Children with Attention-Deficit/Hyperactivity Disorder

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Children with Attention-Deficit/Hyperactivity Disorder (ADHD) face a range of learning difficulties in the school environment, thus several strategies have been developed to enhance or optimise their performance in school. One possible way is to actively enable appropriate restlessness using dynamic seats.

ADHD electrodermal activity motion thermal imaging inertial measurement unit

1. Background

Neurological developmental disorder Attention-Deficit/Hyperactivity Disorder (ADHD) is expressed in children as difficulty maintaining attention, inhibiting behaviour (impulsivity), and managing excessive motor and speech activity [1][2]. Start of schooling coincides with the period of typically the most intense symptoms of ADHD [3]. At the same time, most diagnoses of ADHD are made during the early school years due to the occurrence of learning difficulties and disruptive behaviour during class [4].

ADHD is denoted with weaker executive functions such as inhibition, working memory, planning, and task switching [5][6][7]. Problems with reading and reading comprehension in children with ADHD are also explained by the higher incidence of specific learning disabilities [8], with as many as 25–40% of children with ADHD meeting the criteria for dyslexia [9]. In the school environment, this manifests itself as carelessness at school tasks, disorganization, interrupting the teacher (and classmates), poor listening and following instructions, speaking without permission, avoiding mentally demanding tasks, forgetfulness, restlessness, and poor in-seat behaviour [10][11]. Although all children occasionally exhibit such behaviour, it is so common and intense in children with ADHD that it prevents them from functioning normally in the school environment and in everyday life [2].

It is recommended to combine several measures to manage behaviour in children with ADHD at school, such as adjusted classroom arrangement (grid arrangement of desks, sitting close to the teacher and away from windows, lower lighting, larger workspace for a child), smaller classes, interesting and short explanations (treatment of material in small sets with regular breaks, multi-sensory presentations, e.g., use of visual aids, enrichment of the lesson with novelties, e.g., quizzes and films), sensible distribution and composition of tasks (shorter and original tasks, start of the class with easier tasks, which become more difficult over time), encouraging and rewarding good work habits (writing notes, daily report cards, raising the hand before talking), and preventing inappropriate behavior with a calm but firm warning [10][11][12][13].

Problems with the regulation of psychological arousal are also often attributed to ADHD [14]. Psychological arousal encompasses behavioural and physiological mechanisms for regulating the state of mindfulness and attention [14]. According to Yerkes–Dodson law [15], good cognitive functioning requires an optimal level of psychological arousal, determined by interactions between the central and autonomic nervous systems. To better understand the atypical functioning of the autonomic nervous system and the cognitive activity of children with ADHD, physiological parameters such as electrodermal activity and skin temperature can be measured.

Electrodermal activity (EDA) can be observed by measuring changes in the electrical properties of the skin due to the activity of the sweat glands [16][17]. Although the main function of sweating is the body thermoregulation, sweat glands are active also during psychological or emotional arousal and stressful situations [16][18]. Using the EDA signal, researchers can determine the level of psychological arousal by observing skin conductance level (SCL) and skin conductance response (SCR). SCL determines the level of psychological arousal and the baseline [16]. Current skin conduction values are described by SCRs, the density of which indicates the degree of psychological arousal (for example, more than 20 SCRs/min means high psychological arousal) [16]. SCRs represent values that exceed a certain threshold within the selected time frame [16]. Usually, SCR occurs 2–9 s after the start of the stimulus, when the amplitude of the SCR signal exceeds a threshold with a typical value between 0.01 µS and 0.05 µS [16]. The type of electrodes and the place of their installation depend on the purpose of the measuring device. The highest density of sweat glands is on the palms [16], so silver wet electrodes with a thin silver/silver chloride (Ag/AgCl) layer placed on the posterior joints of the index finger and middle finger are usually used [16][17]. A gel containing the electrolyte is required for optimal operation of such electrodes [16][17]. In the case of wearable sensors, the emphasis is on ergonomic design and ease of use, so dry stainless steel electrodes mounted on the upper arm are often used [17]. This site is suitable for measuring EDA, as all sweat glands are active in psychological sweating, and differences in the amount of sweat occur only due to the density of their distribution [19].

