The Effects of Videogames on Full-term and Preterm Brain Structure and Attention

Humaira Afrin
humaira.afrin.stockholm@gmail.com

under the direction of
Samson Nivins, PhD
Department of Cognitive Neuroscience
Karolinska Institute

Research Academy for Young Scientists
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Abstract

The effect of playing video games on the developing brain during childhood is a huge topic of debate in society today. Some studies show that video games have an impact on behavior. Preterm birth is often associated with behavioural deficits and impaired motor difficulties. Previous studies have reported that children born preterm tend to spend more time playing video games as opposed to their full-term born peers. However, their effect on the brain and behavioural difficulties is less clear. Therefore, this study investigated the association between playing video games and children's attention ability and brain structure in children born full-term and preterm. Regression models were used for all the analyses. The relevant brain structures investigated were the surface area of the prefrontal cortex and, insula; and volumes of the basal ganglia, and total brain. Results showed that video games negatively affect attention among children born full-term. There was also an association between video gaming and the surface area of the brain region, particularly the insula. Overall findings suggest that video games do not improve preterm brain development. However, attention difficulties are observed in both children born preterm and at term.

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Contents

1 Introduction

There is an alarming trend of worsening psychological well-being among children due to heavy use of digital media [1]. In the modern and digitalized era, it is difficult to ostracize technology from our daily lives. From communication to entertainment, civilization is highly dependent on the use of digital technologies. One of the most common sources of entertainment today is playing video games. Playing video games is a medium of enjoyment, relaxation as well as challenge, and creativity. However, precisely due to their wide usage, it is important to investigate any potential negative effects. Like many other things, video games come with disadvantages too, for example, it can affect one's aggression. [2].

Recently, the prevalence of playing video games has increased amongst children, especially after the COVID-19 pandemic [3]. However, the major concern is the developmental phase of the brain, as children are in the crucial phase of development. It is less clear whether playing video games does any harm to the brain, such as disrupting development.

1.1 Brain Development

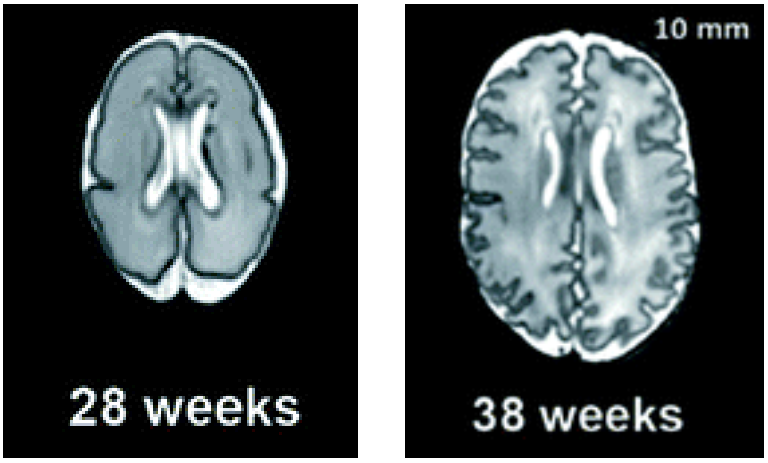
Brain development is influenced by neonatal factors such as birth weight, gestation length, socioeconomic status and environmental changes [4]. In particular during childhood the brain is highly responsive to surrounding stimuli and experiences have an impact on long term behaviour difficulties [5].

1.1.1 Preterm Brain Development

Preterm birth is often defined as babies born before 37 weeks of gestation, which comes with compromised brain function. It is associated with an increased risk of neuro-developmental and behavioural sequelae [6]. Previous studies have found that almost 50% of preterm children develop cognitive, language, and behavioral deficits at later ages [7]. In addition,

children born preterm have higher rates of motor difficulties and tend to spend more time gaming than their full-term born peers, which in turn might lead to behavioural problems. Studies have also shown a significant decrease in brain volume compared to full-term born peers with almost half the volume during early childhood [8]. Furthermore, previous studies have reported a significant relationship between the different brain structures and behavioural outcomes. For example, the limbic system plays an important role in controlling behaviour and emotions [9]. Another example is the association between hippocampus volumes and learning memory (i.e., smaller volumes of the hippocampus cause problems with learning and memory)[10].

