Trends in Neuroscience and Education 17 (2019) 100117

Contents lists available at ScienceDirect

Trends in Neuroscience and Education

journal homepage: www.elsevier.com/locate/tine

Research paper

Screen-exposure and altered brain activation related to attention in preschool children: An EEG study

Michal Zivan[a,b], Sapir Bar[a,b], Xiang Jing[c], John Hutton[d], Rola Farah[a,b], Tzipi Horowitz-Kraus[a,b,d,*]

[a] *Educational Neuroimaging Center, Faculty of Education in Science and Technology, Israel*
[b] *Faculty of Biomedical Engineering, Technion, Haifa, Israel*
[c] *Department of Neurology, Cincinnati Children's Hospital Medical Center, OH, USA*
[d] *Reading and Literacy Discovery Center, Cincinnati Children's Hospital Medical Center, OH, USA*

ARTICLE INFO

Keywords:
Attention
Child development
EEG
Screen exposure

ABSTRACT

Exposure to screens has been shown to reduce attention span in children. Increased slow-wave (theta band) and decreased fast-wave (beta and gamma bands) generated from EEG, as well as increased theta/beta ratio, have been observed in children with Attention-Deficit-Hyperactivity-Disorder (ADHD). This study examined the relationship between 6-weeks screen exposure and attention abilities in typically developing preschoolers using EEG during rest. Theta and beta bands were compared, and visual attention and parental reports for attention abilities were controlled. Results suggested that the active control group showed improved visual-attention abilities following the exposure to stories, whereas the screen group did not show improved visual attention. EEG results suggested a higher connectivity in theta vs. beta bands in the screen group, but not in the control group. Results support the negative relationship between screen exposure and attention-related patterns generated from EEG in typically developing preschool children.

1. Introduction

Several cross-sectional and longitudinal studies have suggested that screen exposure may be associated with a decreased attention span in children and with deleterious effects on their cognitive abilities, behaviors, and academic performance [1–3]. Furthermore, learning processes have been shown to be inefficient when screens are used compared to learning via social interaction: studies on infants' language acquisition indicated that the ability to learn new information is significantly higher when learning through social interaction than when exposed to the same materials on the screen [4–7]. More specifically, one study showed that nine-month-old infants performing a foreign linguistic phonemic learning task during a social interaction compared to a different age-matched group who did not perform the task did not demonstrate learning when the same material was presented through a video on a screen [4]. Another study showed that toddlers learned new verbs better and at a younger age when they were exposed to a live social presenter compared to being exposed to the same materials presented only on screens [7]. Despite these studies, the mechanism for the relationship between screen exposure and attention abilities is not yet clear, with only a handful of studies showing the effect of screen exposure on decreased grey matter integrity [8] or decreased functional connectivity [9] in older children (8 years old and older). While these studies focused mainly on visual-processing regions and in a relatively older children population, there are no previous studies examining the relationship between screen exposure and neurobiological correlates for attention abilities in younger preschool-age children. One way of depicting the effect of screen-exposure on basic attentional mechanisms is by examination of electroencephalogram (EEG) recordings, specifically focusing on attention-related bands.

The delta band (< 4 Hz) and theta band (4–8 Hz) both reflect sleep and decreased vigilance states, whereas the alpha band (8–12 Hz) is related to a relaxed state and the beta band (13–30 Hz) is related to a concentration state [10]. The gamma band contains frequencies between 30 and 60 Hz and is related to attentional processes and specifically to selective attention [11–13]. Previous studies suggest that EEG patterns in children with attention deficit are characterized by a deviant pattern of baseline cortical activity [14]. These studies suggest an increased theta band or slow-wave activity [15–19] with decreased beta and gamma bands (fast-wave([16,20] in 6-18 year-old children with attention deficit compared to controls during resting-state tasks [16,20]. Interestingly, not only the bands themselves were related to attention abilities, but also the ratio between theta and beta was found to be increased in 6–18 year-old children with attention deficit

* Corresponding author at: Reading and Literacy Discovery Center, Cincinnati Children's Hospital Medical Center, Cincinnati, OH, USA.
E-mail address: tzipi.kraus@technion.ac.il (T. Horowitz-Kraus).

https://doi.org/10.1016/j.tine.2019.100117
Received 30 March 2019; Accepted 5 July 2019
Available online 06 July 2019
2211-9493/

compared to controls [16,17,21]. Children diagnosed with attention deficit also showed a negative linear correlation between the theta/beta ratio and the scores of an attention task [16]. However, the relationship between screen exposure and the theta/beta ratio in children has yet to be determined.

