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Sustained attention in sensory modulation disorder and attention deficit/hyperactivity disorder

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ABSTRACT

Background: There are high comorbidity rates between sensory modulation disorder (SMD) and attention deficit hyperactivity disorder (ADHD). Knowledge regarding the objective neuropsychological differentiation between them is scarce.
Aim: This study examines the effects of SMD and ADHD on a sustained attention task with and without aversive auditory conditions.
Method: Sixty six young adult females were tested on the Conjunctive - Continuous Performance Task-Visual (CCPT-V) measuring sustained attention, under two conditions: 1) aversive condition (with the three most aversive sounds chosen by the participant), and 2) non-aversive condition (without sounds).
Results: Both the SMD and ADHD factors exhibited performance deficits in the sustained attention task. All study participants performed worse on both sustained attention and speed of processing when aversive sounds were present.
Conclusion: We conclude that impaired sustained attention cannot differentiate between SMD and ADHD. Hence, these results should be taken under consideration in the assessment process of ADHD vs. SMD.

What this paper adds?

- This is the first study documenting, similarly to individuals with ADHD, an impairment in sustained attention for adults with SMD using the Conjunctive-Continuous Performance Task-Visual (CCPT-V).
- Exposure to aversive auditory stimulation impedes the efficiency of information processing and the ability to stay focused on a monotonous task irrespective of ADHD and/or SMD.

1. Introduction

Sensory Processing Disorder (SPD) is a heterogeneous dysfunction in the way children process and use sensory information for regulation, motor performance and function. Initially identified by Ayres (1972) as sensory integration dysfunction, SPD is currently the diagnostic term most commonly used. Children and adults with Sensory Modulation Disorder (SMD), one of three primary patterns of SPD, find it challenging to elicit an adaptive and graded response to stimuli from different sensory modalities. A person

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with SMD has difficulties in regulation of emotional, attentional and motor responses to sensory stimulation (Miller, Reisman, McIntosh, & Simon, 2001; Miller, Anzalone, Lane, Cermak, & Osten, 2007). One subtype of SMD is Sensory Over- Responsivity (SOR), constituting 80% of children diagnosed with SMD (Reynolds & Lane, 2008). People with SOR experience sensations in an intensified way, for a longer extent compared to typicals, and usually respond defensively to non-noxious sensations (Ayres, 1979; Dunn, 1999; Kinnealey, Oliver, & Wilbarger, 1995; McIntosh, Miller, Shyu, & Hagerman, 1999; Miller, Nielsen, & Schoen, 2012; Parham & Mailloux, 1996).

The estimated prevalence of SMD in the general pediatric population is 5–16% (2009b, Ben-Sasson, Carter, & Briggs-Gowan, 2009; Gouze, Hopkins, Lebailly, & Lavigne, 2009) and rises as high as 30–80% in people with neurodevelopmental disabilities (2009b, Ahn, Miller, Milberger, & McIntosh, 2004; Ben-Sasson, Carter et al., 2009). The prevalence of SMD in the adult population is unknown, but there is evidence that it continues into adulthood (Brown, Tollefson, Dunn, Cromwell, & Filion, 2001; Oliver, 1990). Examining sensory over-responsivity in adults is important because over-responsivity is frequently linked to high rates of depression and anxiety. SOR in adults disrupts engagement in daily occupations, and has a negative impact on the participation and quality of life of these individuals (Jerome & Liss, 2005; Kinnealey & Fuiek, 1999; Kinnealey, Koenig, & Smith, 2011; Liss, Timmel, Baxley, & Killingsworth, 2005).

Distractibility, hyperactivity, and impulsivity are the hallmarks of Attention Deficit Hyperactivity Disorder (ADHD) (American Psychiatric Association (APA) (2000), 2013). These behavioral expressions are also present in SMD (Cohn, Miller, & Tickle-Degnen, 2000; Miller et al., 2001; Parham & Mailloux, 1996), making the differentiation between the two disorders a challenge (Miller et al., 2012; Yochman, Alon-Beery, Sribman, & Parush, 2013). Furthermore, there is evidence in both clinical and population based studies that a high percentage of children with ADHD also have sensory modulation disorders (Cermak, 1991; Miller et al., 2001; Parush, Sohmer, Steinberg, & Kaitz, 1997; Yochman, Ornoy, & Parush, 2006). Several clinical observations and studies have reported a high incidence of tactile overresponsivity in children with ADHD (Bauer, 1977; Mangeot et al., 2001; Parush et al., 1997).