Body temperature depends on environmental conditions, both on biological conditions (adaptation to ambient temperature, overcoming a virus) and on emotional responses (social interactions, fight-or-flight) [20]. In the latter, the autonomic nervous system controls temperature through narrowing (vasoconstriction) and widening of subcutaneous vessels (vasodilation) and psychological sweating [20][21]. Vasoconstriction of peripheral facial vessels and increased cognitive load redirects blood flow from the face to the brain and thus affects the temperature image of the entire face [22][23]. The most stable temperature is in the forehead area and the most variable at the tip of the nose; therefore, these areas are often the subject of research [24][25][26]. There is also a very dense distribution of sweat glands on the forehead, so in case of stressful situations, psychological sweating is noticeable [19], which (negatively) affects the measurement of forehead temperature in the case of water film formation [27].

2. Enabling Restlessness in School

Hyperactivity is a unique feature of ADHD [28], but its role is not entirely clear. One explanation is given by the theory of optimal stimulation [29], according to which hyperactivity is a mechanism that compensates for the lack of psychological arousal with an additional visual and kinesthetic contribution. Thus, increased activity occurs only in low-stimulation environments [29]. This theory is also supported by the model of functional working memory [30], which attributes to hyperactivity the role of stimulating the activity of the prefrontal cortex in demanding cognitive tests. At the same time, increased activity enables the avoidance of environmental requirements or tasks that are too demanding and overloading for their less developed working memory [30]. The model is supported by more research showing that children with ADHD move more intensely than typically developed children in more cognitively demanding tasks involving working memory load [31][32][33]. In contrast, in children without ADHD, increased exercise results in poorer functioning of their working memory [33]. Increased movement in children with ADHD may reflect the use of multiple cognitive resources [31]. With more intense physical activity, it is possible to strengthen the functioning of the cognitive control in children with ADHD [33].

The hyperactivity characteristic of children with ADHD therefore plays a functional role in their neurocognitive functioning [30][31][32][33]. The ability to direct and shift attention plays a key role in controlling movement [34]. Movement control is more effective when the individual has as many sources of attention as possible and at the same time as few distractions as possible [35]. Children with ADHD have shorter attention span [36]; therefore, movement control, imposed by any seating that does not allow spontaneous movement, can be an important consumer of attention. The positive link between hyperactivity, appropriate behaviour and problem-solving efficiency is also supported by other research [31][33], resulting in an idea of allowing for restlessness during class. Possible strategies are the use of dynamic seats (therapy ball, balance pillow, one-legged chair, standing desks), inclusion of physical activity in lessons (active games, moving furniture, carrying books, distributing papers to classmates, cleaning the board), holding classes outside and using classroom-friendly fidget toys [10][12][13].

Increasing physical activity and allowing for restlessness during class can also reduce the risk of many health problems resulting from prolonged sedentary position in school [37][38][39][40][41][42]. A commonly used alternative to the standard school chair is the therapy ball. Research on the impact of sitting on a therapy ball has divided opinions. While some confirm the positive effects of the therapy ball on in-seat behaviour and improving attention span in children with ADHD [43][44][45], recent research has not seen improvements in behaviour and productivity [46][47]. The potential benefits of the therapy ball have most likely not been revealed because it allows too much movement and overloads children with ADHD who have difficulties with self-control [47]. Despite the disagreement about the impact of the therapy ball on behaviour, there is no doubt about its popularity among children, as they labelled it as very comfortable and that it helped them improve concentration in solving tasks [43][46]. There are also many other kinaesthetic seats available that encourage active sitting in a unique way. This entry evaluates an active seat that does not restrict legs movement and at the same time stabilizes the torso, thus enabling writing and solving tasks despite increased activity. The chair’s advantage is also in the adjustable height and shape of the seat, so it can be perfectly adapted to the child. This eliminates many of the potential negative consequences of an oversized or undersized seat [48][49][50].

