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Relationships Between Sensory Processing, Temperament Characteristics for Effortful Control, and Executive Function in School-Age Children

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Abstract

Background: Sensory processing behaviors, the temperament characteristic for effortful control, and executive function promote self-regulation, activity engagement, and problem-solving. This study examined inter-relationships between executive function, effortful control, and sensory processing in school-aged children between 7 and 10.11 years of age.

Method: Descriptive correlation research design was used to examine relationships of outcomes from three caregiver-reported, standardized questionnaires of behaviors related to sensory processing (*Sensory Profile-2*), effortful control (*Temperament in Middle Childhood Questionnaire*) and executive function (*Behavior Rating Inventory of Executive Function-2*) in daily activities (N = 19).

Results: Data analysis using descriptive statistics and Spearman's *R* revealed statistically significant (*p*-value < .05) positive and negative correlations between constructs of executive function, effortful control, and sensory processing behaviors. Only positive correlations were found between sensory processing behaviors and executive function.

Conclusion: Findings indicate that typical responses to sensory experiences were related to typical abilities for executive function and effortful control, whereas increased sensory reactivity was associated with decreased abilities for executive function and effortful control along with an increased expression of impulsivity, reduced attention, and decreased on-task behavior. Outcomes support the need to address sensory responsiveness and reactivity in the context to support behavior management for effortful control and executive function.

Comments

The authors declare that they have no competing financial, professional, or personal interest that might have influenced the performance or presentation of the work described in this manuscript.

Keywords

attention/focus, behavioral inhibition, self-regulation, sensory

Cover Page Footnote

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Sensory processing behaviors have been identified as a factor in self-regulation and emotional development in children (Critz et al., 2015; Dunn, 2007; Miller et al., 2007). Temperament and executive function have been identified as neurological factors in behavioral styles, self-regulation, and social-emotional development in children (Dixon et al., 2006; Edossa et al., 2018; Gioia et al., 2015; Henderson & Wachs, 2007; Janson & Mathiesen, 2008; Rothbart & Bates, 2006). Research regarding the relationships between temperament and sensory processing behaviors indicates that descriptive features of temperament and descriptive features of sensory processing behaviors are interrelated (DeSantis et al., 2011; Diamant, 2011; Gouze et al., 2012). Findings show that extreme behavioral reactivity toward sensory experiences can play a role in the development of behavioral issues in children (DeSantis et al., 2011; Gouze et al., 2012). Children with diagnostic conditions, such as autism, attention deficit disorder, and reactive attachment disorder, often demonstrate issues with behavioral self-regulation and executive functions (Critz et al., 2015; Diamond, 2013). Thus, the ability to identify factors that influence behavioral self-regulation in children is a critical component in intervention planning and positive outcomes regarding behavior management and activity engagement.

Behavioral Self-Regulation

Behavioral self-regulation is a construct that encompasses one's ability to actively or passively engage and respond to the demands of tasks and the physical and/or social environments (Dunn, 2007). Individuals adjust their emotions, cognition, and behavior according to internal (i.e., body responses) and external demands (i.e., contextual experiences) (McClelland et al., 2010). A child's ability to adjust emotions and behavior is a developmental process that emerges through daily experiences and cultural/social expectations. Self-regulatory skills are crucial in early development and throughout the lifespan and can have an influence on behavioral management and academic success (Caughy et al., 2018). Several factors influence behavioral self-regulation, including brain and physiological maturation, parenting styles, peer socialization, and contextual demands (Edossa et al., 2018; McClelland et al., 2010; Rothbart & Bates, 2006).

Temperament and Effortful Control

Temperament is a compilation of behavior characteristics in a continuum and describes how an individual may approach or interact within his or her context (Institute for Learning & Brain Sciences, 2016; Rothbart & Bates, 2006; Zentner & Bates, 2008). Temperament characteristics include behavioral responses to fear, anger and frustration, positive affect and approach, activity level, inhibition, and attention that relate to capacities that form individual differences in personality (Rothbart & Bates, 2006). Theories of temperament indicate that differences in emotionality, activity level, and attention are based on brain systems that shape a child's behavioral reactivity and self-regulation (Institute for Learning & Brain Sciences, 2016; Rothbart & Bates, 2006; Zentner & Bates, 2008).

Effortful control is a temperament characteristic defined by the ability to modulate responses, plan, focus, and regulate emotions and actions through behavioral inhibition (Diamond, 2013; Simonds & Rothbart, 2004). For example, according to Rothbart and Bates (2006), children with strong abilities for effortful control can put off a desired activity, wait for a desired activity, or complete a less desirable activity before starting a more desirable activity. Other children with fewer abilities for effortful control might be more impulsive, more distracted, less attentive and/or have issues with task completion (Rothbart & Bates, 2006). Thus, attentional control and inhibitory control are key components of effortful control (Zentner & Bates, 2008).