Several studies focused on the differentiation between SMD and ADHD, all of them were conducted on children. Ognibene (2002) demonstrated, in some of the study cases, opposing profiles for SMD and ADHD - slow habituation in children with SMD, in contrast to problems with response inhibition in children with ADHD.

Miller et al. (2012) compared the behavior and physiology of children with clinical ADHD, SMD, and dual diagnoses to those of typical peers. Children with SMD significantly differed from children with ADHD on behavioral measures of sensation, emotion and attention as well as physiological reactivity to a variety of sensory stimuli. Based on *parental report measures* children with only SMD had more sensory problems, more somatic complaints, were more likely to be withdrawn or anxious/depressed, and had more difficulty adapting, but had fewer attentional difficulties than children referred with ADHD. Children with SMD and ADHD had significantly more sensory problems than did children with a clinical diagnosis of only ADHD. Yet another research (Yochman et al., 2013) differentiated children with SMD from those with ADHD on sensory components, but found no difference between groups on attention components (according to the TEA-Ch). The attentional components studied were selective, sustained and divided attention.

It should be noted that studies that used objective physiological measures explored the sensory issues of SMD/ADHD, measuring only responses to sensory stimuli without parallel measures of objective cognitive performance. None of these studies addressed the specific attentional profile of SMD and tried to compare it to that of ADHD.

1.1. Study rationale and goals

In light of the high comorbidity rates between these two diagnoses and the absence of research regarding the objective neuropsychological differentiation between them, especially in adults, we recently succeeded to dissociate between them using a spatial Stroop-like task that assessed executive attention focusing on conflict resolution and by applying a full factorial design. A specific core deficit in executive attention was obtained for the ADHD factor, but not for the SMD one, whereas SMD was uniquely associated with impaired conflict resolution only when aversive sounds were presented (Mazor-Karsenty, Parush, Bonneh, & Shalev, 2015). Here, we aimed at further testing the attentional profiles of young adult females with SMD-SOR and females with ADHD, more specifically - how SMD and ADHD manifest in another aspect of attention - sustained attention. Sustained attention can be broadly characterized as the ability to focus on a specific stimulus over a period of time while excluding distracting stimuli (Shalev, Ben-Simon, Mevorach, Cohen, & Tsal, 2011).

Hence, the goals of this study were (a) to examine the effects of SMD-SOR and ADHD on sustained attention of young adult females, and (b) to assess the effects of aversive auditory conditions on their performance in this attention task.

2. Method

2.1. Study design

This study used a factorial design to compare the performance of SMD and ADHD on the CCPT under aversive and non-aversive auditory conditions.

2.2. Participants

Following approval from the university institutional review board, participants were recruited from undergraduate university students, some of them fulfilling course requirements.

Sixty six young adult females, 18–34 years of age (Mean = 25; SD = 3.5) participated in the current study, of which 20 had only SMD, 20 had both ADHD and SMD, six had only ADHD, and 20 were typical controls. Participants were the same subjects that comprised the Mazor-Karsenty et al. (2015), study.

The initial intention of this study was a balanced male-female sample. Unfortunately, it became practically impossible to recruit male participants with SMD and without ADHD. We therefore chose to focus only on females, preventing a possible gender bias. When we analyzed in retrospect the few articles published on SMD in adults we found a clear gender imbalance in study samples: A ratio of 3 women : 1 man (Kinnealey & Fuiek, 1999); 4 woman : 1 man (Kinnealey et al., 1995); 14 women: 1 man (Pfeiffer & Kinnealey, 2003); and a ratio of almost 4: 1 in Kinnealey et al., 2011. Our decision is further supported by the higher rates of sensory sensitivity in Israeli women compared to men as reported by Engel-Yeger (2012).

No significant difference in age was found between participants with and without ADHD: $F(1, 62) = 2.81$, $p = .10$, participants with and without SMD: $F(1, 62) = 2.69$, $p = .11$, and no significant interaction effect of ADHD X SMD: $F(1, 62) = 1.97$, $p = .16$.

