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RESEARCH

Exploring the Link Between Temperament, Sensory Processing, and Characteristics of Autism in Autistic and Non-Autistic Children

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Abstract

Examining temperamental and sensory processing characteristics in autism may help in understanding variability in the spectrum. The first aim of this study was to investigate the temperamental characteristics, including surgency, negative affectivity, and effortful control, of both non-autistic and autistic children. Second, the association between sensory processing (measured as sensory discomfort with the Short Sensory Profile Scale) and temperament was examined across the groups. Third, the relationship between temperament, sensory processing, and characteristics of autism was examined in autistic children. Participants included 55 non-autistic and 66 autistic preschoolers. The study revealed no differences in negative affectivity and surgency between the two groups after controlling for child age and family income, but autistic children had lower scores for effortful control. Furthermore, higher negative affectivity scores were linked to more sensory discomfort. Finally, lower scores for effortful control and higher sensory discomfort were associated with more autism characteristics in the autistic group. This study revealed temperamental differences between the groups and demonstrated that the joint contribution of temperament and sensory processing helps explain individual differences in autism.

Keywords Autism · Effortful control · Negative affectivity · Sensory processing · Temperament

Introduction

Autism is a complex neurodevelopmental condition primarily characterized by repetitive behaviors and challenges with social behavior and communication (American Psychiatric Association, [1]). Despite the existence of specific diagnostic criteria, there is considerable heterogeneity that cannot be fully explained by the levels of autism characteristics [53]. Autistic children exhibit distinct temperamental and sensory processing (SP) characteristics [52] in comparison to non-autistic children, but there is also variability in these characteristics among autistic children.

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This variability may be associated with social behavioral adjustment and functioning [15, 31]. Thus, an "individual differences" approach within clinical populations has been suggested [53] and adopted in recent studies [25, 57]. In line with this perspective, the current study explores the temperament and SP characteristics of autistic and non-autistic preschoolers.

Temperament and Autism

Temperament is defined as biologically based individual differences, encompassing emotional and behavioral reactivity, recovery, and regulation strategies [43, 46]. It is a broad and multidimensional concept, commonly measured by scales focusing on several dimensions. Numerous scales were developed using nine dimensions extracted from the New York Longitudinal Study, concentrating on the behavioral characteristics of infants [51]. However, researchers subsequently expanded those dimensions by incorporating a theory-driven approach [45] and created the Children's Behavior Questionnaire (CBQ) [45], comprising the three broader dimensions of surgency, negative affectivity (NA), and effortful control (EC). The current study focuses on these three dimensions as temperament characteristics. Surgency/extraversion is associated in the CBQ with high levels of activity, laughter, and high-intensity pleasure and low shyness [44]. Children with high levels of surgency tend to be more active and enthusiastic about physical play and social interactions, whereas children with low levels of surgency may be quieter and more shy, especially in unfamiliar settings. NA is linked to dimensions such as discomfort, fear, sadness, and falling reactivity/recovery from distress [44]. A child high in NA may become easily upset, have difficulty calming down, or show strong reactions to sensory input. In contrast, a child low in NA is typically more emotionally stable and less reactive to minor stressors. EC encompasses dimensions such as inhibitory control, attention focusing, low-intensity pleasure, and perceptual sensitivity [44]. Children with low EC may struggle to sustain or shift their attention or regulate their behavior effectively. Understanding how these temperamental traits relate to autism characteristics may help to clarify individual differences in developmental trajectories.

Previous studies have reported temperamental differences between autistic and non-autistic children, but inconsistencies have also been observed. For example, it was shown that autistic children have higher scores for difficult temperament as reported by their parents, such as high NA scores [10, 15], while other studies reported no difference in NA [30] or lower NA scores in autistic children [58]. Lower scores for EC [15, 58] and attention skills [30] were also reported in autistic children. Furthermore, temperamental differences have been found between groups with high and low probability of autism in longitudinal studies. For example, Garon et al., [24] found that infants with autistic siblings (high-probability group) scored higher on NA and lower on EC compared to infants without autistic siblings (low-probability group). This variability in temperamental characteristics could account for the heterogeneity within the autism spectrum [9], which might be associated with the levels of autism characteristics. In a recent study, NA and perceptual sensitivity were found to be positively associated with increased levels of autism characteristics [58]. In a prospective study, changes in perceptual sensitivity and inhibitory control as subscales of EC predicted autism characteristics at 3 years of age [34]. Infants later diagnosed with autism often have low attention-shifting profiles as a component of EC, but 34.1% show well-regulated profiles and 22.5% have low attention-focus profiles [25]. These findings indicate that, although there are substantial differences between autistic and non-autistic children, heterogeneity exists within both groups, highlighting the importance of individual differences. Additionally, contradictory findings exist in relation to temperamental differences. Thus, the first aim of the current study is to examine the differences in temperament between autistic and non-autistic children.