Although we know these brain-behavior relationships, what is not known is how external factors could affect or alter these relationships. One such external factor is playing video games. Since video games are ubiquitous today, it is relevant to investigate the long-term effects of gaming, especially in the underdeveloped and developing brains of preterm birth. Studies investigating the effect of playing video games on behavioural problems in children born preterm are limited. We are not aware whether behavioral problems get worse or improved after exposure to video games. Therefore it is crucial to investigate the effects of playing video games on behavioural problems and how these intend to alter brain structure in children born preterm.



(a) Preterm Brain (b) Term brain

Figure 1: The difference in brain structure between preterm and full-term babies. As expected, the cortical folds in black enveloping the brain, is immensely greater in full-term babies compared to babies born preterm [11].

1.2 Factors Associated with Attention

One major concern with preterm birth is attention deficits. Preterm birth is associated with impairments in various attention indices [12]. Playing video games has had positive consequences in terms of attention ability among expert gamers over the age of 18 [13]. Limitations of this study included developed brains and no information regarding neonatal factors such as birth weight or gestational length. The ability to focus on limited stimuli is a complex cognitive process taking part in different brain regions. The main regions that control attention are the prefrontal cortex, basal ganglia and the insular cortex.

1.2.1 Prefrontal Cortex

The prefrontal cortex, is a part of the frontal lobe located most anteriorly in the cerebral hemisphere. It is responsible for higher cognitive functions such as the ability to pay attention to certain stimuli. It also involves the ability to filter information which is key to attention [14]. However, the preterm brain is associated with decreased grey matter volume and surface area in the prefrontal cortex which means an underdeveloped prefrontal cortex [14].

1.2.2 Basal Ganglia

The basal ganglia are a group of structures such as the caudate nucleus, putamen, and subthalamic nucleus, which are located deep within the brain [15]. It functions in motor learning, administrative work, attention, etc.Studies have shown that the preterm brain has a 15% risk of axonal/neuronal loss in the basal ganglia and 40% in the thalamus[16]. Moreover, Magnetic Resonance Imaging (MRI) data have supported decreased volume of basal ganglia and thalamus in preterm infants.

1.2.3 Insular Cortex

Insula is found deep within the lateral sulcus. It is an important brain region responsible for numerous cognitive functions such as attention and salience processing. The activation of the insula is associated with the autonomous detection of surrounding stimuli. [17]

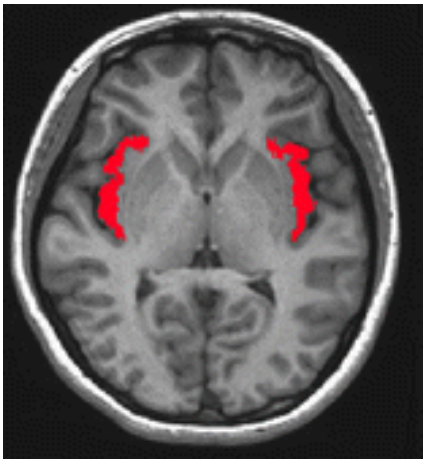


Figure 2: Left and right insular cortex marked in red [18].

1.3 Magnetic Resonance Imaging (MRI)

MRI scans are immensely useful for the study of brain structure. It provides higher resolution than a computed tomography(CT) scan and displays contrast between brain structure better without being exposed to radiation. The powerful magnets inside the MRI machine create a strong magnetic field by making the protons resonate with the field. A

computer detects the released energy from the protons to translate the information.

1.4 Aim of The Study

This study aims to investigate the association of playing video games and attention as well as brain structure such as the prefrontal cortex, insula, and basal ganglia differ on children born preterm and full-term. This study will also look at the effect of sex on these relationships.