ADHD was diagnosed by a qualified psychiatrist or neurologist based on DSM-IV criteria. The SRQ (Sensory Responsiveness Questionnaire - Bar-Shalita, Seltzer, Vatine, Yochman, & Parush, 2009) was used to diagnose SMD-SOR.

Inclusion criteria for all groups - normal hearing and normal or corrected to normal vision, no impaired color vision, and no reported traumatic life events.

Inclusion criteria for participants with only SMD and for typical controls were good health and no known psychological, medical or learning disorder. The criteria for those with ADHD stated no psychiatric or neurological comorbidity according to self-report.

2.3. Measures

2.3.1. BAS- Battery of Aversiveness to Sounds (BAS) (Mazor-Karsenty, Shalev, Parush, & Bonneh, 2018)

Ten standardized sound presentations: dish (eating utensils scratching dish), apple eating, ocean waves, rain, clock ticking, high pitch tone, water drops, alarm, machinery (construction equipment), birds chirping. Sounds intensity ranges from 55 to 80 dB. Each sound is presented three times, for 30 s each time. There are therefore 30 sound presentations in total. All sounds were presented binaurally in pseudorandom order using headphones (Koss TD-80). Sounds were recorded using waveform audio file format and programmed into a p file. A Dell laptop controlled auditory stimuli presentation. Participants were asked to rate each sound stimulus according to its perceived unpleasantness (level of aversiveness) on a Visual Analogue Scale of 0 to 10, 0 representing '*no unpleasant sensation*' and 10 '*the most unpleasant sensation imaginable*'. Every participant rated each sound three times and a mean score for each sound was calculated.

2.3.2. Conjunctive - continuous performance task-visual (CCPT-V; Avisar & Shalev, 2011; Shalev et al., 2011) (see Fig. 1)

To measure sustained attention participants were presented with a single block which included a sequence of 320 trials preceded by 15 practice trials. The stimulus in each trial was a colored geometric shape presented at the center of the screen. The size of each stimulus ranged from 1.4 to 1.8 cm in height and from 1.8 to 1.9 cm in width. The task included 16 different stimuli resulting from the possible factorial combinations of four shapes (square, circle, triangle, or star) and four colors (red, blue, green and yellow). The target (red square) appeared on 30% of the trials. Participants were instructed to respond by pressing the space bar with their preferred index finger, as soon as the target appeared and to withhold responses to all other stimuli. On 17.5% of the trials a non-red square appeared. On 17.5% of the trials a red non-square appeared, and on 35% of the trials a non-target shape appeared that shared neither identity nor color with the target. Each stimulus was presented for 100 ms. and was separated from the next by an inter-stimulus interval (ISI) of 1000, 1500, 2000, or 2500 ms. with each ISI appearing in 25% of the trials. The various stimulus types and inter-stimulus intervals were randomly intermixed. Four performance measures were used to assess sustained attention: a. mean Reaction Time (RT) (in ms), measures speed of processing; b. standard deviation of RT (SD-RT) (in ms) in responding to the target, measures sustained attention; c. proportion of omissions (target trials that were missed), measures sustained attention; and d. proportion of commissions (non-targets to which the participant responded erroneously), measures response inhibition and/or sustained attention (Shalev et al., 2011).

2.4. Procedure

The experimental protocol was approved by the Hebrew University – Faculty of Medicine institutional review board. All participants signed an informed consent, after which the BAS was administered. The 1st author then calculated a mean score for each sound and chose the three most aversive sounds for each participant. The three most aversive sounds were then programmed into a p file.

The CCPT-V was subsequently administered under two conditions: 1) Aversive condition (with the three most aversive sounds that were chosen by the participant on the BAS). 2) Non-aversive condition (without sounds). Half of the participants in each group were assigned to the aversive condition (with aversive sounds) first and after a 30 min break had to perform the CCPT-V under a non-aversive condition (without aversive sounds). This was labelled as ***order 1.*** The remaining half of the participants in that group were assigned to the non-aversive condition first and after a 30 min break had to perform the attention task under aversive sounds. This was referred to as ***order 2***. The attention task was administered on an IBM PC with a graphic display that controlled stimulus presentation and data collection. All stimuli were presented against a dark background. Viewing distance was set at about 50 cm so that 1 cm represented about 1.15 deg of visual angle. The task was preceded by practice trials during which auditory feedback was given on incorrect responses. No feedback was provided on the experimental trials. Reaction time (RT) was recorded in ms. starting