Executive Function

Executive function is the neurological ability to direct or manage cognitive, emotional, and behavioral functions to problem-solve. It involves three core abilities: inhibitory control, working memory, and cognitive flexibility (Diamond, 2013). Inhibitory control allows an individual to control impulses and respond appropriately to the situation. Working memory is the ability to use stored information for application in an appropriate situation at a later time (Diamond, 2013). Cognitive flexibility allows for adaptive thinking, taking responsibility for actions, and accepting unexpected challenges (Diamond, 2013).

Sensory Processing

Sensory processing is the ability to receive and detect sensory input through the nervous system and modulate, integrate, organize, and interpret the information to create a response (Dunn, 2001; Dunn, 2007). These responses can occur differently between individuals and conditions and influence mood, temperament, activity choices, and participation (Dunn, 2001; Dunn, 2007). The Model of Sensory Processing describes sensory-based behavioral responses routinely experienced in everyday activities (Dunn, 2001; Dunn, 2007). This model identifies four sensory processing behavior patterns that describe the style of behavior responses or reactivity to routine sensory experiences (Dunn, 2007, 2014). These sensory processing behavior patterns are:

- **Sensory Registration**. Sensory registration (e.g., high sensory neurological threshold and passive self-regulatory behavior responses) is passive self-regulation behavior in which the individual may not notice sensory cues that others can attend to easily (Dunn, 2014).
- **Sensory Seeking**. Sensory seeking (e.g., high sensory neurological threshold and active self-regulatory behavior responses) is an active self-regulation behavioral strategy with which the individual is driven to increase engagement in sensory experiences (Dunn, 2014).
- **Sensory Sensitivity**. Sensory sensitivity (e.g., low sensory neurological threshold and passive self-regulatory behavior responses) is a passive self-regulation behavior strategy with which the individual attends or responds quickly to sensory experiences (Dunn, 2014).
- **Sensory Avoiding**. Sensory avoiding (e.g., low sensory neurological threshold and active self-regulatory behavior responses) is an active self-regulation behavioral strategy with which the individual becomes anxious or bothered by sensory experiences and may be driven to avoid sensory experiences (Dunn, 2014).

Literature Review

Research has shown that low sensory neurological threshold responses (i.e., increased reactivity to sensory experiences) can be related to an inability to pay attention and can result in higher distractibility (Bundy et al., 2007; Chien et al., 2016). Generally, children with high sensory neurological thresholds (i.e., reduced reactivity to sensory experiences) respond to fewer stimuli than children with low sensory thresholds (Dunn, 2014).

Research suggests that relationships exist between sensory behavioral reactivity, effortful control, and behavioral self-regulation among children, especially those with challenges in inhibitory control (Diamant, 2011; Gouze et al., 2012). Since inhibitory control is a component of executive function (Diamond, 2013), the temperament characteristic of effortful control has the potential to support executive function through the facilitation of attention, focus, and inhibitory control (Johnson, 2012; Nakagawa et al., 2016). Supportive environments and parenting strategies for children with negative emotionality in temperament and fearfulness have been found to encourage the development of successful socialization

(Kochanska et al., 2007). Understanding the relationships between sensory processing behaviors, the temperament characteristic of effortful control, and abilities related to executive function may allow for the development of supportive strategies that promote self-regulation, successful activity engagement, and problem-solving. These supportive strategies could include management of the sensory attributes of the context to promote successful task participation, engagement, and completion of daily occupations for children.

Purpose of the Study

This study's purpose was to examine the extent to which relationships exist between the temperament characteristic of effortful control, executive function, and descriptive features of sensory processing behaviors in school-aged children between 7.0 and 10.11 years of age. This study hypothesized that statistically significant relationships exist between sensory processing behaviors, executive function, and the temperament characteristic of effortful control in school-aged children between 7.0 and 10.11 years of age when physiological factors that may influence the reception of sensory input are minimized.

Method

This study's research design used a non-experimental, descriptive correlation format to examine the relationships between the parameters under investigation (i.e., temperament effortful control, executive function, and sensory processing behaviors). The A. T. Still University Institutional Review Board approved this study in May 2018.

Participants

Participants were parents or primary caregivers of school-aged children between 7.0 and 10.11 years of age. Criteria for inclusion were: healthy adults; 19 years of age or older; does not take medications that may impact the responses on the questionnaires; are the primary caregiver of a healthy child between 7.0 and 10.11 years of age; and has no history of un-correctable sensory-neural hearing loss, un-correctable visual impairment, or a medical condition that would require the regular use of medications that may influence behavior. Data from parents, primary caregivers, or their children who do not meet the inclusion criteria were excluded. Participants were recruited through the use of flyers and snowball sampling.

Instruments

Three standardized questionnaires were used to collect data regarding effortful control, executive function, and sensory processing behaviors.