SP and Its Association with Autism

Differences in SP and interest in sensory elements such as lights or textures are among the diagnostic criteria for autism in the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) (American Psychiatric Association, [1]). Autistic children may show hyper- or hyposensitivity/reactivity to sensory stimuli, including auditory, tactile, or social stimuli [6, 36]. They also report more sensory reactivity and discomfort as measured with sensory profile scales [42, 52]. SP includes perceiving and integrating stimuli, reacting to sensory stimuli, and exhibiting neurological and behavioral responses [21, 40]. The SP characteristics of children are defined by how they respond to sensory inputs and are measured using questionnaires that provide sensory patterns or profiles of children [17, 18]. Little et al., [33] classified the sensory profiles of non-autistic and autistic children between the ages of 2 and 14 years using the Child Sensory Profile 2 (SP2) [20]. In their study, 88.6% of non-autistic children were categorized as having balanced sensory profiles, characterized by a low frequency of sensory behaviors, while only 35.1% of autistic children fell into this category. In contrast, 2% of typically developing children and 19.5% of autistic children were classified as having intense sensory profiles, characterized by high avoidance, sensitivities, registration, and seeking. Furthermore, the neurobiological basis of SP is increasingly being explored, particularly in the context of autism. Recent evidence shows that sensory characteristics are associated with atypical neural activation and connectivity in regions involved in emotion regulation, sensory integration, and attention [7, 27].

Although there are significant group differences between autistic and non-autistic children, not all autistic children fall into the same category, indicating variability within groups. This variability in SP within autism groups may even entail different physiological responses. For example, DeBoth et al., [14] identified four subtypes based on SP profiles as measured by the Short Sensory Profile Scale (SSP) [39] and found that autistic children with adaptive SP profiles showed respiratory sinus arrhythmia differences compared to autistic children with more dysfunctional SP profiles.

In the current study, the SSP [39] was used, focusing primarily on SP discomfort in children. The SSP has been widely applied for both autistic and non-autistic children, providing three profiles that indicate sensory discomfort [39]; [56]. Research using the SSP showed that, based on the total SSP score, 62.9% of autistic children aligned with the "definite difference" profile, while 18.6% exhibited the "probable difference" profile [57]. Although these profiles represent the characteristics of autistic children, they are also observed in the general population [33], and differences in sensory responses are associated with non-adaptive behaviors in both autistic and non-autistic children [13, 54].

SP and Its Association with Temperament

According to Dunn [21], differences in SP may form the basis for temperamental variances. Specifically, neurological thresholds, which determine when the nervous system is activated, and self-regulation strategies, which modulate behavioral responses, are central to SP profiles [19]. Because SP is assessed based on individuals' responses to sensory input, it aligns conceptually with aspects of temperament, particularly in terms of emotional and behavioral reactivity and regulation. Although Dunn and other researchers have proposed that differences in SP may contribute to individual differences in temperament [4, 21], the relationship between these two constructs appears to be reciprocal and developmentally intertwined. Some studies have examined temperament traits as predictors of SP characteristics [41], while others have conceptualized SP as influencing the development of temperament [12]. These varying approaches reflect ongoing theoretical debate, and findings should be interpreted as correlational rather than causal. Additionally, some degree of conceptual overlap may exist between these constructs. For example, the dimensions of the Behavior Style Questionnaire (BSQ) [38], based on the model proposed by Thomas and Chess [51], include adaptability to new stimuli, the intensity of response, or distractibility by environmental stimuli that tap SP. Brock et al., [4] showed that slowness to adapt, low reactivity, and low distractibility as measured with the BSQwere associated with sensory hyporesponsiveness in autistic children, while increased sensory features were positively associated with withdrawal and negative mood. Similarly, Chuang et al., [12] demonstrated that difficult temperamental characteristics measured by the BSQ (i.e., higher activity level and lower adaptability) were associated with SP dysfunction as reflected by sensory-seeking behaviors.