In this study, we aimed to determine the effect of 6-weeks screen-based stories-listening exposure compared to a story-telling intervention delivered by an interactive human presenter on attention abilities in 4–6-year-old children. More specifically, we compared the effect of screen exposure in the screen group vs. interactive storytelling in the storytelling group on the participants' attention abilities, as well as on the brain's electrical activity in theta and beta frequency bands, which are related to attention abilities. Based on previous studies, we hypothesized that the screen group would show EEG activity that was previously shown to be related to attention difficulties (i.e., increased activity at resting state in theta band vs. beta band) compared to the storytelling group.

2. Methods

2.1. Participants

Thirty preschool children, ages 4–6 years (average age 63.76 ± 6.72 months; 46.7% females), from a middle-class background, with normal developmental history, and without a history of attention difficulties were randomly divided into two intervention groups - screen-based stories listening ($n = 14$) and live-presented interactive storytelling ($n = 16$).

The two groups were matched for age (screen: Mean = 64.78 ± 7.23 months, story-telling: Mean = 62.87 ± 6.34 months; $t(28) = -0.772$, ns) and gender (screen: 50% females, storytelling: 43.8% females; $\chi^2 = 0.117$, ns). Participants were matched for attention abilities using both parental reports [Conners [22]; $t(28) = 0.961$; ns] and a performance task [TEA-Ch [23], Sky Search; $t(28) = -0.34$, ns; TEA-Ch [23], score; $t(28) = -0.842$, ns]. The two groups also were matched for both their verbal abilities [WPPSI [24], Naming; $t(27) = 0.316$; ns] and non-verbal abilities [WPPSI [24], Matrix; t(28) = 0.528, ns. See Table 1 for details.

The study was approved by the appropriate Institutional Review Board. Parents signed informed consent letters prior to participation. Families were compensated for their participation in the study.

2.2. Study procedure

Storytelling interventions were performed either using a screen for stories listening by the screen group or administered by an interactive experimenter to the storytelling group. Behavioral assessments for attention and basic cognitive abilities were performed before (Test 1) and after (Test 2) the intervention. EEG recording during a resting-state task was conducted in the laboratory after the intervention (Test 2).

2.2.1. Behavioral measures

To evaluate the intervention effects on attentional performance and compare that between the two intervention types, attention and cognitive abilities were assessed using a battery of behavioral measures and parental questionnaires before (Test 1) and after (Test 2) the intervention. Each behavioral-measures testing session lasted approximately 1.5 h.

The behavioral measures included baseline measures of 1) verbal abilities using the Naming subtest from the WPPSI [24], 2) non-verbal abilities using the Matrix task, from the WPPSI [24], and 3) attention abilities using visual and auditory attention subtests [Sky Search and Score subtests, from the TEA-Ch battery [23]]. In addition, parents were asked to fill out questionnaires related to the child's exposure to screens and storytelling at home and attention assessment using the Conners parental questionnaire [22] and the Behavior Rating Inventory of Executive Function (BRIEF; [25]).

2.2.2. Screen vs storytelling

The overall training for both groups (screen/storytelling) contained 18 sessions, 30 min each, and lasted for 6-weeks. The screen group watched recorded videos of age-appropriate books read by an experimenter. The video condition included a visual of the books' pages and audio of the reader's voice. The video was presented on a 15-inch laptop placed in front of the participants. An experimenter was sitting by the computer screen, but no interaction between the participants and the experimenter took place. Storytelling to the storytellling group was performed by the same experimenters who were reading the same books to which the screen group was exposed, while also asking the children questions about the story while they were reading it.

2.2.3. EEG data acquisition

Following the intervention, the participants were invited into the laboratory where they underwent an EEG recording during a resting-state condition. The data was recorded continuously from 64 electrodes mounted on a custom-made cap (EasyCap, Brain Products GmbH, Germany) according to the international10/20 system [26]. The data was sampled and stored at a rate of 500 Hz using an analogue band-pass filter of 0.1–70 Hz and 12-bit A/D converter. A ground electrode was placed on a special location at the front of the cap. All electrode impedances were maintained at 5 KΩ or less. During the resting-sate condition, the participants were guided to rest for 2 min with their eyes open, followed by another 2 min with their eyes closed.