References

1. Barkley, R.A. Attention-Deficit Hyperactivity Disorder: A Handbook for Diagnosis and Treatment, 2nd ed.; The Guilford Press: New York, NY, USA, 1998.
2. Association, A.P. Desk Reference to the Diagnostic Criteria from DSM-5; American Psychiatric Association: Washington, DC, USA, 2013.
3. Halperin, J.M.; Schulz, K.P. Revisiting the role of the prefrontal cortex in the pathophysiology of attention-deficit/hyperactivity disorder. Psychol. Bull. 2006, 132, 560.
4. Cherkasova, M.; Sulla, E.M.; Dalena, K.L.; Pondé, M.P.; Hechtman, L. Developmental course of attention deficit hyperactivity disorder and its predictors. J. Can. Acad. Child Adolesc. Psychiatry 2013, 22, 47–54.
5. Sergeant, J.A.; Geurts, H.; Oosterlaan, J. How specific is a deficit of executive functioning for attention-deficit/hyperactivity disorder? Behav. Brain Res. 2002, 130, 3–28.
6. Boonstra, M.; Oosterlaan, J.; Sergeant, J.; Buitelaar, J. Executive functioning in adult ADHD: A meta-analytic review. Psychol. Med. 2005, 35, 1097–1108.
7. Fischer, M.; Barkley, R.A.; Smallish, L.; Fletcher, K. Executive functioning in hyperactive children as young adults: Attention, inhibition, response perseveration, and the impact of comorbidity. Dev. Neuropsychol. 2005, 27, 107–133.
8. DuPaul, G.J.; Gormley, M.J.; Laracy, S.D. Comorbidity of LD and ADHD: Implications of DSM-5 for assessment and treatment. J. Learn. Disabil. 2013, 46, 43–51.
9. Boada, R.; Willcutt, E.G.; Pennington, B.F. Understanding the comorbidity between dyslexia and attention-deficit/hyperactivity disorder. Top. Lang. Disord. 2012, 32, 264–284.
10. Barkley, R.A. Managing ADHD In School: The Best Evidence-Based Methods for Teachers; PESI Publishing Media: Eau Claire, WI, USA, 2016.
11. DuPaul, G.J. School-based interventions for students with attention deficit hyperactivity disorder: Current status and future directions. Sch. Psychol. Rev. 2007, 36, 183–194.
12. Zentall, S.S. Theory-and evidence-based strategies for children with attentional problems. Psychol. Sch. 2005, 42, 821–836.
13. Mulligan, S. Classroom strategies used by teachers of students with attention deficit hyperactivity disorder. Phys. Occup. Ther. Pediatr. 2001, 20, 25–44.
14. Bellato, A.; Arora, I.; Hollis, C.; Groom, M.J. Is autonomic nervous system function atypical in attention deficit hyperactivity disorder (ADHD)? A systematic review of the evidence. Neurosci. Biobehav. Rev. 2020, 108, 182–206.
15. Yerkes, R.M.; Dodson, J.D. The relation of strength of stimulus to rapidity of habit-formation. J. Comp. Neurol. Psychol. 1908, 18, 459–482.