2 Method

The study from the Adolescent Brain Cognitive Development (ABCD) was used to collect data using CBCL and MRI Screening. Participants were western and were recruited from 21 sites with consent from participants and their guardians. The collection of data from participants took place between September 1st, 2016, and August 31st, 2018. [19]

2.1 Participant's Data

The total cohort of this study was N= 6190 children aged between 9 to 10 years old(mean [SD] = 118.6 [7.3], i.e., 9.9 years); Of this cohort, children who were born at term, n (%) =5331 (86%) and children born preterm n(%) =850 (14%). Among children born full-term, there were 2575 girls and 2756 boys. As for the children born preterm 469 were boys and 390 were girls. The average time spent on gaming among term-born children was $0.9h$ and for children born preterm was $1h$.

2.1.1 Image Processing

Cortical measures were generated from T1-weighted images using the software Freesurfer 5.3.0. From this software, the surface area and volume of the relevant brain regions were used in this study. All the brain (MRI)-scans that had head-motion artefacts or other

abnormalities present were marked. The children that did not pass the quality controls during MRI scan were removed from the data set.

2.2 Child Behavior Checklist (CBCL)

The behavioural score was collected through a questionnaire filled by the teacher of the child to collect data about the child's school performance, attention, social behaviour, etc. The CBCL score was categorized into different behaviour. The lower the score the more well-developed behaviour. From this questionnaire the attention score was collected where the higher attention score showed poor attention ability.

2.3 Ordinary Least Squares regression (OLS) Modeling

OLS modelling estimates the slope, Beta (β) coefficient, of multiple linear regression. The data sets collected were analyzed through OLS regression modelling. The covariates controlled were age in months, sex, scanner sites, Socioeconomic status (SES), gaming time (h), and birth weight (lbs). The dependent variable investigated was attention score and the different brain regions (the prefrontal cortex (mm^3), basal ganglia (mm^3), insular cortex (mm^2) and total brain volume (mm^3). The beta (β) coefficient showed the slope and correlation between the variables and the p value was used to determine the likelihood of the relationships where a p-value <0.05 was considered to show strong significance in this study. The standard error (Stderr) showed the measurement uncertainty.

3 Results

Association between gaming time and attention (high CBCL score) as well as gaming time and the surface area of the insular cortex, prefrontal cortex, basal ganglia and total brain volume were looked into the overall cohort, preterm and term brain and between girls and boys.

3.1 Overall Cohort

Gaming is positively associated with CBCL attention score among the total cohort(beta coefficient, $\beta = 0.3625; [0.278 - 0.447]; p < 0.001$). There was a positive association between gaming and the surface area of the insula $\beta = 11.6502; [1.899 - 21.401]; p = 0.019$).