Temperament in Middle Childhood Questionnaire

The temperament characteristic of effortful control was measured by the Temperament in Middle Childhood Questionnaire (version 3.0) (TMCQ), a parent-report, standardized 157-item questionnaire for children between 7.0 and 10.11 years of age (Simonds & Rothbart, 2004). Responses to the TMCQ reflect the child's temperament behavior in relation to everyday situations. Studies of psychometric properties report adequate internal consistency ($\alpha > .70$) for all temperament subscales, with the exception of activation control ($\alpha = 0.64$) and supported convergent validity (Kotelnikova et al., 2016; Nystrom & Bengtsson, 2017).

Factor analysis of the 16 subcategories of temperament characteristics of the TMCQ resulted in four major factors labeled as negative affect, effortful control, surgency, and sociability. Temperament subcategories of the TMCQ that compile the major factor of effortful control were attention/focusing, inhibitory control, low-intensity pleasure, perceptual sensitivity, and activation control.

The participants rated their child's behavior on a 5-point Likert scale. Scaled scores are created for each subcategory and major temperament characteristic. Scores that approach five indicate a higher expression of that temperament characteristic.

Behavior Rating Inventory of Executive Function-2®

The Behavior Rating Inventory of Executive Function®, second edition (BRIEF®2), a parent-report, standardized, 63-item questionnaire for children between 5 and 18 years of age (Gioia et al., 2015), was used to assess executive function in relation to everyday situations. Reports of internal consistency of all the subtests were within acceptable ranges ($\alpha > .80$), as was test-retest reliability (> 0.82). Concurrent validity studies indicate that the BRIEF®2 can demonstrate significant differences between children with attention-deficit hyperactivity disorder (ADHD) and a control group of typically developing children. The BRIEF®2 demonstrates strong construct validity with other tools of executive function.

Nine subcategories and three major indexes of executive function behaviors are measured by the BRIEF®2 (see Appendix A). The participants rate their child's behavior as never, sometimes, or often. Responses are numerically coded and converted to raw scores and T-scores. Higher scores (i.e., T-scores of 70 or above) indicate dysfunctional abilities in that category of executive function, whereas lower scores (i.e., T-scores of 60 or below) indicate typical abilities in the described category of executive function.

Sensory Profile-2

The Sensory Profile-2 (SP-2) (Dunn, 2014), an 86-item, parent-report standardized questionnaire for children between 3 and 14.11 years of age, was used to describe the style of behavior reactivity to sensory experiences routinely experienced in everyday activities. Internal consistency, test-retest reliability, and inter-rater reliability of the SP-2 are within acceptable ranges. Validity studies indicate that significant differences exist in sensory-based behaviors between typically developing matched peers and diagnostic groups of children with ADHD, autism, or dual diagnosis of ADHD and autism (Dunn, 2014).

The SP-2 describes sensory-based behaviors as four major quadrant factors (i.e., sensory registration, sensory seeking, sensory sensitivity, and sensory avoiding) and nine sensory-behavioral subtests. Scores can be interpreted as sensory-based behaviors that are "just like the majority of others," "more or much more than others," and "less or much less than others." Higher scores indicate sensory-based behaviors that are "more or much more than others."

Data Collection and Analysis

The participants completed a packet of three standardized questionnaires and returned packets to the researchers by mail in a pre addressed, stamped envelope. Descriptive statistics and Spearman's *R* correlation were used to analyze relationships between effortful control, executive function, and sensory-processing behaviors using the data from the standardized questionnaires. SPSS ver. 23 (IBM Corp, Armonk, NY) statistical package was used to analyze the data. A *p*-value of $\leq .05$ was used to test for significance.

Results

Thirty-seven packets were delivered to potential participants. Twenty-three packets were returned, and of those 23 packets, 19 were usable, leaving a sample size of N = 19 and an overall response rate of 51%.

Participants

The children in the sample were the following ages: 7 to 7.11 = five; 8 to 8.11 = seven; 9 to 9.11 = four; 10 to 10.11 = three. They were enrolled in the following grade levels: 1st = one; 2nd = eight; 3rd = four; 4th = four; 5th = two). Thirteen of the children in the sample were male (68%), and six were female

(32%). Thirteen of the children in the sample were white (68%), and six were Hispanic (32%). The caregivers in the sample were the following ages: 19 to 29 = two; 30 to 39 = eight; 40 to 49 = eight; 50 to 59 = one. Nine of the caregivers had education beyond the baccalaureate level; seven had 4 years of college, while one caregiver had each, some high school, some college, or community college. Eleven of the caregivers reported income greater than $75,000, while seven of the caregivers reported incomes between $40,000 and $60,000. One caregiver reported an income between $60,000 and $75,000.