16. Boucsein, W. Electrodermal Activity; Springer Science & Business Media: New York, NY, USA, 2012.
17. Geršak, G. Electrodermal activity—A beginner's guide. Elektrotehniski Vestn. 2020, 87, 175–182.
18. Storm, H. Development of emotional sweating in preterms measured by skin conductance changes. Early Hum. Dev. 2001, 62, 149–158.
19. Harker, M. Psychological sweating: A systematic review focused on aetiology and cutaneous response. Ski. Pharmacol. Physiol. 2013, 26, 92–100.
20. Ioannou, S.; Gallese, V.; Merla, A. Thermal infrared imaging in psychophysiology: Potentialities and limits. Psychophysiology 2014, 51, 951–963.
21. Charkoudian, N. Skin blood flow in adult human thermoregulation: How it works, when it does not, and why. Mayo Clin. Proc. 2003, 78, 603–612.
22. Abdelrahman, Y.; Velloso, E.; Dingler, T.; Schmidt, A.; Vetere, F. Cognitive heat: Exploring the usage of thermal imaging to unobtrusively estimate cognitive load. ACM Interact. Mob. Wearable Ubiquitous Technol. 2017, 1, 1–20.
23. Cabanac, M.; Brinnel, H. Blood flow in the emissary veins of the human head during hyperthermia. Eur. J. Appl. Physiol. Occup. Physiol. 1985, 54, 172–176.
24. Moliné, A.; Dominguez, E.; Salazar-López, E.; Gálvez-García, G.; Fernández-Gómez, J.; De la Fuente, J.; Iborra, O.; Tornay, F.; Gómez Milán, E. The mental nose and the Pinocchio effect: Thermography, planning, anxiety, and lies. J. Investig. Psychol. Offender Profiling 2018, 15, 234–248.
25. Or, C.K.; Duffy, V.G. Development of a facial skin temperature-based methodology for non-intrusive mental workload measurement. Occup. Ergon. 2007, 7, 83–94.
26. Engert, V.; Merla, A.; Grant, J.A.; Cardone, D.; Tusche, A.; Singer, T. Exploring the use of thermal infrared imaging in human stress research. PLoS ONE 2014, 9, e90782.
27. Quesada, J.I.P.; Guillamón, N.M.; de Anda, R.M.C.O.; Psikuta, A.; Annaheim, S.; Rossi, R.M.; Salvador, J.M.C.; Pérez-Soriano, P.; Palmer, R.S. Effect of perspiration on skin temperature measurements by infrared thermography and contact thermometry during aerobic cycling. Infrared Phys. Technol. 2015, 72, 68–76.
28. Halperin, J.M.; Matier, K.; Bedi, G.; Sharma, V.; Newcorn, J.H. Specificity of inattention, impulsivity, and hyperactivity to the diagnosis of attention-deficit hyperactivity disorder. J. Am. Acad. Child Adolesc. Psychiatry 1992, 31, 190–196.
29. Zentall, S.S.; Zentall, T.R. Optimal stimulation: A model of disordered activity and performance in normal and deviant children. Psychol. Bull. 1983, 94, 446.