In the current study, Rothbart's temperament model is employed, which focuses more on individual differences in reactivity and self-regulation [46]. In Dunn's model, sensory responsiveness (ranging from low to high) and self-regulation strategies (ranging from active to passive) are used [16, 21], which may also reflect some temperamental characteristics. Although Dunn [21] suggested a possible association between SP and temperament, few studies have examined that relationship, particularly using the SSP, which focuses more on sensory discomfort, and findings to date have primarily entailed correlational associations. First, surgency/extraversion in the CBQ is expected to be associated with sensation seeking, while NA is proposed to be associated with sensation avoidance and sensitivity [21]. Previous findings have supported such associations, showing that sensory sensitivity was associated with changes in anxiety as measured with the Infant-Toddler Social and Emotional Assessment (ITSEA) [8] in autistic toddlers [26]. Similarly, sensory profiles associated with high frequencies of sensory under- and overresponsivity were linked to higher levels of negative emotionality and anxiety symptoms as measured with the ITSEA [3]. Finally, EC is suggested to be related to low registration due to a lack of noticing other external stimuli [21]. A study conducted with a community sample showed that increased levels of EC were associated with higher SP scores [17], indicating fewer sensory difficulties [41].

More empirical research is needed to examine the possible association between temperament and SP characteristics, particularly in autistic populations. Therefore, the current study aimed to explore this association in both autistic and non-autistic children.

Temperament, SP, and Autism

As noted above, several studies have shown that certain temperamental and SP characteristics are associated with autism [23, 34]. Additionally, increased sensory discomfort is linked to higher levels of autism characteristics [29]. However, further exploration is required to understand the joint contribution of temperament and SP to characteristics of autism, which has been the focus of few studies. For example, a recent study examined the relationship between temperament, sensory processing profiles, and autism characteristics in preterm infants [55]. The findings revealed that sensation seeking and perceptual sensitivity explained 19% of the variance in autism characteristics (social affect subscale). However, the sample of that study consisted of preterm infants rather than autistic or non-autistic children. Therefore, further research is needed to examine these associations in more representative developmental groups. Furthermore, methodological differences, including variations in scales and differences in how these scales are utilized, could potentially hinder our understanding of the associations in question. To address these gaps, the current study also aims to examine the associations among temperament, sensory discomfort, and autism characteristics in autistic children.

Aims and Hypotheses of the Current Study

- First, the temperamental characteristics of autistic and non-autistic children are compared. It is hypothesized that autistic children will have higher scores in NA and lower scores in surgency and EC than non-autistic children.
- Second, the association between temperament from Rothbart's perspective and sensory discomfort based on Dunn's model is investigated and whether this association differs across groups is also explored. Based on previous findings, it is hypothesized that sensory discomfort will exhibit a positive association with NA while showing a negative association with surgency and EC. The potential variation of these associations across groups will be exploratory.
- Third, the association of temperament, sensory discomfort, and autism characteristics in autistic children is examined. It is hypothesized that increased levels of autism characteristics will be associated with heightened sensory discomfort and NA while being associated with decreased surgency and EC.

Method

Participants

Preschool children and their mothers were recruited for an ongoing longitudinal project (Maman S'adapte Project) in Québec, Canada. Since the data were collected during the COVID-19 pandemic, parents reported whether their children had diagnoses or not. The autistic group included children with an official diagnosis or those undergoing the diagnostic process who also had at least one older autistic sibling or parent. The non-autistic group included children without autism or other developmental conditions. Additionally, having an autistic sibling or parent was an exclusion criterion for the non-autistic group. In the autistic group, some children were reported to have co-occurring conditions, including ADHD (n = 7) and epilepsy (n = 4). These cases were not excluded from the analyses, as the aim was to reflect the heterogeneity commonly observed within the autism spectrum. There were 55 children in the non-autistic group (male = 27, female = 28) and 66 children in the autistic group (male = 50, female = 16). The sample size was determined by the practical constraints of the larger longitudinal project. However, sample sizes of approximately 50 autistic children per group are common in published research with this population, as summarized in Table 1 of Mallise et al., [35], reflecting the practical challenges of recruitment in early childhood autism studies. Crosstab analysis revealed a significantly higher proportion of males in the autistic group compared to the non-autistic group [$\chi^2(1, N = 121) = 9.22, p < .01$]. The ages of the children ranged between 1.57 and 7.59 years. Participants in the autistic group (M_{age} = 4.59, SD = 1.24) were slightly older than participants in the non-autistic group (M_{age} = 4.06, SD = 1.16) ($F(1,119) = 5.98, p < .05$).