2.3. Data analyses

2.3.1. Behavioral data analysis

To control for group differences before the intervention (Test 1), independent *t*-test analyses were performed comparing the baseline abilities prior to intervention between the two groups. To assess the intervention's effect on attentional performance, a 2 × 2 [Behavioral

Table 1
Differences between the screen exposure and the storytelling intervention groups before intervention (independent *t*-test/chi square test).

Measures	Screen (A) Mean (SD)	Storytelling (B) Mean (SD)	Contrast	*t*	Significance
Age (months)	64.78 (7.23)	62.87 (6.34)	A > B	−0.772	0.447
Verbal ability (Naming, WPPSI) Standard score	9.07 (2.53)	9.37 (2.53)	B > A	0.316	0.755
Non-verbal abilities (Matrix, WPPSI) Standard score	10.14 (3.32)	10.75 (2.98)	B > A	0.528	0.602
Visual attention (TEA-Ch, Sky Search) Standard score	7.14 (4.67)	6.56 (4.65)	A > B	−0.34	0.736
Auditory attention (TEA-Ch, Score) Correct items	2.28 (2.4)	1.62 (1.89)	A > B	−0.842	0.407
Attention and Hyperactivity parental report (Conners)	9.35 (6.94)	11.5 (5.24)	B > A	0.961	0.345

measures for Group (screen/storytelling), Test (Test1/Test 2)] Repeated Measures ANOVA was performed.

2.3.2. EEG data analysis

The brain waves activity recordings during the first 30 s of the resting-state task, to avoid loss of interest in the task, were analyzed using the CxC method (channel-cross-channel) of the 'EEG Studio' program (MEG Center, Cincinnati Children's Hospital Medical Center, Ohio, USA) [27,28]. First, the data were filtered for each of the tested frequency bands (theta, beta). Then, the covariance of each pair of channels was calculated for each band separately to create an overall covariance matrix per frequency band for each participant. The mean covariance values were used for the statistical analysis and were related as the functional connectivity measure.

To test the effect of screen exposure vs. storytelling on brain waves frequency bands, a 2 × 2 [Group (screen/storytelling)], Frequency bands (theta /beta)] Repeated Measures ANCOVA was conducted using the computed functional connectivity measure. To exclude the effect of the initial attention abilities, as well as the overall exposure to screen at home from the results, the Conners questionnaire score and the number of hours that the children were exposed to screens per day at home [following [9]; based on parental reports] were include as covariates of no interest.

2.3.3. Relationship between EEG data and parental report of attentional difficulties

To test the relationship between the EEG data and the parental reports of attentional difficulties, Pearson correlations were conducted between the parental questionnaires (Conners, BRIEF) scores and either the functional connectivity in theta band or the theta/beta functional connectivity ratio.

3. Results

3.1. Behavioral measures before intervention

The *t*-test analyses showed no differences between groups in visual attention, auditory attention, or verbal and non-verbal abilities. (See Table 1)

3.2. Intervention effects on attention abilities

Repeated Measures ANOVA showed a significant Group x Test interaction for the visual-attention measures [$F(1,28) = 7.525, p = 0.01$, $\acute{\eta}^2 = 0.212$] (see Fig. 1). Post hoc comparisons revealed that the storytelling group showed improved visual attention after the intervention [$F = 17.404, p < 0.001, \acute{\eta}^2 = 0.383$] while the screen group did not improve in visual attention after the intervention. No main effect of Group was found [$F(1,28) = 0.742, p = 0.396$, $\acute{\eta}^2 = 0.026$].

3.3. EEG frequency bands as a function of group

The repeated measures ANCOVA showed a significant Group x Frequency interaction [$F(1,26) = 5.302$; $p = 0.03$; $\acute{\eta}^2 = 0.169$] (See Fig. 2). Post hoc comparisons showed that the screen group had a higher functional connectivity in theta band compared to beta band [$F(1,26) = 17.267, p < 0.001, \acute{\eta}^2 = 0.399$], while the storytelling group showed no differences between the frequencies bands. No main effect of Group was found [$F(1,26) = 0.752, p = 0.394, \acute{\eta}^2 = 0.028$]. See Figs. 2 and 3 for these results.

