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Television viewing duration during childhood and long- association with adolescent neuropsychological outcomes

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ABSTRACT

This study is aiming to evaluate the association between television viewing during childhood and long-term adolescent neuropsychological outcomes and the potential explanatory pathways. This is a longitudinal study based on 278 children participating in the INMA birth cohort (1998) in Menorca Island, Spain. The exposure is parent-reported duration of child television viewing (hours per week) at 6 and 9 years of age. Neuropsychological outcomes were assessed at 14 years of age using the N-back test. Behavioral outcomes at 14 years of age were assessed using the Strengths and Difficulties Questionnaire (SDQ) and school performance was assessed by the global school score. Regression models were developed to quantify the associations between duration of television viewing and neuropsychological outcomes adjusted for child and parents' characteristics. The average of weekly TV viewing from 6 to 9 years was 9.2 h (SD: 4.1). Only N-back test outcomes exhibited statistically significant differences in crude models. Children viewing >14 h per week tended to show larger latencies in working memory reaction time (HRT in ms), beta (CI) = 53 (0–107). After adjusting for potential social confounders, the association weakened and became non-significant but adverse trends were slightly preserved. Early life TV viewing was not associated with adolescent neuropsychological outcomes after adjustment for potential confounders. Further research including larger and exhaustive population-based cohort studies is required in order to verify our conclusions.

1. Introduction

In the past years, there has been a dramatic increase in the use of television and digital media. Nowadays media plays a central and ever increasing role in the lives of children and adolescents [1]. This has raised a question on whether media affects neuropsychological development in children and adolescent. Some studies have aimed to address the potential health effects of media exposure over the years but the effects remain unclear due to the complexity of the exposure and the possible confounders such as socio-economic status, family structure and mother's mental health [2–5].

The American Academy of Pediatrics (AAP) in 2011 reaffirmed its original 1999 statement on children and media, leaving it essentially unchanged [6]. AAP discourages television viewing in the first two years of life and recommends a daily limit of 1 to 2 h of quality programming for older children. Despite these recommendations, many studies in the last ten years have shown most of children surpass this recommended exposure time [7–8].

Available evidence on the impact of television watching and media use on neuropsychological development is inconsistent. While a few cross-sectional studies and fewer longitudinal studies suggest adverse effects, others suggest media has a beneficial effect on neuropsychological development [9,10]. Such inconsistency can be partly attributed to

Abbreviations: AAP, American Academy of Pediatrics; d′, Accuracy; HTR, Hit Reaction Time; INMA, INfancia y Medio Ambiente Project; SDQ, Strengths and Difficulties Questionnaire; SD, Standard Deviation; TV, Television.

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different methodologies applied by these studies. The majority of studies available are cross-sectional by design and have a limited capability to establish a causal link. To establish such a link an experimental study would be ideal although it would require an unlikely long term modification of lifestyle factors to study of the possible cognitive effects of television viewing on children. A longitudinal design is warranted in order to attribute certain degree of causality in the association, particularly in population-based cohort studies followed consistently for long-term periods.

The aim of this study was to evaluate the association between television viewing time during childhood and long-term adolescent neuropsychological outcomes including cognitive performance, mental health, and school performance, as well as to explore and the potential explanatory pathways.

2. Methods

2.1. Population and study design

This study was conducted in an established population-based birth cohort in Menorca, Spain, which is a member of the INMA (INfancia y Medio Ambiente) network of birth cohorts [11]. In INMA cohorts, mothers were recruited at the first prenatal check-up if they met the inclusion criteria [1] to be resident in the cohort area, [2] to be at least 16 years old, [3] to have singleton pregnancy, [4] to not have followed any program of assisted reproduction, [5] to wish to deliver in the reference hospital and [6] to have no communication problems. Further description of INMA cohorts have been detailed elsewhere [11]. In the Menorca cohort, recruitment of pregnant woman began in 1997–1998 ($n = 482$, 94% eligible). Written consent was obtained from all participants at recruitment and before each follow-up. At the final follow up (year 2012) there was a 58% of participation rate ($n = 278$). The study was approved by the appropriate ethical committees, and written informed consent was obtained from the parents of all children before enrollment in the study.