Table 1 Descriptive statistics for the variables

	Non-autistic group					Autistic group				
	n	M	SD	Min.	Max.	*n*	M	SD	Min.	Max.
SP discomfort	53	161.63	11.55	128.20	183.00	60	117.67	20.51	72.00	175.09
NA	52	3.86	0.75	2.33	5.39	63	4.19	0.90	2.61	5.74
Surgency	53	4.37	0.87	2.65	6.45	62	4.37	0.86	2.58	6.27
EC	52	5.49	0.50	4.60	6.33	63	4.30	0.66	2.79	5.78
CARS2-ST						57	31.86	5.10	20.50	43

SP discomfort = Sensory processing discomfort measured with the Short Sensory Profile Scale.

NA = Negative affectivity measured with the Children's Behavior Questionnaire.

EC = Effortful control measured with the Children's Behavior Questionnaire.

CARS2-ST = Autism characteristics measured with the Childhood Autism Rating Scale Standard Version, Second Edition.

Household income was measured with a 4-point Likert-type scale (1 = 40,000 CAD or lower per year, 2 = 41,000 to 80,000 CAD, 3 = 81,000 to 120,000 CAD, 4 = 121,000 CAD and above). Household income was slightly higher in the non-autistic group ($F(1,107) = 4.41$, $p < .05$; $M = 2.79$, SD = 0.84 and $M = 2.41$, $SD = 1.04$, respectively). The education levels of the mothers were measured using a 6-point Likert-type scale (1 = elementary education, 4 = bachelor's degree, 6 = PhD). There was no group difference in mothers' education levels (whole sample: $M = 4.14$, $SD = 1.15$) or the mothers' ages (whole sample: $M_{age} = 34.85$, $SD = 4.71$).

Measures

Temperament

The CBQ [45] as translated to French by Lemelin et al., [32] was used to measure children's temperament. Mothers answered 94 items on a 7-point Likert-type scale (1 = extremely untrue of your child, 4 = neither true nor false of your child, 7 = extremely true of your child). There are 15 subscales and three factors, the latter of which include Negative Affectivity (NA), Surgency/Extraversion, and Effortful Control (EC). Cronbach's alpha for factor scores, calculated separately for each group, ranged between 0.71 and 0.89.

Sensory Processing

The Short Sensory Profile Scale (SSP) [39] was used to measure SP discomfort in children. This scale has 38 items and seven subcategories including tactile sensitivity, taste/smell sensitivity, movement sensitivity, underresponsivity/seeking sensation, auditory filtering, low energy/weakness, and visual/auditory sensitivity. Mothers completed the items on a 5-point Likert-type scale (1 = always, 2 = frequently, 3 = occasionally, 4 = seldom, and 5 = never), with lower scores indicating higher sensory discomfort. The total score ranges between 38 and 190. With this scale, children can be categorized based on their scores as demonstrating "typical performance" (TP: scores of 155 and above), "probable difference" (PD: scores of 154 − 142), or "definite difference" (DD: scores of 141 and below). The majority of the non-autistic children were in the TP category (n = 38) in the current study, with some in the PD (n = 12) and DD (n = 3) categories. Almost all autistic children were in the DD category (n = 52), with 6 children in the PD category and 1 child in the TP category. This study evaluated the total SSP score as a continuous variable, with lower scores indicating higher SP discomfort. Cronbach's alpha for the total scale was 0.84 for the non-autistic group and 0.91 for the autistic group.

Characteristics of Autism

Autism characteristics were measured using the Childhood Autism Rating Scale Standard Version, Second Edition (CARS2-ST) [50]. This measure provides additional information about the functioning of children who have already been diagnosed with autism or are likely to be diagnosed. It assesses the duration and intensity of behaviors across 15 items, focusing on different function domains. Items are rated on a 7-point scale (1, 1.5, 2, …, 4), where 1 represents "within the age range" and 4 represents "severe for that age." The researchers conducted semi-structured phone interviews with the mothers for the current study due to pandemic conditions. Before their interviews, the mothers filled out the 39-item questionnaire (CARS-QCP) that comes with the CARS2-ST manual [50]. In addition to administering the CARS-QCP and conducting the semi-structured interview, researchers rated the child's functioning. Inter-rater reliability (ICC) was found to be 0.92 for the raters.

The total CARS2-ST score is calculated by summing the subscores, ranging from 15 to 60. A cut-off score of 30 is used to differentiate between autistic and non-autistic children [49], although lower cut-off scores, such as 25.5, have been suggested by some researchers [11]. The majority of children (85.2%) in this sample had scores of 25.50 and above, while eight children out of 54 (14.8%) had lower scores. Those children were retained in the autistic group for analysis, as the CARS2-ST was used to gather descriptive information from participants rather than serve as a diagnostic tool. The total CARS2-ST score was utilized as a continuous variable to measure the levels of autism characteristics in the current study.