3.4. Relationship between attentional assessment questionnaires and EEG patterns

A correlation was determined between the parental report of attention scores (Conners) and the functional connectivity in the theta band ($r = 0.39, p = 0.033$). A correlation was also determined between the BRIEF total score and the theta/beta ratio ($r = 0.407, p = 0.026$). More specifically the scales within the BRIEF that supported this relationship with the theta/beta ratio were the BRIEF monitoring scale ($r = 0.382, p = 0.041$) and the BRIEF meta-cognition scale ($r = 0.476$, $p = 0.008$)

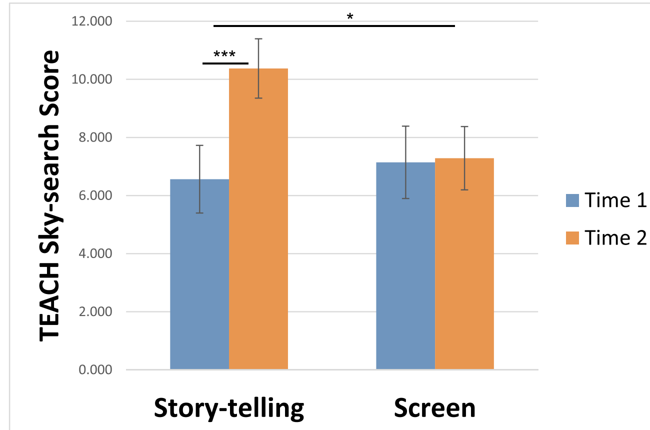

Fig. 1. Changes in visual attention following screen vs. storytelling intervention. Visual attention score as measured in scaled score before (blue) and after (orange) storytelling intervention (left) and screen intervention (right). ***$p < 0.001$, *$p < 0.05$. The *Y* axis represent standard scores from the Sky-search task [23]. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

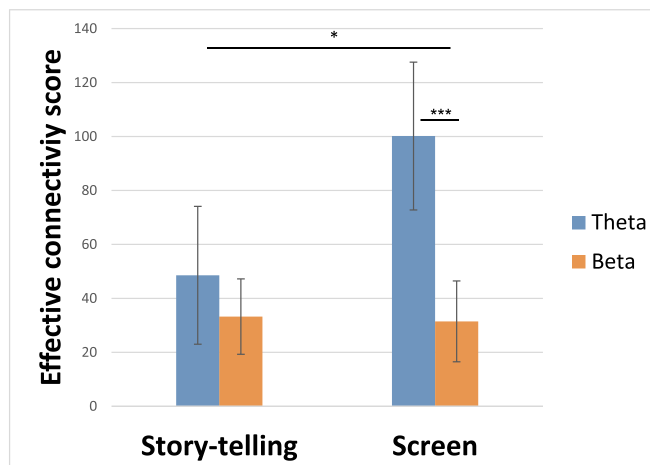

Fig. 2. Differences in functional connectivity in theta vs. beta frequencies between the screen and storytelling groups. Theta band (blue) vs. beta band (orange) frequencies of the storytelling group (left) vs. the screen group (right). ***$p < 0.001$,*$p < 0.05$. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

4. Discussion

The current study was designed to identify the relationship between 6 weeks of screen-based story listening vs. human-based storytelling and attention abilities accompanied by EEG patterns previously related to attention difficulties in preschool children. Supporting our hypothesis, children exposed to screens demonstrated higher functional connectivity in EEG frequencies related to attention difficulties, compared to the storytelling group. Our results support previous studies supporting the negative effect of screens on attention abilities in children [1–3]. Although the screens stimuli presented to the participants in the current study were stories with both visual and auditory stimulation