2.2. Main exposure: television viewing time

Data were obtained prospectively by interviewing the children and their parents using standardized questionnaires completed by trained evaluators. Children were assessed with repeated measures on time spent watching television at 6, 9 and 14 years old. The child's television viewing duration was assessed according to parental report at 6 and 9 years of age by asking the following open-ended question "How many hours per week does your child watch television?" We constructed a four part categorical variable with the mean of weekly television viewing duration at 6 years and at 9 years. The groups were: reference group (children viewing <7 h/w), short duration (from 7 to 9 h/w), medium duration (from 10 to 13 h/w) and long duration (>14 h/w). Since the American Academy of Pediatrics recommends watching <2 h per day [6] (14 h per week), children surpassing the recommended time are found in the last group.

2.3. Main outcomes: neuropsychological outcomes

Neuropsychological assessments were conducted at the 14 year old follow-up using the N-Back test by trained examiners. This test has been employed to investigate the neural basis of working memory processes and for the purpose of this study consists of a series of 2 different stimuli (numbers and words) presented in the center of the screen. All participants are required to press a specific button whenever a given stimulus is the same as the one presented *n* trials previously (1-, 2- and 3-back) [12]. Hit Reaction Times (HRTs) are obtained for each of the n trails (e.g. HRT2). An average HRT is computed from the hits of each load separately. As a measure of response accuracy, the d prime (d') was calculated as a measure of detection, for each block separately. Higher d' indicates better signal detection whereas higher HRT indicates more time for reaction.

2.4. Other outcomes

The Strengths and Difficulties Questionnaire (SDQ) was used to evaluate children's behavioral functioning at 14 years old. The SDQ questionnaire consists of four difficulties subscales including emotional symptoms, conduct problems, hyperactivity/inattention, and peer relationship problems, and a strengths subscale for pro-social behavior. Each subscale comprises five items that can be scored zero, one, or two, with each total subscale score can range from zero to 10. An SDQ total difficulties score (range 0–40) was calculated by summing the scores of the four difficulties subscales (i.e. all subscales except for pro-social) [13]. Higher scores for total difficulties and individual difficulties subscales indicate more behavioral problems. For this study, the total SDQ score was used as a continuous variable in our analyses.

School performance at 14 years of age was obtained through the question "Which was the global mark in your last course?" The marks were classified into the following categories: fail (1–4.9), pass (5–6.9), good (7–8.4) and excellent (8.5–10).

2.5. Confounding and mediating variables

Data was obtained through standardized questionnaires administered to the parents in each follow-up visit by a trained examiner. These questionnaires included socio-demographical characteristics of the parents and information about child lifestyles (physical activity, sleeping duration, cultural activities). The children's cognitive background was obtained by a trained psychologist using different tests (Bayley's and McCarthy Scales). Other variables such as anthropometric measures were obtained through review of clinical reports and parental mental health (SCL90-R) and maternal IQ (Factor G Catell) were obtained by self-completed rating scales and a trained psychologist, respectively.

A priori, we took into consideration an extended list of confounders (Appendix 1) including: age in years at test, sex, body mass index at 14 years, parental education level and parental social class (both indicators of socio-economical status), having babysitter at 4 years and mother alcohol and tobacco consumption during pregnancy.

Mediating variables (i.e. variables in the causal pathway between TV viewing time and neuropsychological outcomes) were obtained from the questionnaires and tests administered at the 6 and 9 year follow-up. The child physical activity and sleep duration were assessed according to parental report at 6 and 9 years of age. For each mediating factor, a new variable was created using the mean of hours per week at 6 and 9 years of age. Cultural activities (theatre, languages) only were asked at 9 years of age and a new variable was constructed with hours per week practicing these kinds of activities. Television viewing time at 14 years was obtained through the same question as at ages 6 and 9 years and a continuous variable was constructed.