Procedure

Ethical approval was obtained from the Human Research Ethics Committee of Université du Québec à Trois-Rivières (CER-18-252-07.27). Participants were recruited between 2020 and 2023 after having given their informed consent. Mothers completed the questionnaires online via the Qualtrics platform. Because of the extended duration of the data collection process, a control variable was created to control for the influence of timing since data were largely collected during the COVID-19 pandemic. This newly created variable was scored on a 4-point Likert-type scale, with higher scores indicating later time periods in the context of the pandemic (1 = from February 27, 2020, to the reopening of primary schools on January 11, 2021; 2 = January 12, 2021, to the cessation of curfews on January 17, 2022; 3 = January 18, 2022, to the conclusion of pandemic reports on October 5, 2022; and 4 = after October 5, 2022). There was a significant group difference in the timing of data collection, with data from the non-autistic group collected earlier than data from the autistic group ($F(1, 119) = 12.31$, $p < .05$; non-autistic: $M = 1.42$, $SD = 0.50$; autistic: $M = 1.89$, $SD = 0.90$).

Results

Data Screening

Data cleaning procedures including assumption checks were run separately for each group. The expectation-maximization algorithm was used to handle missing items among the responses to the scales. If all items within a subscale were missing for a participant, that subscale score was left missing and not imputed; therefore, the sample size may vary slightly across analyses for different subscales (see Table 1 for the descriptive statistics). The z-scores fell within a range of ±3.29 for the CBQ subscales and the SP discomfort score for both groups. The skewness of the scores was within an acceptable range of ±1 for both groups.

The linearity assumption was assessed with scatterplots, pp plots of residuals, and standardized residuals. Standardized residuals for the predicted values fell between −3 and +3, indicating a linear relationship. The Shapiro-Wilk test did not show significance ($p > .05$) for the three temperament dimensions (except for NA in autistic group), SP discomfort in either group, or CARS2-ST scores in the autistic group, indicating the normal distribution of the data. The Shapiro-Wilk test for NA scores in the autistic group was statistically significant ($p = .031$), but visual inspection of the histogram and Q-Q plots, as well as the skewness (-0.10 to +0.31) values, suggested no meaningful deviation from normality. Therefore, normality was also accepted for this variable. Statistical analyses were conducted using IBM SPSS Statistics 29.00.

Correlations Between Variables

To see the associations of all study variables and for descriptive purposes, bivariate correlations between the study variables were evaluated separately for each group. The findings showed that for the non-autistic group, there was a positive correlation between child age and EC and between child sex (0 = male, 1 = female) and EC. Furthermore, SP discomfort was negatively correlated with NA, indicating that higher levels of sensory discomfort are associated with higher NA scores. For the autistic group, child age was positively correlated with EC and negatively associated with the timing of the data collection and CARS2-ST score. Additionally, family income was positively correlated with SP discomfort and negatively correlated with CARS2-ST score. SP discomfort was negatively associated with NA and CARS2-ST, indicating that higher levels of SP discomfort are associated with higher NA scores and higher levels of autism characteristics. Finally, EC was negatively correlated with CARS2-ST score. Please see Table 2 for the coefficients.

Temperamental Differences Between Groups

For the first aim of the study, analysis of covariance (ANCOVA) was conducted since there were significant group differences in family household income, child age, sex distribution between groups, and data collection time. This allowed for an examination of whether there was a group difference in temperament after accounting for these covariates. For the homogeneity of variance assumption, Levene's test was applied to see whether temperament variances were equal in each group. Levene's test was not significant for NA, surgency, or EC, indicating that variances were comparable across the groups. Furthermore, the interaction terms between group and each covariate (child age, sex, family income, and data collection time) were not significant, indicating that the assumption of homogeneity of regression slopes was met for ANCOVA. For the three temperament factors (NA, surgency, and EC), three sets of ANCOVA were performed with the four specified covariates. However, since child sex and data collection time were not significant in the three models, they were dropped from the analysis to increase the degrees of freedom. The result showed no significant group difference in NA or surgency after controlling for child age and family income ($F(1,102) = 1.34$, $p = .25$[1], and $F(1,102) = 0.00$, $p = .95$, respectively). Child age was significantly associated with NA ($F(1, 102) = 5.34$, $p < .05$, partial $\eta^2 = 0.05$).