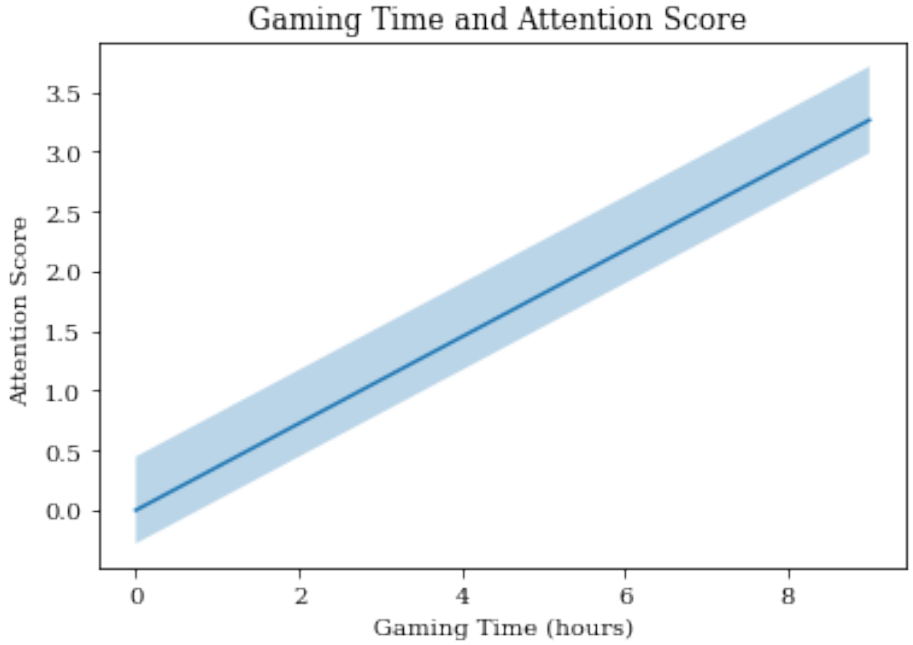


Figure 3: The regression line shows the correlation between gaming time and attention score among the total cohort. The shaded area shows 95% confidence interval.

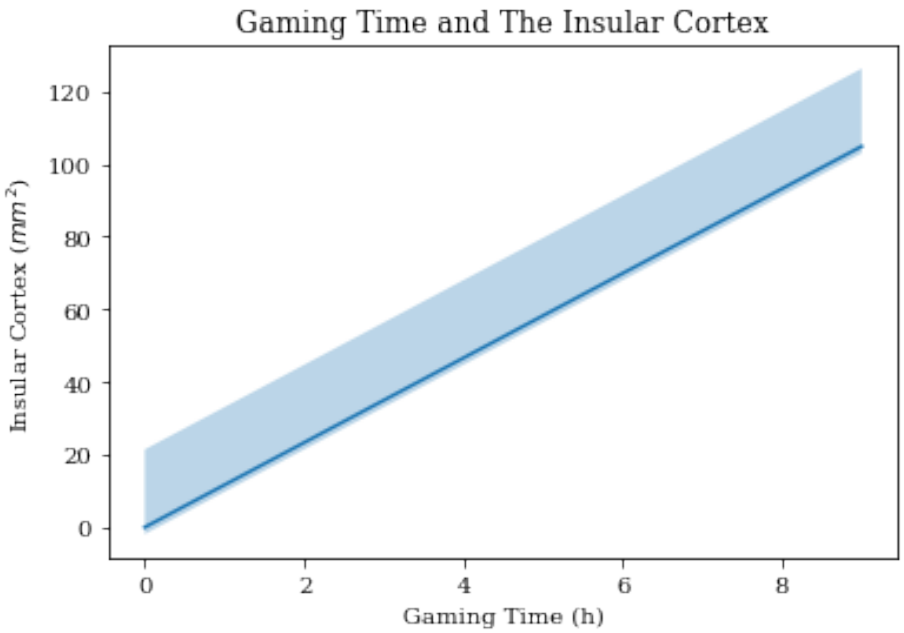


Figure 4: Correlation between gaming time and the surface area of the insular cortex among total cohort. The shaded area shows the 95% confidence interval.

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3.1.1 Preterm brain

Gaming had a positive trend with CBCL attention score for preterm brain ($\beta = 0.2165$, CI [-0.006 - 0.439] , p= 0.056) .Gaming time was not significantly associated with the surface area of the prefrontal cortex, total brain volume, insula or basal ganglia among children born preterm (see Table 1)

Table 1: β coefficient and p-value significance for gaming and attention as well as the brain structures.

OLS model	Prefrontal Cortex	Basal ganglia	Total brain	Attention	Insula
β	-31.0875	111.6187	77.1986	0.2165	12.9320
p-value	0.794	0.122	0.985	0.056	0.360

3.1.2 Term brain

Gaming was positively associated with attention scores in children born full-term (see Table 2). There was also an association found between gaming and the surface area of insula 2. There was no association between gaming and the prefrontal cortex, basal ganglia, and whole brain .

Table 2: Beta (β) coefficient, p-value and 95% confidence interval for attention and the relevant brain regions among children born at term.