2.6. Statistical analysis

Of all 14 year old participants, 80% had complete data on neuropsychological development and the main covariates and were included in the final analysis ($n = 278$). Linear regression models were used to estimate the effects of television exposure on neuropsychological test outcomes. School marks were not shown in Section 3 as no crude association was found. Minimally-adjusted models included age at test as a mandatory child variable.

Correlations between the three measures of TV viewing times (6, 9 and 14 years of age) were analyzed. To address confounding, bivariate analyses were conducted. Predefined variables were selected a priori based on available literature (Appendix I). However, covariates were included in the final model only when they showed a crude association

with both the exposure and the outcome (p-values < 0.20) and they were retained in the final fully adjusted model only if they modified the coefficient by >10%. Covariates retained in each model are listed in Result table footnotes. DAG models were also constructed as an alternative method (Appendix II). Since DAG final results were similar to that observed in stepwise models, data is not shown.

Supplemental analyses were conducted in order to examine the role of possible intermediate factors (physical activity, sleeping habits and cultural activities) using the Baron and Kenny method with regression models to test mediation. In these analyses, minimally-adjusted models included all the covariates found in the analyses performed above and were compared to other two models. Collapsed model (all covariates and mediators were included) and separate models excluding only each intermediate factor each time.

Statistical analyses were performed using STATA Special Edition 12.1 (Stata Corp, College Station, TX, USA).

3. Results

On average, children watched 7.7 (SD: 4.3) hours of TV per week at 6 years and 10.7 (SD: 5.7) hours/week at 9 years. The average of weekly TV viewing from 6 to 9 years was 9.2 (SD: 4.1) hours. A description of the characteristics of the study population by duration of TV viewing is shown in Table 1. In the bivariate analysis, boys watched more hours of TV per week compared to girls. Children with a BMI of >25 kg/m [2] were associated with being more likely to watch more television. Children who lived in homes with lower social class and lower parental education, as 50% of the mothers and 64% of the fathers who belong to a manual social-class have stronger association with TV viewing duration. Almost 60% of the children did not have babysitter at 4 years which was associated with longer television viewing. Related to children lifestyles, less average of sleep per day and longer duration of TV viewing in childhood were associated with more TV viewing at 14 years of age (Table 1). At the 14 years old visit, the median of television viewing per week increased and was 21 h per week. Moderate correlations coefficients were observed between 6 and 9 years exposure (0.34) and between 9 and 14 years of age (0.23).

Table 2 is a description of neuropsychological outcomes of children at 14 years of age by duration of TV viewing time at 6 and 9 years of age. Some of the N-back test outcomes exhibited differences statistically significant between children viewing TV <9.5 h compared to children viewing TV >14 h per week. Children classified in this last group tended to show larger latencies in working memory reaction time (HRT). We found no relevant differences in the other outcomes except for d′ in 3-back-words tests which showed better scores with those children viewing less TV.

Table 1
Study variables of interest by duration of TV viewing at child's 6 and 9 years of age (Menorca, 1998–2012).