The descriptive characteristics of each assessment measure indicated that all components of the SP-2 were found to score in the range of "just like the majority of others." The participants' mean scores for the BRIEF®2 all fell in the "typical function" range with the exception of the Global Executive Composite Index, whose mean score indicated a "clinically significant difference." The total mean scaled score for all 20 components of the TMCQ was 3.24 on a scale of 1 to 5. Scores that fall closer to five indicate a stronger behavioral influence of that particular temperament characteristic. See Appendix A and B for information about descriptive outcomes from assessment measures.

Higher raw scores for the SP-2 equate to the presence of behavior responses that are more than or much more than others, which indicates increased reactivity to sensory experiences. Mid-range raw scores on the SP-2 can equate to typical responses to stimuli, while raw scores that are very low indicate behavior responses that are less than or much less than others (i.e., decreased reactivity). The BRIEF®2 measures areas of executive function associated with executive function in relation to everyday situations that involve behavioral regulation, emotional regulation, and cognitive regulation. Higher scores for the BRIEF®2 indicate increased dysfunction in the specific area of executive function, whereas lower scores indicate typical executive function. The TMCQ measures temperament behavior in the constructs of negative affect, effortful control, surgency, and sociability. Higher scores for the TMCQ indicate increased behavioral expression of the specific temperament characteristic. Examination of effortful control in relation to sensory-based behaviors and executive function was the primary focus of the correlation analyses.

Results of Correlation Analysis

Spearman's R correlation statistical analyses were used to examine the extent to which statistically significant relationships existed between effortful control and subcategories, the four main categories for sensory-processing behaviors and subcategories, and the major composite categories for executive function and subcategories. Statistically significant positive and negative correlations at or less than a *p*-value of $\leq .05$ were found.

Statistically significant positive correlations were found between the BRIEF®2 and SP-2 main categories and subcategories. These positive correlations indicate that high scores for the BRIEF®2 (i.e., greater dysfunction) are associated with higher scores on the SP-2, which indicate a more reactive sensory response (i.e., "more than or much more than others"). Whereas low scores for the BRIEF®2 indicate typical behavioral abilities for executive function and are associated with lower scores on the SP-2, which indicate less sensory reactivity. Of note, only statistically significant positive correlations were found between the BRIEF®2 and the SP-2; no negative correlations were found. Table 1 displays the statistically significant positive correlations at $p \leq .05$ between the SP-2 sensory sensitivity and BRIEF®2 Behavioral Regulation Index, Emotional Regulation Index, Global Executive Composite Regulation, and positive correlations between the SP-2 sensory seeker and BRIEF®2 Behavioral Regulation Index, and the SP-2 sensory registration and the BRIEF®2 Cognitive Regulation Index.

Table 1

Correlations using Spearman's R Between the Main Quadrants from the Behavior Rating Inventory of Executive Function (BRIEF®2) and the Main Quadrants from the Sensory Profile-2 (SP-2) (N = *19*)

	BRIEF®2: Behavioral Regulation Index (BRI)	BRIEF®2: Emotional Regulation Index (ERI)	BRIEF®2: Cognitive Regulation Index (CRI)	BRIEF®2: Global Executive Composite Regulation Index (GEC)
SP-2: Sensory Seeker	.538*	0.089	0.222	0.445
SP-2: Sensory Avoider	0.336	0.393	0.054	0.331
SP-2: Sensory Sensitivity	.537*	.534*	0.219	.533*
SP-2: Sensory Registration	0.375	-0.013	.531*	0.405

*Correlation is significant at the 0.05 level (2-tailed).

As illustrated in Table 2, statistically significant negative correlations at $p \leq .05$ were found between TMCQ effortful control and the main categories BRIEF®2. These findings suggest that a strong presence for the temperament ability for effortful control (i.e., higher scores on the TMCQ) is related to typical skills for executive function (i.e., lower scores that indicate typical executive function according to the BRIEF®2). Conversely, the reduced ability for effortful control is associated with challenges in executive function. Statistically significant negative correlations at $p \leq .05$ were also found between TMCQ effortful control and the sensory behavior of sensory seekers. This finding suggests that a reduced ability for effortful control (i.e., lower scores on the TMCQ) is associated with increased sensory-seeking behaviors that are "more or much more than others," whereas a strong presence of temperament effortful control (i.e., higher scores on the TMCQ) is related to the expression of sensory seeking behaviors that are "just like" or "less than" others.

