., Schoen, S., Miller, L. J., … Marco, E. J. (2019). Sensory over-responsivity: Parent report, direct assessment measures, and neural architecture. *Molecular Autism, 10*. https://doi.org/10.1186/s13229-019-0255-7, 4–4.

Tomchek, S. D., & Dunn, W. (2007). Sensory processing in children with and without autism: A comparative study using the short sensory profile. *American Journal of Occupational Therapy, 61*(2), 190–200. https://doi.org/10.5014/ajot.61.2.190.

Uljarevic, M., Baranek, G., Vivanti, G., Hedley, D., Hudry, K., & Lane, A. (2017). Heterogeneity of sensory features in autism spectrum disorder: Challenges and perspectives for future research. *Autism Research, 10*(5), 703–710. https://doi.org/10.1002/aur.1747.

Üstün, T. B., Chatterji, S., Kostanjsek, N., Rehm, J., Kennedy, C., Epping-Jordan, J., & Pull, C. (2010). Developing the world health organization disability assessment schedule 2.0. *Bulletin of the World Health Organization, 88*(11), 815–823. https://doi.org/10.2471/BLT.09.067231.

Van Duijn, G., Dijkxhoorn, Y., Noens, I., Scholte, E., & van Berckelaer-Onnes, I. (2009). Vineland screener 0–12 years research version (NL). constructing a screening instrument to assess adaptive behaviour. *International Journal of Methods in Psychiatric Research, 18*(2), 110–117. https://doi.org/10.1002/mpr.282.

Van Hoeken, D. (2014). *De WHODDAS2.0 brengt beperkingen in het psychosociaal functioneren in kaart.* Retrieved from http://www.dsm-5-nl.org/documenten/artikel/25/De-WHODAS2-0-brengt-beperkingen-in-het-psychosociale-functioneren-in-kaart.

Van Widenfelt, B. M., Goedhart, A. W., Treffers, P. D., & Goodman, R. (2003). Dutch version of the Strengths and Difficulties Questionnaire (SDQ). *European child & adolescent psychiatry, 12*(6), 281–289. https://doi.org/10.1007/s00787-003-0341-3.

Verhulst, F. C., & Van der Ende, J. (1997). *The Dutch translation of the Child Behavior Checklist 1 ½ - 5*. Rotterdam: Erasmus Medical Centre- Sophia Kinderziekenhuis.

Vostanis, P. (2006). Strengths and difficulties questionnaire: Research and clinical applications. *Current Opinion in Psychiatry, 19*(4), 367–372. https://doi.org/10.1097/01.yco.0000228755.72366.05.

Watson, L. R., Patten, E., Baranek, G. T., Poe, M., Boyd, B. A., Freuler, A., & Lorenzi, J. (2011). Differential associations between sensory response patterns and language, social, and communication measures in children with autism or other developmental disabilities. *ournal of speech, language, and hearing research, 54*(6), 1562–1576. https://doi.org/10.1044/1092-4388(2011/10-0029).

Wigham, S., Rodgers, J., South, M., McConachie, H., & Freeston, M. (2015). The interplay between sensory processing abnormalities, intolerance of uncertainty, anxiety and restricted and repetitive behaviours in autism spectrum disorder. *Journal of Autism and Developmental Disorders, 45*(4), 943–952. https://doi.org/10.1007/s10803-014-2248-x.

Williams, K. L., Kirby, A. V., Watson, L. R., Sideris, J., Bulluck, J., & Baranek, G. T. (2018). Sensory features as predictors of adaptive behaviors: A comparative longitudinal study of children with autism spectrum disorder and other developmental disabilities. *Research in Developmental Disabilities, 81*, 103–112. https://doi.org/10.1016/j.ridd.2018.07.002.

World Health Organization. (2001). *International classification of functioning disability and health (ICF)*.

World Health Organization (WHO). (2010). *Measuring health and disability. Manual for WHO Disability Assessment Schale. WHODAS 2.0. [assessment manual]*. Downloaded on December 11th, 2017, Retrieved from https://apps.who.int/iris/bitstream/handle/10665/43974/9789241547598-dut.pdf?sequence=31&isAllowed=y.