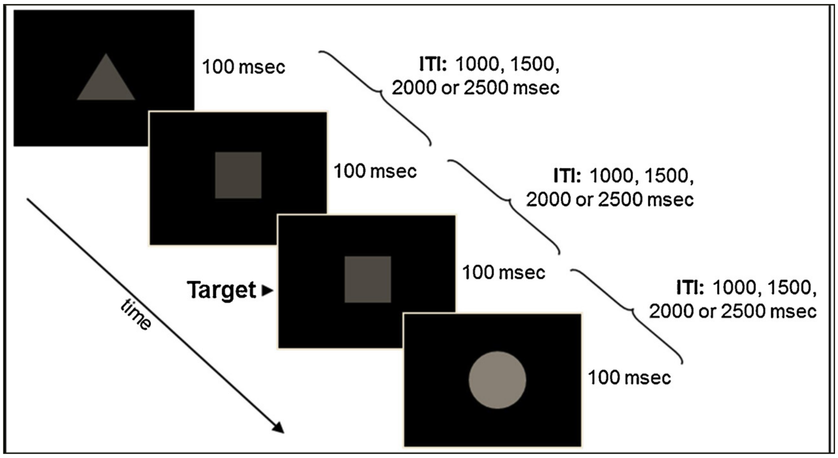

Fig. 1. The Conjunctive - Continuous Performance Task (CCPT). ITI = Inter Target Interval.

from the onset of the test stimuli. Participants were instructed to respond as fast and as accurately as possible.

2.5. Data analysis

In order to compare between study groups in relation to the sustained attention task a factorial ANOVA was used. Analyses were performed using 2 × 2 × 2 × 2 (ADHD × SMD × sound order × sound) ANOVA with Repeated Measures on sound. Simple effects were conducted according to findings.

3. Results

3.1. Mean RT (measures speed of processing)

A significant difference in the mean RT was found between ***sound*** conditions: $F(1,58) = 4.505$, $p = .038$, $\eta 2 = .072$. The mean RT for no sounds (NS) condition: M = 441, SE = 9 was significantly faster than the mean RT for with sounds (WS) condition: M = 458, SE = 12. No other effects were significant.

3.2. SD of RT (measures sustained attention)

Analysis of variance found a main effect for ***ADHD***: $F(1,58) = 4.330$, $p = .042$, $\eta 2= .069$. The mean SD of RT for participants with ADHD was higher (M = 89.254, SE = 8.437) indicating more variability than the mean SD of RT for those without ADHD (M = 68.326, SE = 5.475). No interaction effect for ADHD and sound was found $F(1,58) = 3.506$, $p > .05$. Another main effect was found for ***SMD***: $F(1,58) = 5.262$, $p = .025$, $\eta 2 = .083$. The mean SD of RT for participants with SMD was significantly higher (M = 90, SE = 5) indicating more variability than the mean SD of RT for those without SMD (M = 67, SE = 8). No interaction effect was found for SMD and sound: $F(1,58) = 0.082$, $p > .05$. A significant difference in the SD of RT was found between ***sound*** conditions: $F(1,58) = 11.616$, $p = .001$, $\eta 2 = .167$. The mean SD of RT for no sounds (NS) condition: M = 70, SE = 5 was lower (that is, better) overall than the mean SD of RT for with sounds (WS) condition: M = 87 SE = 6.

3.3. Omission (measures sustained attention)

A main effect was found for ***ADHD***: $F(1,58) = 4.303$, $p = .042$, $\eta 2 = .069$. The proportion of omissions (that is, misses of targets) for participants with ADHD was significantly higher (M = .018, SE = .004) indicating more omissions than the proportion for those without ADHD (M = .007, SE = .003). No interaction for ADHD and sound was found: $F(1,58) = 1.582$, $p > .05$. A significant difference in omissions was found between ***sound*** conditions: $F(1,58) = 9.041$, $p = .004$, $\eta 2= .135$. The mean score for no sounds (NS) condition: M = .007, SE = .002 was lower (i.e. fewer target misses) than the mean score for with sounds (WS) condition: M = .018 SE = .004. No other effects were significant.