Table 2

Correlations using Spearman's R Between the Main Variables for Temperament in Middle Childhood Questionnaire (TMCQ) and the Main Quadrants from the Sensory Profile-2 (SP-2) and the Main Quadrants from the Behavior Rating Inventory of Executive Function (BRIEF®2) (N = *19*)

	TMCQ Surgency	TMCQ Effortful Control	TMCQ Negative Affect
SP-2: Sensory Seeker	0.119	-.504*	0.104
SP-2: Sensory Avoider	0.160	-0.318	0.256
SP-2: Sensory Sensitivity	0.094	-0.345	-0.078
SP-2: Sensory Registration	0.257	-0.221	-0.072
BRIEF®2: Behavioral Regulation Index (BRI)	0.297	-0.294	-0.223
BRIEF®2: Emotional Regulation Index (ERI)	0.125	-0.040	0.449
BRIEF®2: Cognitive Regulation Index (CRI)	0.382	-.511*	-0.200
BRIEF®2: Global Executive Composite Regulation Index (GEC)	0.393	-.551*	-0.123

*Correlation is significant at the 0.05 level (2-tailed).

Table 3 presents the correlations between the BRIEF®2 executive function subcategories and the SP-2 sensory processing subcategories. Results demonstrated statistically significant positive correlations at $p \leq .05$, especially between auditory, movement and conduct subcategories on the SP-2 and the inhibit, self-monitor, emotional control and initiate subcategories on the BRIEF®2. Again, no significant negative correlations were found between the BRIEF®2 executive function subcategories and the SP-2 sensory processing subcategories.

Table 3

Correlations using Spearman's R between the Subcategories for the Behavior Rating Inventory of Executive Function (BRIEF) and the Subcategories from the Sensory Profile-2 (SP-2) (N = *19*)

	BRIEF®2: Inhibit	BRIEF®2: Self-Monitor	BRIEF®2: Shift	BRIEF®2: Emotional control	BRIEF®2: Initiate
SP-2: Auditory	.589**	.599**	0.245	0.072	0.313
SP-2: Visual	0.079	0.095	0.285	0.222	0.079
SP-2: Touch	0.348	0.349	-0.065	-0.326	0.022
SP-2: Movement	0.333	.536*	0.073	-0.105	.477*
SP-2: Body Position	0.196	0.240	-0.065	0.218	0.196
SP-2: Oral	0.186	0.133	-0.040	-0.386	-0.200
SP-2: Conduct	.506*	.460*	0.237	0.380	0.381
SP-2: Social Emotional	-0.036	0.151	0.294	.683*	0.077
SP-2: Attention	.509*	.465*	0.254	0.389	0.375

*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).

Analysis between the subcategories for the TMCQ and the SP-2 found both statistically significant positive and negative correlations at $p \leq .05$ (see Table 4). The significant positive correlations were found between the TMCQ subcategory of impulsivity and the SP-2 subcategories of movement, conduct, and attention, which indicates that a greater tendency towards impulsive behavior is associated with "more or much more than others" for reactivity toward vestibular experiences, and sensory-based issues in behavioral conduct and inattention. Also noteworthy were the negative correlations between the Auditory subcategory on the SP-2 and the TMCQ subcategories of fantasy/openness, inhibitory control, and perceptual sensitivity, which infers that greater ability to regulate auditory sensory experiences is related to increased expression of inhibitory control and perceptual awareness.

Table 4

Correlations using Spearman's R Between the Subcategories for the TMCQ and the Subcategories from the SP-2 (N = *19*)

	SP-2: Auditory	SP-2: Visual	SP-2: Touch	SP-2: Movement	SP-2: Body Position	SP-2: Oral	SP-2: Conduct	SP-2: Social Emotional	SP-2: Attention
TMCQ- Activation Control	-.349	.282	-.043	-.375	.000	-.013	-0.157	-.305	-.175
TMCQ- Activity Level	.015	-.472*	-.130	.151	-.346	-.026	0.220	-.167	.220
TMCQ- Affiliation	-.543*	-.094	.173	-.105	-.389	.106	-0.189	-.480*	-.205
TMCQ- Anger & Frustration	.135	.283	-.324	-.063	.086	-.211	0.283	.367	.290
TMCQ- Assertive-Dominance	.120	.110	-.195	-.046	.216	-.013	0.267	-.012	.283
TMCQ- Attention Focusing	-.229	-.345	-.151	-.263	-.065	.303	-0.298	.052	-.287
TMCQ- Discomfort	-.150	.376	-.280	.201	-.216	-.224	.408	.497*	.415
TMCQ- Fantasy-Openness	-.543*	-.157	-.130	-.166	-.345	.132	-.157	-.17	-.178
TMCQ- Fear	-.224	-.157	-.259	-.119	-.302	-.158	.016	.275	.013
TMCQ- High-Intensity Pleasure	.059	.078	.345	-.126	.086	-.040	.282	-.068	.285
TMCQ- Impulsive	.402	.298	.301	.518*	.129	-.066	.470*	-.174	.474*
TMCQ- Inhibitory Control	-.545*	-.157	-.259	-.284	-.216	.053	-.188	.034	-.208
TMCQ- Low-Intensity Pleasure	-.332	-.125	.280	-.295	-.215	.488*	-.219	.016	-.237
TMCQ- Perceptual Sensitivity	-.673**	.000	.151	-.588**	-.151	.277	-.157	-.203	-.176
TMCQ- Sadness	-.118	.047	-.216	-.202	-.086	-.132	.220	.633**	.220
TMCQ- Shyness	-.043	.000	.130	-.338	.281	-.119	-.031	.364	-.040
TMCQ- Sooth-ability & Falling Reactivity	.080	-.219	.086	0.013	-.108	.277	-.282	-.580**	-.293

*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).