There was a significant group difference in EC after controlling for child age and family income $F(1,102) = 111.49$, $p < .001$, partial $\eta^2 = 0.52$. The non-autistic group had higher EC scores (adjusted $M = 5.52$) than the autistic group (adjusted $M = 4.30$). Child age was positively associated with EC $F(1,102) = 9.68$, $p < .01$, partial $\eta^2 = 0.09$, as was family income $F(1,102) = 4.69$, $p < .05$, partial $\eta^2 = 0.04$, with older age and higher family income being associated with higher EC scores.

Association Between Temperament and SP Discomfort Across Groups

To investigate the relationship between temperament characteristics and SP discomfort in children and to explore this association across different groups, moderation analysis was conducted with the PROCESS macro (v4.1) of Hayes

[1] Without covariates, the model was significant $F(1, 113) = 4.44$, $p < .05$; autistic children had higher NA scores than non-autistic children (see Table 1).

Table 2 Bivariate correlations between study variables

	Non-autistic group									Autistic group									
	n	1	2	3	4	5	6	7	8	*n*	1	2	3	4	5	6	7	8	9
1. Age	55	1								66	1								
2. Sex	55	0.19	1							66	−0.06	1							
3. Income	53	−0.07	0.20	1						56	0.22	0.07	1						
4. DataC	55	−0.20	−0.05	0.08	1					66	−0.33**	0.07	−0.09	1					
5. SP discomfort	53	−0.05	0.17	0.24	0.01	1				60	0.08	0.12	0.44**	−0.13	1				
6. NA	52	0.17	.27ᵃ	−0.11	−0.03	−0.45**	1			63	0.23	−0.07	−0.15	0.07	−0.35**	1			
7. Surgency	53	0.07	−0.12	0.13	0.14	−0.10	0.10	1		62	−0.07	−0.06	−0.20	0.04	−0.06	−0.07	1		
8. EC	52	0.38**	0.40**	0.21	0.05	0.08	0.12	−0.15	1	63	0.26*	−0.00	0.23	0.02	0.13	0.23	−0.22	1	
9. CARS2-ST		-	-	-	-	-	-	-	-	57	−0.30*	−0.09	−0.31*	−0.11	−0.44**	−0.06	−0.02	−0.32*	1

*$p < .05$; **$p < .01$; ᵃ$p = 0.05$.

DataC = Timing of data collection.

SP discomfort = Sensory processing discomfort measured with the Short Sensory Profile Scale.

NA = Negative affectivity measured with the Children's Behavior Questionnaire.

EC = Effortful control measured with the Children's Behavior Questionnaire.

CARS2-ST = Autism characteristics measured with the Childhood Autism Rating Scale Standard Version, Second Edition.

[28]. The group variable was included as the moderator (0 = non-autistic group, 1 = autistic group). Assumptions of the linearity of variables were met for each group. However, Levene's test was significant for SSP scores $F(1, 111) = 17.85$, $p < .001$, indicating that the variance of SP discomfort differed across groups. Therefore, moderation analyses were conducted using the HC3 robust standard errors and bootstrapping options to account for the violation of the homogeneity of the variance assumption. Four covariates were included in the models (age, sex, household income, data collection time), but non-significant covariates were dropped from the reported model and only household income was retained. Three moderation analyses were run for each temperament characteristic. The model was significant for NA, $R^2 = 0.71$, $F_{HC3}(4,101) = 64.49$, $p < .001$, surgency, $R^2 = 0.68$, $F_{HC3}(4,101) = 49.30$, $p < .001$, and EC, $R^2 = 0.68$, $F_{HC3}(4,102) = 50.64$, $p < .001$. The interaction terms (NA × group, surgency × group, and EC × group) were not significant in all models, indicating that the association between temperament and SSP scores did not change across groups. Additionally, NA was negatively associated with SSP scores ($B = -6.28$, $p < .05$, 95% CI [-10.78, -1.78]), indicating that higher NA scores were related to more sensory discomfort. Moreover, in all models, the group variable was significantly associated with SSP scores, with membership in the autistic group being negatively associated with total SSP scores ($B = -38.50$, $p < .001$, 95% CI [-44.30, -32.70]). In other words, autistic children had more sensory discomfort. Finally, household income was positively associated with SP discomfort in all models ($B = 5.67$, $p = .001$, 95% CI [2.51, 8.82], indicating lower sensory discomfort (values reported from the model for NA).