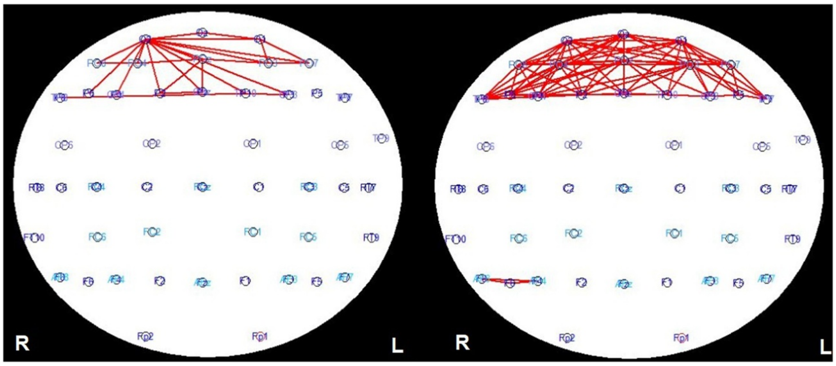

Fig. 3. Functional connectivity in the theta band: Storytelling (left) vs. Screen exposure (right). Red lines represent functional connectivity scheme (threshold = 80). Electrodes locations are noted in circles. Neurological orientation (R = right, L = left). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

(visual of pages of a book and an audio recording of the story), the passive gaze at the screen without the human interaction or the need to respond had an overall negative effect on the attention abilities of the screen group compared to the storytelling group. The negative effect of screens on learning was previously demonstrated in a group of young infants that watched sessions of a foreign language through video recording presented on a screen [4]. These children's sensitivity to this new learned language was examined following 12 sessions and was found to be significantly lower than in children exposed to the same stimuli mediated by an interactive experimenter. The aim of the current study was to investigate brain activity patterns during rest that might be related to screen exposure. The EEG findings suggest that exposure to screens enhances the EEG functional connectivity of the theta band compared to the beta band, a pattern that was previously found to be related to attention deficits [15–19]. Previous studies have shown an association between ADHD and decreased dopaminergic level [29–32]. This decrease is thought to be reflected in increased slow-wave activity [15,33]. These altered brain-wave activities among ADHD patients are normalized using stimulant medications [34]. The current study supports previous reports on EEG patterns related to children with ADHD and extend them with typically developing preschool children. Our results suggest a relationship between higher functional connectivity in the theta band, as well as higher theta/beta ratio, and also higher scores of attentional difficulties according to parental reports.

The results support previous functional MRI data during rest showing a correlation between increased screen time and reduced functional connectivity between visual processing regions and frontal regions related to attention abilities in 8–12 year-old children [9]. It may be that without an engaging activity or the need to respond or communicate, the exposure to screens in childhood, even with linguistic stimuli, reduces the attention levels similarly to a phenomenon of “brain wondering”. Overall, the results offer a possible mechanism related to enhanced theta vs. beta functional connectivity that underlies the behavioral cognitive changes observed between the two groups.

A recent study demonstrating the differences in animation vs. an illustration while listening to stories in preschool children may provide an interesting perspective relevant to the current results [35]. The researchers demonstrated that during an ongoing fMRI paradigm where children watched animated movies of children's books vs. watching pages of an illustrated book while listening to the story, functional networks related to attention to the stimuli, visual processing, language, and imagination showed reduced functional connectivity within and between the network [35]. The authors suggest that the animated condition, which represents the more “passive” movie condition usually used on screens, is much less engaging than the illustrated condition, which is more similar to a “storytelling” condition, and also engaged less networks related to attention and imagination, supporting our results [35].

On the other hand, storytelling seems to have a positive effect on attention abilities in young children. This positive effect of human interaction was previously reported [36–40]. In contrast to a passive attendance to the screen, children listening to stories told by the interactive experimenter engaged the children using eye contact and gestures prompting them to stay alert. This effect of social interaction has been reported to show a positive effect on learning and attention in children [36–40] that seems to result in brain patterns different than those observed in attention difficulties and improved visual attention abilities in this storytelling group. Our behavioral results further support these previous studies with improved visual attention after the interactive storytelling intervention, but not after the screen exposure intervention.

4.1. Study limitations

The results of the current study should be interpreted taking into account the following limitation. Since we did not collect the EEG data prior to intervention, we could not directly compare the effect of screen exposure vs storytelling within each group, not could we compare the EEG data in both groups prior to intervention. This limitation was addressed by controlling for the children's attentional and linguistic levels before the intervention.

5. Conclusions

Despite APA recommendation to reduce screen time in young children [41], the mechanism and effect of screen exposure on brain activation is still not clear. Our results support the negative influence of exposure to screens compared to storytelling among preschool children and suggest a link between screens vs. human storytelling and cognitive skills among pre-school children. Brain activity patterns, previously related to attention deficits, that were determined for the screen group, but not the storytelling group, suggest a mechanism underlying the behavioral differences between the two groups.