OLS model	Prefrontal Cortex	Basal ganglia	Total brain	Attention	Insula
β	9.5807	-23.2235	124.7938	0.3849	10.8798
P-value	0.839	0.406	0.937	$<$0.001	0.039

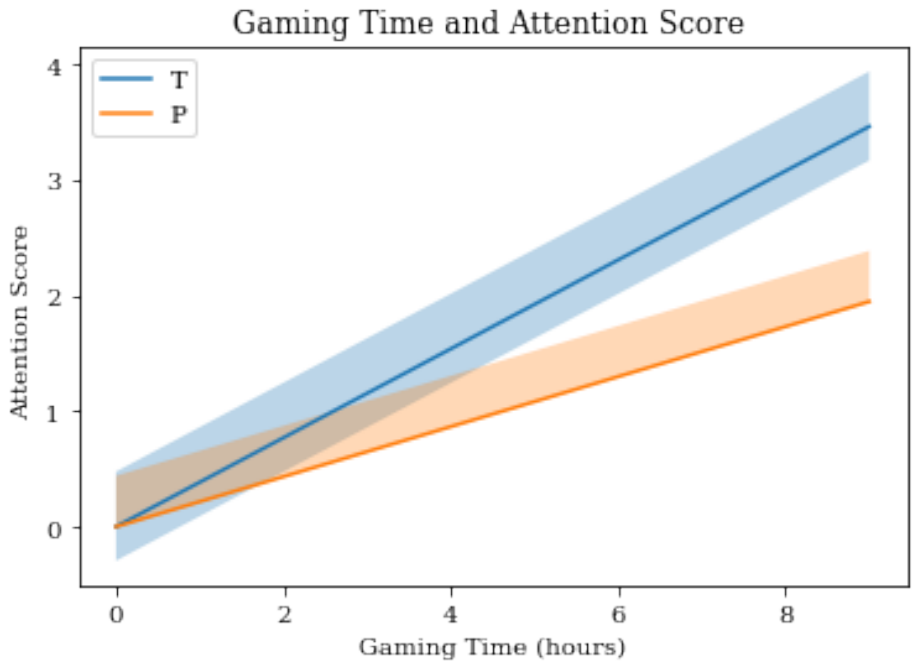

Figure 5: Correlation between gaming time and attention score among children born full-term (T) and preterm (P). Positive trend in both cases. Consider the p-value in table 1. The shaded areas show the 95% confidence interval.

Association between gaming and insula among children born at term and preterm with p-value significance (0.019) for children born full-term.

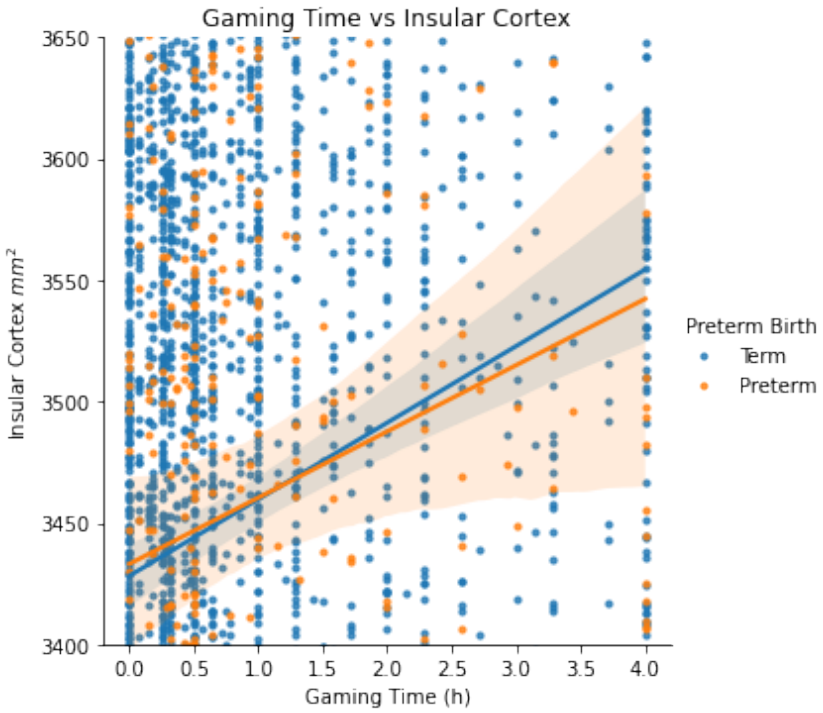

Figure 6: Correlation between gaming time and the surface area of insula among children born preterm and at term. The shaded area shown 95% confidence interval.