Association Between Temperament, SP Discomfort, and Characteristics of Autism

For the third aim of this study, multiple regression analysis was carried out to examine how much of the variance in autism characteristics was explained by temperament and SP discomfort. To increase the power of the model, only variables that significantly correlated with the outcome of CARS2-ST score were included. As independent variables, only EC and SP discomfort were correlated with the children's CARS2-ST scores, while child age and household income were correlated with CARS2-ST as covariates (see Table 2). The model was significant, Adj.$R^2 = 0.25$, $F(4,49) = 5.36$, $p = .001$, and only SP discomfort was negatively associated with CARS2-ST scores ($\beta = -0.38$, $p < .01$, 95% CI [-0.16, −0.03]). The model was also run after removing the non-significant covariates. Results indicated that 23% of the variance was explained by EC and SP discomfort, Adj. $R^2 = 0.23$, $F(2,51) = 9.09$, $p < .001$. Both EC

Table 3 Association between EC, SP discomfort, and autism characteristics (CARS2-ST Scores)

	B	*SE*	*β*	*t*	*p*
EC	−1.93	0.92	−0.25	−2.09	0.041
SP discomfort	−0.11	0.03	−0.41	−3.39	0.001

SP discomfort = Sensory processing discomfort measured with the Short Sensory Profile Scale.

EC = Effortful control measured with the Children's Behavior Questionnaire.

($\beta = -0.25$, $p < .05$, 95% CI [-3.79, −0.08]) and SP discomfort ($\beta = -0.41$, $p = .001$, 95% CI [-0.17, −0.04]) were negatively associated with CARS2-ST scores, indicating that lower levels of EC and greater sensory discomfort were associated with higher levels of autism characteristics (see Table 3).

Discussion

This study aims to deepen our understanding of the variability in autism. Although temperamental differences have been widely demonstrated in autism, contradictory findings remain. Furthermore, the association between temperament characteristics from Rothbart's model and the SP characteristics of children from Dunn's perspective has not been thoroughly examined. This study examined those associations across autistic and non-autistic samples to clarify previous contradictory findings and possible associations. To the best of our knowledge, this is the first study to examine associations among temperament, SP characteristics, and autism characteristics in an autistic sample.

First, in terms of temperament, as expected, it was found that autistic children had lower levels of EC than non-autistic children after controlling for child age and family income. This finding is supported by earlier research indicating that autistic children demonstrate lower attention and EC skills ([15]; [30]; [58]). A recent systematic review also reported lower EC in autistic children [35]. Contrary to our expectations, however, the groups in the current study were not differentiated by NA or surgency after controlling for child age and family income. Similar to the current findings, some previous studies did not report a group difference in terms of NA [30], while one study reported lower scores in the autistic group than in the comparison group [58]. However, the majority of studies report that autistic children have higher NA scores and lower surgency scores than non-autistic children [10, 15]. When we excluded the covariates of child age and family income from our model, a significant group difference emerged, supporting the earlier findings. This change in the results might be explained by variability in child age, as the autistic group was slightly older than the non-autistic group. Additionally, there was a positive correlation between child age and NA in the overall dataset ($r = .24$, $p < .05$), showing that age may have contributed to the group difference.

Second, the association between temperament and SP discomfort across groups was examined. The results indicated that the interaction terms of group and temperament dimensions were not significant, with the association not changing across groups. As expected, NA was associated with more SP discomfort in all children. Chuang et al., [12] also showed that SP discomfort is more prevalent in children with difficult temperament characteristics as measured with the BSQ [37] in autistic and non-autistic children, supporting our findings. Similarly, Brock et al., [4] showed that increased SP scores indicating sensory difficulties [17] were associated with increased levels of negative mood and withdrawal, while hyporesponsiveness was associated with low reactivity as measured with the BSQ [38] in autistic children. These findings corroborate the current research, suggesting that children with a temperament characterized by higher reactivity and greater NA tend to exhibit more sensory discomfort.

Contrary to our hypothesis, there was no association between surgency, EC, and SP discomfort in children. In contrast, a study of non-autistic children showed that increased levels of EC as measured with the CBQ were associated with higher SP scores [17], indicating fewer sensory difficulties [41]. Another study of autistic children concluded that sensory hyporesponsiveness as measured by SP [17] was associated with slowness to adapt as measured with the BSQ, which taps the surgency in the current study [4]. According to these results, children who can regulate themselves and who are more extroverted and social will have fewer sensory difficulties.