Conflict of interest

The authors declare no conflict of interest related to the data collected, analyzed and the data published in this paper.

Financial interest

The authors declare no financial interest or competing financial interest involved in study design, data collection and analyses and manuscript writing.

Ethical statement

The data was collected, analyzed and handled according to the principles outlined in the Helsinki guidelines for human research and according to the ethical committee of the Institution. The parents or legal guardians of the participants provided written consents for participation in this study

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.tine.2019.100117.

References

[1] D.A. Christakis, et al., Early television exposure and subsequent attentional problems in children, Pediatrics 113 (4) (2004) 708–713.
[2] J.G. Johnson, et al., Extensive television viewing and the development of attention and learning difficulties during adolescence, Arch. Pediatr. Adolesc. Med. 161 (5) (2007) 480–486.
[3] J.G. Johnson, et al., Television viewing and aggressive behavior during adolescence and adulthood, Science 295 (5564) (2002) 2468–2471.
[4] P.K. Kuhl, F.-M. Tsao, H.-M. Liu, Foreign-language experience in infancy: Effects of short-term exposure and social interaction on phonetic learning, Proc. Natl. Acad. Sci. 100 (15) (2003) 9096–9101.
[5] M. Krcmar, B. Grela, K. Lin, Can toddlers learn vocabulary from television? An experimental approach, Media Psychol. 10 (1) (2007) 41–63.
[6] M.B. Robb, R.A. Richert, E.A. Wartella, Just a talking book? Word learning from watching baby videos, Br. J. Dev. Psychol. 27 (1) (2009) 27–45.
[7] S. Roseberry, et al., Live action: Can young children learn verbs from video? Child Dev. 80 (5) (2009) 1360–1375.
[8] M.P. Paulus, L.M. Squeglia, K. Bagot, J. Jacobus, R. Kuplicki, F.J. Breslin, J. Bodurka, A. Morris, W.K. Thompson, H. Bartsch, S.F. Tapert, Screen media activity and brain structure in youth: evidence for diverse structural correlation networks from the ABCD study, NeuroImage 185 (2019) 140–153.
[9] T. Horowitz- Kraus, J. Hutton, More screen time correlates with decreased functional connectivity in reading-related brain regions, Human Brain Mapping Mapping Organization, Vancuver, Canada, 2017.
[10] T. Banaschewski, D. Brandeis, Annotation: what electrical brain activity tells us about brain function that other techniques cannot tell us – a child psychiatric perspective, J. Child Psychol. Psychiatry 48 (5) (2007) 415–435.
[11] J. Fell, et al., Is synchronized neuronal gamma activity relevant for selective attention? Brain Res. Rev. 42 (3) (2003) 265–272.
[12] A.K. Engel, P. Fries, W. Singer, Dynamic predictions: oscillations and synchrony in top–down processing, Nat. Rev. Neurosci. 2 (10) (2001) 704.
[13] A.A. Benasich, et al., Early cognitive and language skills are linked to resting frontal gamma power across the first 3 years, Behav. Brain Res. 195 (2) (2008) 215–222.
[14] R.J. Barry, A.R. Clarke, S.J. Johnstone, A review of electrophysiology in attention-deficit/hyperactivity disorder: I. Qualitative and quantitative electroencephalography, Clin. Neurophysiol. 114 (2) (2003) 171–183.
[15] S.M. Bresnahan, J.W. Anderson, R.J. Barry, Age-related changes in quantitative EEG in attention-deficit/hyperactivity disorder, Biol. Psychiatry 46 (12) (1999) 1690–1697.
[16] T. Shi, et al., EEG characteristics and visual cognitive function of children with attention deficit hyperactivity disorder (ADHD), Brain Dev. 34 (10) (2012) 806–811.
[17] A.R. Clarke, et al., Age and sex effects in the EEG: differences in two subtypes of attention-deficit/hyperactivity disorder, Clin. Neurophysiol. 112 (5) (2001) 815–826.
[18] I. Lazzaro, et al., Quantified EEG activity in adolescent attention deficit hyperactivity disorder, Clin. Electroencephalogr. 29 (1) (1998) 37–42.