3.4. Commission (measures response inhibition and/or sustained attention)

Analysis of variance found a main effect for ***SMD***: $F(1,58) = 5.095$, $p = .028$, $\eta 2= .081$. The proportion of commissions (that is, responding to a distractor as if it was a target) for participants with SMD was higher (M = .009, SE = .002) indicating more commissions than the proportion for those without SMD (M = .003, SE = .002), but no interaction effect for SMD and sound was obtained ($F(1,58) = 0.529$, $p > .05$.). No other significant effects were found.

Table 1
Mean, Standard Error and main effect for each independent variable on CCPT measures.

CCPT Measures[1]	Independent Variable	condition	Mean	SE	F(1, 58)	η^2
M- RT (in ms)	**Sound**	**No sounds**	441	9	4.5*	.072
speed of processing		**With sounds**	458	12		
SD - RT (in ms)	**ADHD**	**No ADHD**	68	5	4.3*	.069
sustained attention	**SMD**	**With ADHD**	89	8		
	Sound	**No SMD**	67	8	5.3*	.083
		With SMD	90	5		
		No sounds	70	5	11.6***	.167
		With sounds	87	6		
% Omissions	**ADHD**	**No ADHD**	0.7	0.3	4.3*	.069
sustained attention	**Sound**	**With ADHD**	1.8	0.4		
		No sounds	0.7	0.2	9.04**	.135
		With sounds	1.8	0.4		
% Commissions	**SMD**	**No SMD**	0.3	0.2	5.09*	.081
response inhibition		**With SMD**	0.9	0.2		

Note[1]. CCPT = Conjunctive - Continuous Performance Task-Visual.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

Table 1 summarizes results of all CCPT measures.

4. Discussion

Behavioral expressions of SMD are often difficult to distinguish from those of ADHD in children and adults. There is also no research that attempted to systematically differentiate these two disorders in adults. Recently, we demonstrated a distinct profile for each disorder on the *Stroop-like Location – Direction Task (SLDT)* measuring executive attention (Mazor-Karsenty et al., 2015). In the current study we set out to investigate how SMD and ADHD manifest in another aspect of attention - sustained attention, which is included in several models of attention describing attention as a varied system (Mirsky, Pascualvaca, Duncan, & French, 1999; Petersen & Posner, 2012; Posner & Petersen, 1990; Sohlberg & Mateer, 1987, 1989; Tsal, Shalev, & Mevorach, 2005).

4.1. ADHD factor

One of the most popular and consistent neuropsychological tasks used in ADHD research to study sustained attention is the Continuous Performance Test (CPT; Hervey, Epstein, & Curry, 2004). The performance of children and adults with ADHD has been found to be worse compared to typical controls in many studies using various versions of this task (Doehnert, Brandeis, Schneider, Drechsler, & Steinhausen, 2013; Epstein, Johnson, Varia, & Conners, 2001, 2003; Greenberg & Kindschi, 1996; Lufi & Fichman, 2012; Pennington & Ozondff, 1996; Riccio, Reynolds, Lowe, & Moore, 2002; Taranovsky, Prinz, & Nay, 1986; Tsal et al., 2005; Weyandt, Mitzlaff, & Thomas, 2002). In these studies sustained attention was measured by the standard deviation of reaction time (SD of RT) and by omission errors. The validity of the CCPT used in this study as a pure measure of sustained attention (measured by mean RT and SD-RT) was established in Shalev et al. (2011) study.

Congruent with above studies on ADHD that have used different versions of CPT, participants with ADHD in the current study performed significantly worse than those without ADHD as measured in the *SD of RT* and had significantly more *omission errors* on this task. Both of these are measures of sustained attention.

Few studies relating to CPT performance under “noise” or distracting conditions are comparable to our study. Studies reporting the effects of noise (either auditory or visual) on the CPT performance of children with ADHD, relate to “noise” (or “sensory stimuli”) in the same modality (visual task and visual noise; auditory task and auditory noise, see Huang-Pollock, Karalunas, Tam, & Moore, 2012; Uno et al., 2006) and/or of the same semantic content (visual target and auditory noise, see Berger & Goldzweig, 2010) as the target stimulus. The sounds in the current study were not in the same modality as the task and had a different semantic content.