Analysis between the subcategories for the TMCQ and the BRIEF®2 found both statistically significant positive and negative correlations at $p \leq .05$ (see Table 5). Several significant negative correlations were found between the subcategory of attention/focusing on the TMCQ and the BRIEF®2 subcategories of initiate, working memory, plan/organize, task-monitor, and organization of materials, which indicates that increased ability to attend/focus (i.e., higher scores on the TMCQ) is associated with typical executive function (i.e., lower scores on the BRIEF®2). Of interest is that statistically significant positive correlations were found between the BRIEF®2 subcategory of inhibit and the TMCQ subcategories of high-intensity pleasure and impulsivity, as well as between the TMCQ subcategories of anger/frustration, assertiveness/dominance, high-intensity pleasure, impulsivity, discomfort, sadness and shyness and the BRIEF®2 subcategories of shift, emotional control and inhibit. These findings indicate that increased expressions of these temperament subcategory traits (i.e., higher scores on the TMCQ) are associated with atypical executive function abilities to shift attention, self-inhibit, and emotional self-control (i.e., higher scores that indicate dysfunction according to the BRIEF®2).

Table 5

Correlations using Spearman's R Between the Subcategories for TMCQ and the Subcategories Categories for the BRIEF® (N = *19*)

	BRIEF®2 Inhibit	BRIEF®2 Self-Monitor	BRIEF®2 Shift	BRIEF® 2: Emotional Control	BRIEF®2: Initiate	BRIEF®2: Working Memory	BRIEF®2: Plan & Organize	BRIEF®2: Task Monitor	BRIEF®2: Organization of Materials
TMCQ Activation Control	-.106	-.363	-.280	-.294	-.518*	-.080	-.471*	-.006	.081
TMCQ-Activity Level	.264	.080	-.057	-.268	.248	.144	.137	.396	.110
TMCQ Affiliation	-.096	-.439	-.240	-.434	-.296	-.015	-.218	-.146	-.002
TMCQ Anger & Frustration	-.094	-.037	.759**	.684**	.151	-.100	.117	.053	-.038
TMCQ Assertive-Dominance	.194	-.187	.474*	.354	-.318	-.258	-.133	.000	.147
TMCQ Attention Focusing	-.401	-.205	-.035	.129	-.662**	-.732**	-.692**	-.520*	-.460*
MCQ Discomfort	-.162	-.101	.558*	.637**	-.038	-.334	.030	-.273	-.246
TMCQ Fantasy-Openness	-.528*	-.573*	-.356	-.320	-.337	-.273	-.492*	-.251	-.286
TMCQ Fear	-.459*	-.386	.287	.338	-.221	-.563*	-.257	-.265	-.502*
TMCQ High-Intensity Pleasure	.459*	.032	-.113	-.145	.099	.226	.283	.245	.416
TMCQ Impulsive	.459*	.032	-.113	-.145	.099	.226	.283	.245	.416
TMCQ Inhibitory Control	-.654**	-.557*	-.248	-.045	-.362	-.362	-.624**	-.293	-.470*
TMCQ Low-Intensity Pleasure	-.272	-.113	.004	-.045	-.367	-.218	-.524*	-.374	-.414
TMCQ Perceptual Sensitivity	-.183	-.406	.110	.036	-.349	-.080	-.488*	-.277	-.030
TMCQ Sadness	-.254	-.031	.603**	.833**	.044	-.301	.051	-.268	-.276
TMCQ Shyness	-.244	-.015	.224	.555*	.066	-.145	-.019	-.132	-.229
TMCQ Sooth-ability & Falling Reactivity	.124	-.063	-.481*	-.791**	-.180	.214	-.195	.297	.184

*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).

Discussion

Various positive and negative correlations were identified between the main categories and subcategories from the BRIEF®2, TMCQ, and SP-2, and indicate that behaviors related to effortful control, sensory processing, and executive function are interrelated. Interpretation of positive correlations suggests that increased behavioral reactivity to sensory input is related to greater issues and dysfunction in executive function, whereas more typical reactions to sensory input are related to more typical executive function. For example, the positive correlation between the sensory seeker category on the SP-2 and the Behavioral Regulation Index on the BRIEF®2 indicates that the demonstration of increased sensory-seeking behaviors is associated with increased challenges in executive function for behavioral regulation. Conversely, typical sensory-seeking behaviors are associated with executive function for typical behavioral regulation. Positive correlations between the BRIEF®2 Cognitive Regulation Index and the SP-2 sensory registration category suggest that the ability to problem solve, learn, and recall complex information is associated with the ability to attend to sensory cues in the environment appropriately. These findings are supported by prior research that explored relationships between temperament, sensory reactivity, and behavioral regulation in activity engagement (DeSantis et al., 2011; Gouze et al., 2012).