[19] R.J. Chabot, G. Serfontein, Quantitative electroencephalographic profiles of children with attention deficit disorder, Biol. Psychiatry 40 (10) (1996) 951–963.
[20] R.J. Barry, et al., Resting-state EEG gamma activity in children with attention-deficit/hyperactivity disorder, Clin. Neurophysiol. 121 (11) (2010) 1871–1877.
[21] M.M. Lansbergen, et al., The increase in theta/beta ratio on resting-state EEG in boys with attention-deficit/hyperactivity disorder is mediated by slow alpha peak frequency, Prog. Neuro-Psychopharmacol. Biol. Psychiatry 35 (1) (2011) 47–52.
[22] C.K. Conners, Conners Rating Scales' Manual, Multihealth System, North Towonada NY, 1989.
[23] T. Manly, I.H. Robertson, V. Anderson, I. Nimmo-Smith, TEA-Ch: The Test of Everyday Attention for Children Manual, Thames Valley Test Company Limited, Bury St. Edmunds, UK, 1999.
[24] W. D., The Wechsler Preschool and Primary Scale of Intelligence, Third ed., The Psychological Corporation, San Antonio, TX, 2002 (WPPSI-III).
[25] G.A. Gioia, et al., Test review behavior rating inventory of executive function, Child Neuropsychol. 6 (3) (2000) 235–238.
[26] H.H. Jasper, The ten-twenty electrode system of the International Federation, Electroencephalogr. Clin. Neurophysiol. 10 (1958) 370–375.
[27] X. Ran, et al., Effects of gap junctions blockers on fast ripples and connexin in rat hippocampi after status epilepticus, Epilepsy Res. 146 (2018) 28–35.
[28] J. Xiang, et al., Volumetric imaging of brain activity with spatial-frequency decoding of neuromagnetic signals, J. Neurosci. Methods 239 (2015) 114–128.
[29] M. Avale, et al., The dopamine D4 receptor is essential for hyperactivity and impaired behavioral inhibition in a mouse model of attention deficit/hyperactivity disorder, Mol. Psychiatry 9 (7) (2004) 718.
[30] D. Leo, et al., Altered midbrain dopaminergic neurotransmission during development in an animal model of ADHD, Neurosci. Biobehav. Rev. 27 (7) (2003) 661–669.
[31] L. Zimmer, Positron emission tomography neuroimaging for a better understanding of the biology of ADHD, Neuropharmacology 57 (7–8) (2009) 601–607.
[32] K. Blum, et al., Attention-deficit-hyperactivity disorder and reward deficiency syndrome, Neuropsychiatr. Dis. Treat. (2008).
[33] F. di Michele, et al., The neurophysiology of attention-deficit/hyperactivity disorder, International Journal of Psychophysiology 58 (1) (2005) 81–93.
[34] A.R. Clarke, et al., Effects of stimulant medications on the EEG of children with attention-deficit/hyperactivity disorder, Psychopharmacology 164 (3) (2002) 277–284.
[35] J.S. Hutton, J. Dudley, T. Horowitz-Kraus, T. DeWitt, S.K. Holland, Differences in functional brain network connectivity during stories presented in audio, illustrated, and animated format in preschool-age children, Brain Imaging Behav. (2018) 1–12.
[36] G. Lebdeva, P. Kuhl, Individual differences in infant speech perception predict language and pre-reading skills through age 5, Annnual Meeting of the Society for Developmental and Behavioral Pediatrics, Portland, OR, 2009.
[37] P.K. Kuhl, Early language acquisition: cracking the speech code, Nat. Rev. Neurosci. 5 (11) (2004) 831–843.
[38] P.K. Kuhl, Is speech learning 'gated' by the social brain? Dev. Sci. 10 (1) (2007) 110–120.
[39] P.K. Kuhl, B.T. Conboy, S. Coffey-Corina, D. Padden, M. Rivera-Gaxiola, T. Nelson, Phonetic learning as a pathway to language: new data and native language magnet theory expanded (NLM-e), Philos. Trans. R. Soc. B 363 (2008) 979–1000.
[40] PK Kuhl, R. R., A Bosseler, JF Lin, T. Imada, Infants' brain responses to speech suggest analysis by synthesis, Proc. Natl. Acad. Sci. USA 111 (31) (2014) 11238–11245.
[41] American Academy of Pediatrics Council on Communications and Media, Children, adolescents, and the media, Pediatrics 132 (5) (2013) 958–961.