3.2 Boys and Girls

Association between playing video games and sex among term and preterm girls and boys attention score.

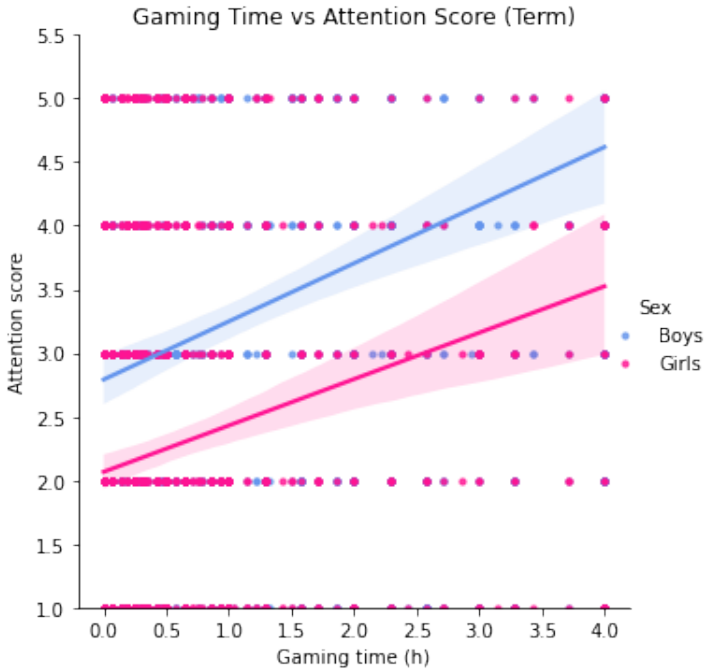

Figure 7: Gaming and Attention association between girls and boys born full-term.

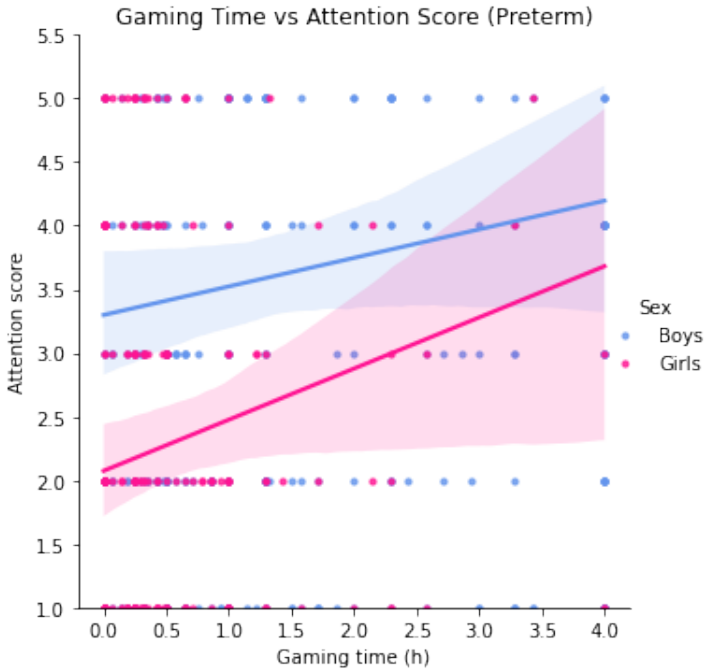

Figure 8: Gaming and Attention association between girls and boys born preterm.

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Table 3: Association between the attention score among boys in general, born at term and preterm.

Variables	β	Stderr	CI	P-value
Total cohort	0.3712	0.058	[0.258 0.484]	<0.001
Term	0.3849	0.046	[0.294 0.476]	<0.001
Preterm	0.1717	0.144	[-0.110 0.454]	0.232

Table 4: Association between attention score among girls in general, born at term and preterm.