Of note, significant positive correlations exist between auditory, movement, and conduct subcategories on the SP-2 and the inhibit, self-monitor, emotional control, and initiate subcategories on the BRIEF®2. These outcomes indicate that less reactive responses to auditory, vestibular, and sensory-related emotional conduct are more likely to be associated with typical executive function for the abilities to inhibit and/or initiate one's behavior and self-monitor/control one's emotions, whereas more reactive sensory responses in these areas are related to more dysfunctional abilities for these executive functions.

Positive correlations were found between the TMCQ subcategory of impulsivity and the SP-2 subcategories of movement, conduct, and attention, which indicate that stronger tendencies toward impulsivity are associated with increased sensory reactivity to vestibular input and sensory-based responses that impact conduct and attention. Conversely, reduced tendencies toward impulsive temperament behavior are associated with typical or less reactive sensory responses to vestibular input, conduct, and attention. Because reduced tendencies toward impulsive temperament behavior are a component of effortful control and abilities for behavioral self-regulation, the ability to demonstrate less reactive sensory responses may support abilities for effortful control. Considering prior research that relates the role of low abilities for effortful control and decreased self-regulation with social-emotional issues in childhood (Nigg, 2017; Zentner et al., 2021), the associations between sensory-based behaviors and effortful control warrant further evaluation. For instance, the role of sensory-based behaviors may have played a part in the outcomes of research by Kochanska et al. (2007) that reported the positive impact of supportive environments on the development of successful socialization in children.

Statistically significant negative correlations were found between the TMCQ subcategories of affiliation, activity level, fantasy/openness, inhibitory control, perceptual sensitivity, and soothability/falling reactivity and the SP-2 subcategories of auditory, movement, visual, and social-emotional sensory reactivity. These findings suggest that increased reactivity toward visual, vestibular, auditory input, and social-emotional sensory reactivity are associated with a reduced ability for temperament inhibitory control, perceptual sensitivity, and reduced ability to self-soothe, which are all components for effortful control. Similarly, negative correlations were found between subcategories on the BRIEF®2 for task initiation, working memory, task planning/organizing, monitoring, organization of material, inhibition, shift, and emotional control, and the TMCQ subcategories for activation control,

attention focusing, fantasy/openness, fear, inhibitory control, soothing/falling reactivity, low-intensity pleasure, and perceptual sensitivity. These findings suggest that typical executive functions for task organization, planning, initiation, attention shifting, and working memory are associated with a stronger expression of temperament abilities related to attention, inhibitory control, and activity focus (i.e., effortful control). This finding is supported by outcomes of research that reported relationships between emotional and behavioral self-regulation and educational achievement in school-aged children (Edossa et al., 2018) and outcomes of cognitive and self-regulatory abilities during adolescence (Zentner & Bates, 2008). Again, the inter-relationships between effortful control and executive function that could be influenced by sensory-based behaviors need to be considered.

Finally, statistically significant negative correlations between the auditory subcategory on the SP-2 and the TMCQ subcategories of inhibitory control and perceptual sensitivity (components of effortful control) suggest that reactivity toward auditory input is related to effortful control. One can infer the ability to process auditory information without being over-reactive is associated with the ability to effectively process information, regulate emotions, concentrate, and problem-solve without being distracted by auditory input. Zentner and Bates (2008) report that sensory sensitivity, especially tactile, visual, and auditory sensitivity, is a dimension of temperament that warrants more research. The outcomes of this study support the need to consider the influence of sensory-based behaviors as they relate to effortful control and executive function.

Limitations

Although the assessments were all standardized, the potential for self-report bias could be a limitation. Perhaps the ability to interview participants during data collection would reduce the possibility of self-report bias or possible misinterpretation of assessment questions and could have yielded a larger sample size.

Conclusion

Relationships exist between sensory processing behaviors, temperament characteristics for effortful control, and executive functioning. Findings indicate that increased sensory reactivity is related to greater issues/dysfunction in executive function and effortful control, whereas more typical responses to sensory experiences are related to more typical abilities for executive function and stronger behavioral self-regulation abilities for effortful control.

Addressing sensory responsiveness/reactivity in the context may support behavior management for effortful control and executive function.