30. Rapport, M.D.; Bolden, J.; Kofler, M.J.; Sarver, D.E.; Raiker, J.S.; Alderson, R.M. Hyperactivity in Boys with Attention-Deficit/Hyperactivity Disorder (ADHD): A Ubiquitous Core Symptom or Manifestation of Working Memory Deficits? J. Abnorm. Child Psychol. 2009, 37, 521–534.
31. Hartanto, T.; Krafft, C.; Iosif, A.M.; Schweitzer, J.B. A trial-by-trial analysis reveals more intense physical activity is associated with better cognitive control performance in attention-deficit/hyperactivity disorder. Child Neuropsychol. 2016, 22, 618–626.
32. Hudec, K.L.; Alderson, R.M.; Kasper, L.J.; Patros, C.H. Working memory contributes to elevated motor activity in adults with ADHD: An examination of the role of central executive and storage/rehearsal processes. J. Atten. Disord. 2014, 18, 357–368.
33. Sarver, D.E.; Rapport, M.D.; Kofler, M.J.; Raiker, J.S.; Friedman, L.M. Hyperactivity in attention-deficit/hyperactivity disorder (ADHD): Impairing deficit or compensatory behavior? J. Abnorm. Child Psychol. 2015, 43, 1219–1232.
34. Song, J.H. The role of attention in motor control and learning. Curr. Opin. Psychol. 2019, 29, 261–265.
35. Song, J.H.; Bédard, P. Paradoxical benefits of dual-task contexts for visuomotor memory. Psychol. Sci. 2015, 26, 148–158.
36. Sinclair, M.; Taylor, E. The neuropsychology of attention development. In Child Neuropsychology: Concepts, Theory, and Practice; Wiley-Blackwell: Chichester, UK; Malden, MA, USA, 2008; pp. 233–263.
37. Hamilton, M.T.; Healy, G.N.; Dunstan, D.W.; Zderic, T.W.; Owen, N. Too little exercise and too much sitting: Inactivity physiology and the need for new recommendations on sedentary behavior. Curr. Cardiovasc. Risk Rep. 2008, 2, 292–298.
38. Proper, K.I.; Singh, A.S.; Van Mechelen, W.; Chinapaw, M.J. Sedentary behaviors and health outcomes among adults: A systematic review of prospective studies. Am. J. Prev. Med. 2011, 40, 174–182.
39. da Costa, B.G.; da Silva, K.S.; George, A.M.; de Assis, M.A.A. Sedentary behavior during school-time: Sociodemographic, weight status, physical education class, and school performance correlates in Brazilian schoolchildren. J. Sci. Med. Sport 2017, 20, 70–74.
40. del Pozo-Cruz, J.; García-Hermoso, A.; Alfonso-Rosa, R.M.; Alvarez-Barbosa, F.; Owen, N.; Chastin, S.; del Pozo-Cruz, B. Replacing sedentary time: Meta-analysis of objective-assessment studies. Am. J. Prev. Med. 2018, 55, 395–402.
41. Triglav, J.; Howe, E.; Cheema, J.; Dube, B.; Fenske, M.J.; Strzalkowski, N.; Bent, L. Physiological and cognitive measures during prolonged sitting: Comparisons between a standard and multi-axial office chair. Appl. Ergon. 2019, 78, 176–183.

42. Kett, A.R.; Sichting, F. Sedentary behaviour at work increases muscle stiffness of the back: Why roller massage has potential as an active break intervention. Appl. Ergon. 2020, 82, 102947.
43. Schilling, D.L.; Washington, K.; Billingsley, F.F.; Deitz, J. Classroom seating for children with attention deficit hyperactivity disorder: Therapy balls versus chairs. Am. J. Occup. Ther. 2003, 57, 534–541.
44. Fedewa, A.L.; Erwin, H.E. Stability balls and students with attention and hyperactivity concerns: Implications for on-task and in-seat behavior. Am. J. Occup. Ther. 2011, 65, 393–399.
45. Wu, W.L.; Wang, C.C.; Chen, C.H.; Lai, C.L.; Yang, P.C.; Guo, L.Y. Influence of therapy ball seats on attentional ability in children with attention deficit/hyperactivity disorder. J. Phys. Ther. Sci. 2012, 24, 1177–1182.
46. Taipalus, A.C.; Hixson, M.D.; Kanouse, S.K.; Wyse, R.D.; Fursa, S. Effects of therapy balls on children diagnosed with attention deficit hyperactivity disorder. Behav. Interv. 2017, 32, 418–426.
47. Macphee, F.L.; Merrill, B.M.; Altszuler, A.R.; Ramos, M.C.; Gnagy, E.M.; Greiner, A.R.; Coxe, S.; Raiker, J.S.; Coles, E.; Burger, L.; et al. The effect of weighted vests and stability balls with and without psychostimulant medication on classroom outcomes for children with ADHD. Sch. Psychol. Rev. 2019, 48, 276–289.
48. Panagiotopoulou, G.; Christoulas, K.; Papanckolaou, A.; Mandroukas, K. Classroom furniture dimensions and anthropometric measures in primary school. Appl. Ergon. 2004, 35, 121–128.
49. Gouvali, M.K.; Boudolos, K. Match between school furniture dimensions and children’s anthropometry. Appl. Ergon. 2006, 37, 765–773.
50. Castellucci, H.; Arezes, P.; Molenbroek, J. Applying different equations to evaluate the level of mismatch between students and school furniture. Appl. Ergon. 2014, 45, 1123–1132.