Variables	β	Stderr	CI	P-value
Total cohort	0.3190	0.065	[-0.362 -0.148]	<0.001
Term	0.3211	0.069	[0.185 0.457]	<0.001
Preterm	0.2165	0.113	[-0.006 0.439]	0.056

4 Discussion

According to the results, longer exposure to plating video games was associated with a lower attention ability (high CBCL attention score) in the overall cohort (see Figure 3). A higher attention score depicts problems regarding attention ability and attention span. There was also a positive association between playing video games and the surface area of the insula among the overall cohort (see Figure 4) and children born at term. However, no significant association was found between gamin and attention score as well as structural alteration among children born preterm. Girls and boys had also different associations with playing video games and attention scores whereas in both term and preterm cases, boys had higher attention scores (poor attention ability) with gaming time (see Figure 7 and 8). Additionally, boys among the total cohort have also an association between

playing video games and the larger the surface area of the insular (see table 3).

4.1 Gaming vs Attention

One reason why attention scores among children born at term have a stronger association with playing video games, compared to children born preterm could be because both have different development trajectories. The brain maturation of children born at term peaks around the age of 9-10 years. However, premature children have an unknown developmental trajectory. Although it can be assumed that their peak of development is after the age of 9-10. It can also be supposed that both development peaks are not identical. This could mean that the behavioural and structural alteration in the brain could be detectable with a long-term study. Another factor that plays a pivotal role in why no relationship was found in the preterm cohort is the fact that the participants' size is inadequate. The sample size for children born at term was higher than preterm which could influence the results.

When it comes to the effect of playing video games on attention among boys and girls, it is found that in overall cohort and children born full-term, boys have a stronger association with playing video games and attention deficit. According to participants' data boys tend to spend more time gaming on average 0,92h [SD= 1,4]. However, no conclusion can be made from the preterm study since the p-value is not significant.

4.2 Gaming vs Brain Structure

There was no significant association between playing video games and the prefrontal cortex, basal ganglia, and total brain volume. A similar association was also found in subgroups (i.e., children born preterm and at term). However, in the cases of overall cohort and children born full-term, insula structure is associated with playing video games. The relation between attention and different brain structure was also studied but results

show no significant association between attention and brain alteration in structure when it comes to the prefrontal cortex, basal ganglia, and total brain volume.

The regression model for the total cohort and children born at term depicts an association between gaming and attention as well as gaming the surface area of insular. To investigate any alteration in brain structure among children born preterm it is crucial to do a long-term study since their growth trajectory differ compared to children born full-term. Even though this study controlled for age, sex, birth weight, socioeconomic status, etc. unknown confounders could affect behavioural and brain development.

4.3 Further Research

Since this study was not longitudinal it is important to further investigate the structural alteration, especially since preterm brain development will require long-term follow-up. Controlling the type of video game as well as time spent on gaming would also give a more accurate association for future studies. Brain waves and signals could also be relevant for the study of behavioural outcomes.

4.4 Conclusion

In the overall cohort, playing video games affected the attention span in children and was more prevalent amongst children born at term. Children born preterm did not benefit from playing video games. However, children born at term were affected by playing video games, particularly the insular cortex. There is a similar trend between playing video games and attention among children born preterm, but it is not statistically significant.

References

[1] Bruggeman H, Van Hiel A, Van Hal G, Van Dongen S. Does the use of digital media affect psychological well-being? An empirical test among children aged 9 to 12. Computers in Human Behavior. 2019;101:104-13.

[2] Scott D. The effect of video games on feelings of aggression. The Journal of Psychology. 1995;129(2):121-32.

[3] Haug E, Mæland S, Lehmann S, Bjørknes R, Fadnes LT, Sandal GM, et al. Increased Gaming During COVID-19 Predicts Physical Inactivity Among Youth in Norway—A Two-Wave Longitudinal Cohort Study. Frontiers in Public Health. 2022;10.