Occupational therapists are able to design strategies that support an individual's ability for task engagement and participation. Outcomes from this study promote the awareness of the interrelationships between effortful control, sensory processing behaviors, executive function, and the potential for the use of sensory strategies as a support for behavioral self-regulation that fosters executive function. Temperament-based intervention (i.e., awareness of temperament styles and contextual goodness of fit) in the context of parenting and school environments can support children who are challenged by decreased behavioral inhibition and inattentiveness (McClowry et al., 2008; Zentner & Bates, 2008). By evaluating a child's sensory-based responses and the sensory attributes of the context, occupational therapists can supplement temperament-based intervention strategies. For example, a child who is easily distracted and agitated by auditory stimuli in a noisy environment may be able to improve effortful control to focus on executive function for task completion through the use of headphones. Or, a child who seeks tactile and vestibular sensory experiences to the point of distraction or impulsivity may present with improved

attention and self-regulation when provided with context-appropriate opportunities for extra tactile and movement experiences (i.e., appropriate tactile fidget toys or an inflatable seat cushion for extra vestibular input while seated at a desk). Future studies could address the effectiveness of supportive sensory strategies in the behavioral management of self-regulation and executive function.

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Appendix A

Descriptive Characteristics of Participants on the Sensory Profile-2 (SP-2) and the Behavior Rating Inventory Executive Function-2 (BRIEF2®) (N = *19*)

Assessment Characteristics	Mean (Raw Scores)	Standard Deviation	Score Interpretation
SP-2 Sensory Seeker Quadrant	32.45	+/-8.00	Just like the majority of others
SP-2 Sensory Avoiding Quadrant	37.47	+/-14.21	Just like the majority of others
SP-2 Sensory Sensitivity Quadrant	32.26	+/-8.44	Just like the majority of others
SP-2 Sensory Registration Quadrant	31.11	+/-6.32	Just like the majority of others
SP-2 Auditory Processing: Subtest	17.58	+/-6.58	Just like the majority of others
SP-2 Visual Processing: Subtest	11.47	+/-2.49	Just like the majority of others
SP-2 Touch Processing: Subtest	15.42	+/-6.29	Just like the majority of others
SP-2 Movement Processing Subtest	11.63	+/-3.53	Just like the majority of others
SP-2 Body Position Subtest	9.68	+/-2.34	Just like the majority of others
SP-2 Oral-Sensory Subtest	16.79	+/-6.89	Just like the majority of others
SP-2 Conduct in relation to sensory processing: Subtest	15.26	+/-4.59	Just like the majority of others
SP-2 Social Emotional Behavior related to sensory processing: Subtest	27.32	+/-11.65	Just like the majority of others
SP-2 Attention Behavior related to sensory processing: Subtest	16.63	+/-4.94	Just like the majority of others
BRIEF2® Behavioral Regulation Index	22.32	+/-5.14	Typical Function
BRIEF2®Emotional Regulation Index	28.16	+/-9.37	Typical Function
BRIEF2® Cognitive Regulation Index	55.63	+/-12.00	Typical Function
BRIEF2® Global Executive Composite	106.11	+/-20.72	Clinically Significant Difference
BRIEF2® Inhibit Subtest	14.89	+/-3.59	Typical Function
BRIEF2® Self-Monitor Subtest	7.42	+/-2.04	Typical Function
BRIEF2® Shift Subtest	12.53	+/-2.97	Typical Function
BRIEF2® Emotional Control Subtest	13.79	+/-4.34	Typical Function
Initiate	8.53	+/-2.09	Typical Function
BRIEF2® Working Memory Subtest	13.63	+/-3.32	Typical Function
BRIEF2® Plan/Organize Subtest	13.47	+/-3.37	Typical Function
BRIEF2® Task/Monitor Subtest	8.53	+/-2.67	Typical Function

Appendix B

Descriptive Characteristics of Participants on the Temperament in Middle Childhood Questionnaire (N = *19*)

Temperament Characteristic	Mean (Scaled Scores)	Standard Deviation
Surgency Composite Score	3.33	+/-0.37
Effortful Control Composite Score	3.33	+/-0.54
Negative Affect Composite Score	2.77	+/-0.41
Activation Control	3.36	+/-0.48
Activity Level	4.07	+/-0.83
Affiliation	4.20	+/-0.63
Anger/Frustration	2.75	+/-0.75
Assertiveness/Dominance	3.67	+/-0.64
Attention Focusing	3.11	+/-0.99
Discomfort	2.61	+/-0.61
Fantasy/Openness	4.07	+/-0.51
Fear	2.54	+/-0.76
High-Intensity Pleasure	3.52	+/-0.73
Impulsivity	3.07	+/-0.67
Inhibitory Control	3.06	+/-0.85
Low-Intensity Pleasure	3.60	+/-0.56
Perceptual Sensitivity	3.09	+/-0.65
Sadness	2.69	+/-0.74
Shyness	2.747	+/-0.99
Soothability	3.28	+/-0.67

Note. On a scale of 1–5, scores that fall closer to 5 indicate a stronger behavioral influence of that temperament characteristic.