Of some relevance to our study is Parsons, Bowerly, Buckwalter, and Rizzo, (2007) research that studied the attentional performance of children with ADHD in a virtual reality (VR) classroom. One of the experimental conditions consisted of a CPT task in the presence of pure auditory distractors (ambient classroom sounds). Children with ADHD were more negatively impacted by distraction in the VR classroom. Similarly, Children with ADHD were more affected by distractions in the VR classroom than those without ADHD in the Adams, Finn, Moes, Flannery, and Rizzo (2009) study.

Moving away from the few existing studies that used various CPT’s, there are studies that observed other cognitive abilities of subjects with ADHD under auditory distraction. Abikoff, Courtney, Szeibel, and Koplewicz (1996) report the facilitative effect of individually tailored music distractors on the arithmetic performance of boys with ADHD, and Van Mourik, Oosterlaan, Heslenfeld, Konig, and Sergeant (2007) similarly refer to auditory distraction as having beneficial effects on children with ADHD. Similar to these results Soderlund, Sikstrom, Loftesnes, and Sonuga-Barke (2010) found that exposure to background noise improved performance for a non-clinical group of inattentive children and worsened performance for attentive children, and that moderate auditory white noise was found to facilitate memory performance in children with ADHD (Söderlund, Sikström, & Smart, 2007).

On the other hand, there are studies that indicate that auditory distraction influences both individuals with and without ADHD. Thus, for example, in Lineweaver et al. (2012) study auditory distraction did not differentially influence the working memory performance of college students with ADHD and their non-ADHD peers. The visual working memory of both groups decreased in the presence of an auditory distraction. Zentall and Shaw (1980) found similar degrees of decline in the scores earned by groups of children with and without ADHD in the presence of classroom noise when the auditory task they were completing was novel and challenging.

This is in accordance with our study - A significant main effect of sound conditions implies that regardless of group placement, all study participants performed worse on both sustained attention (SD of RT and omission) and speed of processing (Mean RT) measures of the CPT when aversive sounds were present.

In our study, aversive sounds did not differentiate participants with and without ADHD. It wasn't clear that an interaction should be obtained since the manipulation was extremely aversive, and impaired the performance of all participants. Stating that, there may have been factors that limited our ability to document ADHD-related deficits under aversive auditory conditions. First and foremost, our study focused on university students with ADHD. They may not be representative of the general population of same age peers with ADHD. Second, previous research has indicated that auditory stimuli that have high linguistic content impair cognition and increase hyperactivity in individuals with ADHD (Zentall & Shaw, 1980). The auditory content of all ten sounds on the Battery of Aversive Sounds used in our study did not include any linguistic content. This may explain why they did not differentially influence participants with ADHD, but rather reduced the attentional performance of all participants. Moreover, in the current study the aversive auditory stimuli were individually tailored; the three most aversive sounds were selected by each participant and used as background noise when she performed the attention tasks (either for the first or the second time). It is reasonable to assume that these sounds were actually distracting to all participants.

4.2. SMD factor

The lack of similar in-depth attentional studies makes it impossible to discuss results of participants with SMD in light of other reported outcomes. In the following paragraphs results will be discussed with regard to current knowledge on the behavioral manifestations and possible underlying mechanisms of SMD-SOR. The sustained attention task yielded a main effect for SMD (in the SD of RT) indicating more inconsistency, or variability, in performance when the SMD factor was present, and more commission errors. These results, indicating worse sustained attention as well as lower response inhibition, are similar to the results for the ADHD factor.

One possible explanation is that participants with SMD performed significantly worse on this task because the CPT is a non-resource demanding cognitive task (Szalma & Hancock, 2011), it enables the participant a certain cognitive "void" in which inner and outer stimuli distract attention. Possibly, thoughts and environmental stimuli receive more attention from participants with SMD precisely because the CPT is a very easy and boring task which does not involve learning (Shalev et al., 2011), and in which attentional resources may not be optimally used. But, one must take into account that this explanation is also relevant to people with ADHD in that it is similar to conclusions of studies that have linked the inefficient engagement of attention in ADHD under low cognitive load to deficits in vigilance or alerting (Friedman-Hill et al., 2010; Huang-Pollock & Nigg, 2003; Huang-Pollock, Nigg, & Halperin, 2006; Sergeant, 2005). In other words, low cognitive load leads to loss of focus on relevant items and increased attention to irrelevant stimuli (Friedman-Hill et al., 2010). In favor of this explanation as a plausible one regarding SMD is our recent study on the performance of adult females with SMD on a high cognitive load task (an executive attention task). In this study individuals with SMD, contrary to participants with ADHD, did not display a core deficit on a conflict resolution task (Mazor-Karsenty et al., 2015).