[4] Caputo DV, Mandell W. Consequence of low birth weight. Developmental Psychology. 1970;3(3p1):363.

[5] Lenroot RK, Giedd JN. The changing impact of genes and environment on brain development during childhood and adolescence: initial findings from a neuroimaging study of pediatric twins. Development and psychopathology. 2008;20(4):1161-75.

[6] Peterson BS. Brain imaging studies of the anatomical and functional consequences of preterm birth for human brain development. Annals of the New York Academy of Sciences. 2003;1008(1):219-37.

[7] Allin M, Walshe M, Fern A, Nosarti C, Cuddy M, Rifkin L, et al. Cognitive maturation in preterm and term born adolescents. Journal of Neurology, Neurosurgery & Psychiatry. 2008;79(4):381-6.

[8] Ment LR, Kesler S, Vohr B, Katz KH, Baumgartner H, Schneider KC, et al. Longitudinal brain volume changes in preterm and term control subjects during late childhood and adolescence. Pediatrics. 2009;123(2):503-11.

[9] Rajmohan V, Mohandas E. The limbic system. Indian journal of psychiatry. 2007;49(2):132.

[10] Driscoll I, Hamilton DA, Petropoulos H, Yeo RA, Brooks WM, Baumgartner RN, et al. The aging hippocampus: cognitive, biochemical and structural findings. Cerebral cortex. 2003;13(12):1344-51.

[11] Belfort MB, Ehrenkranz RA. Neurodevelopmental outcomes and nutritional strategies in very low birth weight infants. In: Seminars in Fetal and Neonatal Medicine. vol. 22. Elsevier; 2017. p. 42-8.

[12] Burstein O, Zevin Z, Geva R. Preterm birth and the development of visual attention during the first 2 years of life: a systematic review and meta-analysis. JAMA network open. 2021;4(3):e213687-7.

[13] Alsaad F, Binkhamis L, Alsalman A, Alabdulqader N, Alamer M, Abualait T, et al. Impact of Action Video Gaming Behavior on Attention, Anxiety, and Sleep Among University Students. Psychology Research and Behavior Management. 2022;15:151.

[14] Lacaille H, Vacher CM, Penn AA. Preterm birth alters the maturation of the GABAergic system in the human prefrontal cortex. Frontiers in Molecular Neuroscience. 2021;14.

[15] Lanciego JL, Luquin N, Obeso JA. Functional neuroanatomy of the basal ganglia. Cold Spring Harbor perspectives in medicine. 2012;2(12):a009621.

[16] Ortinau C, Neil J. The neuroanatomy of prematurity: normal brain development and the impact of preterm birth. Clinical Anatomy. 2015;28(2):168-83.

[17] Uddin LQ, Nomi JS, Hébert-Seropian B, Ghaziri J, Boucher O. Structure and function of the human insula. Journal of clinical neurophysiology: official publication of the American Electroencephalographic Society. 2017;34(4):300.

[18] Jang JH, Kim JH, Yun JY, Choi SH, An SC, Kang DH. Differences in functional connectivity of the insula between brain wave vibration in meditators and non-meditators. Mindfulness. 2018;9(6):1857-66.

[19] Casey BJ, Cannonier T, Conley MI, Cohen AO, Barch DM, Heitzeg MM, et al. The adolescent brain cognitive development (ABCD) study: imaging acquisition across 21 sites. Developmental cognitive neuroscience. 2018;32:43-54.

A Interaction

The statistical interaction between gaming and attention as well as the surface area of the insula among the sub-cohort of children born at term and preterm.

Table 5: Interaction between gaming and attention between children born at term and preterm and the interaction between gaming and the surface area of the insula between children born at term and preterm

Variables	β	Stderr	CI	P-value
Gaming:Attention	-0.1175	0.114	[-0.341-0.106]	0.304
Gaming: Insula SA	-7.3794	11.744	[-30.403 - 15.644]	0.530

According to the interaction model the results are not statically significant or realistic. Therefore gaming could not be considered to be the only factor to Attention deficits or the increase of the surface area of insula.