Besides, being in the autistic group was associated with greater sensory discomfort in this study, a result supported by previous findings [5, 23]. Since SP characteristics are an important dimension for the diagnosis of autism (American Psychiatric Association, [1]), the current findings were in line with expectations. Although there is heterogeneity in the spectrum, autistic children are found to have more differences in sensory responses compared to other developmental disabilities (see the review by [36]). For example, Baranek et al., [2] investigated SP characteristics with the Sensory Experiences Questionnaire across autistic, pervasive developmental, developmental delay, and typical groups. They discovered that the autistic group displayed the most pronounced characteristics compared to all other groups. The SSP also enables the categorization of children into categories of "typical," "probable difference," or "definite difference" in terms of sensory discomfort levels. In the current study, nearly all autistic children fell into the "definite difference" category (valid percent: 88.1%) together with only three children from the non-autistic group (valid percent: 5.7%), supporting previous findings.

Third, the association between temperament, SP discomfort, and characteristics of autism was examined in the autistic group for the first time in this study. Both bivariate correlations and the regression model revealed that lower EC scores and more sensory discomfort were associated with more autism characteristics. EC reflects a child's ability to voluntarily regulate attention, inhibit inappropriate responses, and shift focus when needed [44, 47], capacities that are more challenging for individuals with autism [22]. That is, difficulties in EC may underlie some of the behavioral manifestations of autism, such as resistance to change and challenges with emotional and behavioral regulation [48]. These traits are conceptually aligned with aspects of autism diagnostic criteria. Supporting the current findings, a recent study by Yildiz et al., [58] demonstrated that EC was negatively correlated with the levels of autism characteristics of autistic children. Moreover, Vlaeminck et al., [55] examined the role of temperament and SP characteristics (using the ITSP by [18]) of preterm infants in their autism characteristics with a longitudinal design. They showed that perceptual sensitivity, as a temperament characteristic and a subscale of EC, was positively associated with both observational and parent-reported characteristics of autism, in parallel with the current findings. Although no association was found with NA in the current study, soothability as a subscale of NA was negatively associated with parent-reported autism characteristics in the study by Vlaeminck et al., [55]. Additionally, in their study, regarding sensory processing, the low registration profile was associated with higher levels of parent-reported autism characteristics. One earlier study also showed that sensory dysfunction at both high and low ends of sensory modalities, as measured by Dunn [17], correlated with CARS scores among autistic children aged 3 to 12 years [29], corroborating the current findings.

Overall, the results of this study provide further support for previous findings and help to understand the variability within the spectrum. Additionally, considering the possibility that SP and temperament might be overlapping constructs [21], our results demonstrate an association between temperament, specifically NA, and sensory discomfort. However, NA does not fully explain the variability in SSP scores, indicating divergent constructs. Sensory discomfort and EC accounted for 23% of the variance in CARS2-ST scores, leaving a substantial portion to be elucidated by future studies. Nevertheless, EC and sensory discomfort together accounted for a meaningful proportion of the variance in autism characteristics. This suggests that regulatory capacities and SP characteristics may play a compounding role in how autism manifests in everyday functioning.

From a clinical perspective, these results highlight the importance of incorporating temperament and SP characteristics into early screening and assessment frameworks. Identifying children who exhibit elevated sensory discomfort and lower EC (regardless of diagnostic status) may support more rapid recognition of children with more complex behavioral presentations. This information could also inform intervention planning, particularly by focusing on sensory modulation difficulties and self-regulation. These findings may be valuable for families as well, helping caregivers to better understand and respond to their children's needs in everyday environments.

Strengths and Limitations

The current study provides valuable insights into individual differences in autistic and non-autistic children by examining several aspects including temperament, SP, and characteristics of autism. However, this study has some limitations. First, the sample size was not determined through an a priori power analysis; rather, it was based on practical considerations of a longitudinal project. Although the current sample is likely sufficient to detect medium- to large-sized effects, it may not provide adequate power to detect small effects. Effect sizes were reported throughout the Results section to aid in interpretation. Second, all scales were scored by mothers, which may have led to biased answers. Although the CARS2-ST is designed as an observational measure, in this study it was completed by a researcher based on structured phone interviews with mothers. Third, diagnostic classifications relied on parental reports rather than clinical screening. Due to pandemic-related constraints at the time of data collection, in-person assessments or clinician-led screenings were not feasible. Additionally, the timing of data collection varied over a relatively long period, but to control for this, a control variable was included in the analysis. Finally, despite being recommended for children aged 3 and older [45], the CBQ was also administered to younger participants in this study to maintain consistency across assessments.

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vee@uqtr.ca) and AM played roles in coordinating the main project and data collection. All authors contributed either during the main project design or through conceptual input to the current paper. Additionally, all authors provided feedback on previous versions and approved the final version of the current paper.

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Declarations

Competing interests The authors declare no competing interests.

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