Yet another explanation regards a distinguishing aspect of the CCPT-V computerized test. The CCPT-V task does not allow self-pacing (i.e. stimuli are presented at a pre-designed rate and the time of their appearance is independent of participants' response). This structure of the sustained attention task may have contributed to a perceived "blitz" of visual stimuli by participants with SMD, negatively affecting their performance and their efforts to inhibit responses to stimuli. Previous studies reported less efficient autonomic responses (i.e. increased sympathetic and decreased parasympathetic activity) in response to sensory stimuli (McIntosh et al., 1999; Schaaf, Miller, Seawell, & O'Keefe, 2003; Schoen, Miller, & Green, 2008) hypothesized to contribute to high levels of alertness and, as a result, the inability of individuals with SMD-SOR to moderate the degree, intensity, and type of response to typical environmental sensory stimuli (Miller et al., 2012), not perceived as overwhelming by typical peers. In a recent study on central pain processing in adults with SMD-SOR (Bar-Shalita, Vatine, Yarnitsky, Parush, & Weissman-Fogel, 2014) authors found an atypical response pattern to pain which they explained is a possible result of heightened alertness and activation of central inhibitory mechanisms in order to prevent a further barrage of noxious information to the already bombarded and irritated sensory system. Participants with SMD in our study may have perceived the colored geometric shapes presented in the CCPT-V as an overwhelming barrage of noxious visual stimuli to which they could not habituate/adapt leaving them with the only possible coping strategy – an impulsive pattern of response as was obtained by significantly more commission errors and more inconsistency in performance (as portrayed in SD of RT).

This explanation is also in line with detailed reports of sensory sensitive adults who are more sensitive to visual input. They are bothered by brightness, high contrast, and unfamiliar patterns in situations such as quickly changing images on TV. These individuals will pull shades down, keep lights low in the room, and prefer monochromatic decoration (Dunn, 2008; Kinnealey et al., 2011; Kinnealey et al., 1995; May-Benson, 2011).

On account of the high comorbidity rate between ADHD and SMD (Miller et al., 2001; Parush et al., 1997; Yochman et al., 2006), results of this study should be taken under consideration in the diagnostic process of these two disorders. Testing of sustained attention using various continuous performance tests is very popular in research and in the diagnosis of ADHD. The inability of the CCPT-V to differentiate between ADHD and SMD in the current study mandates a cautious use of sustained attention tasks as a sole neuropsychological testing criterion for ADHD.

4.3. Limitations

The limitations of this research lie in several areas: the gender homogeneity, the limited number of participants in the ADHD without SMD group, the fact that the majority of participants were university students, and the fact that the ADHD diagnosis of participants was made by different neurologists or psychiatrists. Moreover, in the SMD group, ADHD was excluded based on the MATAL ADHD Questionnaire (Ben-Simon, 2007) and not on a diagnosis of a qualified neurologist or psychiatrist.

5. Conclusion

To conclude, this study set out to further investigate the attentional profile of adults with SMD. Exposure to aversive auditory stimulation impedes the efficiency of information processing and the ability to stay focused on a monotonous task irrespective of ADHD and/or SMD. Moreover, regardless of group placement, all study participants performed worse on both sustained attention and speed of processing when aversive sounds were present. Previous studies, using various versions of sustained attention tasks, have shown that the performance of adults with ADHD is impaired compared to typical controls. This is the first study documenting a similar pattern for SMD using the Conjunctive-Continuous Performance Task-Visual (CCPT-V). These results should be taken under consideration in the assessment process of ADHD vs. SMD. An assessment that relies solely on self-report and a CPT as an only objective measure of attention can be problematic. The assessment process of ADHD and SMD must include a clinical evaluation, in addition to self-report measures and a broad battery of objective neuropsychological tests. Future studies should attempt to further explore these findings in children and adult males.

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