Variables of interest		TV viewing time (h/w)				All
		Reference group <7 (n = 88), median	Short duration 7–9 (n = 86), median	Medium duration 10–13 (n = 61), median	Long duration ≥14 (n = 43), median	
Child						
Sex (%)*	Female	58.49	41.35	52.43	40.35	48.62
	Male	41.51	58.65	47.57	59.65	51.38
BMI (%)[a,*]	≥25 kg/m^2	6.82	14.56	19.23	20.0	14.33
Babysitter (%)[b,*]	No	62.26	68.94	65.05	78.95	67.59
Visited a psychologist(%)[c]	Yes	23.58	27.07	20.39	17.54	23.06
MSCA[b]		89	91	91	91.5	91
CPSCS[b]		96	94	91	95	94
ADHD - DSM-IV (%)[b]	>PC80	15.73	16.52	18.89	19.57	17.35
Mother						
Social class (%)[d,*]	CS I + II	21.15	13.95	9	7.14	13.62
	CS III	34.62	36.43	34	25	33.68
	CS IV-VI	25	39.53	32	42.86	34.19
	housewife	19.23	10.08	25.00	25.00	18.51
Education level(%)[d,*]	Primary or less	45.19	53.13	62.50	69.64	55.73
	Secondary	32.69	29.69	29.17	26.79	29.95
	University	22.12	17.19	8.33	3.57	14.32
Marital status(%)[e]	Without a stable partner	23.68	17.82	19.72	24.39	20.76
Mental health (SCL90-R) (%)[f]	>PC 80	18.18	19.33	22.34	24.49	20.50
Maternal IQ (Factor G Catell) (%)[f]	>PC 50	32.08	26.32	36.89	35.09	31.83
Alcohol use during pregnancy (%)*	Yes	4.72	7.52	11.65	14.04	8.77
Smoking during pregnancy (%)	Yes	17.92	17.29	22.33	28.07	20.30
Father						
Social class(%)[d,*]	CS I + II	19.05	13.28	21.57	10.71	16.62
	CS III	24.76	21.09	17.65	8.93	19.44
	CS IV–VI	56.19	65.63	60.78	80.36	63.94
Education level(%)[d,*]	Primary or less	52.83	72.09	63.64	71.93	64.71
	Secondary	34.91	21.71	26.26	24.56	26.85
	University	12.26	6.20	10.10	3.51	8.44
Children lifestyles						
Sleep duration (h/w)[c,e,*]		10.1	9.9	9.7	9.6	9.9
Physical activity (h/w)[c,e,*]		3.5	3.5	3	3.5	3.5
Cultural activities (h/w)[c]		0.75	0	0.5	0	0
Television viewing duration at 14 years (h/w)[a,*]		17.5	21	24.5	26.5	21

[a] 14 year follow-up.
[b] 4 year follow-up.
[c] 9 year follow-up.
[d] Pregnancy follow-up.
[e] 6 year follow-up.
[f] 11 year follow-up.
* p-Value < 0.20 for X^2 tests of differences of percentages by TV viewing time categories.

Table 2
Child neuropsychological outcomes at 14 years old by duration of TV viewing at 6 and 9 years of age (Menorca, 1998–2012).

Child outcomes, ($n = 278$)	All participants, median (range)	TV viewing time (h/w)				p-Trend*
		Reference group <7 ($n = 88$), median	Short duration 7–9 ($n = 86$), median	Medium duration 10–13 ($n = 61$), median	Long duration ≥14 ($n = 43$), median	
N-back test						
HRT1numbers (ms)	467 (272–857)	470	449	465	520	0.052
HRT2numbers (ms)	514 (260–802)	511	520	508	517	0.656
HRT1words (ms)	498 (300–858)	470	499	515	502	0.184
HRT2words (ms)	552 (327–873)	534	571	551	570	0.010
HRT1 global (ms)	730 (459–1161)	721	716	741	760	0.065
HRT2 global (ms)	805 (489–1160)	775	829	805	840	0.027
D2numbers	3.92 (0.5–3.91)	3.92	3.92	3.92	3.92	0.231
D3numbers	1.39 (−0.49–3.03)	1.39	1.42	1.28	1.52	0.314
D2words	3.92 (−0.3–3.92)	3.92	3.92	3.92	3.92	0.736
D3words	1.39 (−0.72–3.03)	1.52	1.28	1.42	1.28	0.096
SDQ	9 (1–25)	9	9	8.5	9	0.899
School performance	6.5 (0−10)	7.5	6.5	6.5	6.5	0.432

SDQ: strengths and difficulties questionnaire.
* p-Value for trend using crude linear regression models.

Table 3 presents the coefficients and 95% CI of association between the duration of television viewing at 6 and 9 years of age and the main N-back outcomes at 14 years of age from crude and adjusted regression models. The HRT1 global model, which is the outcome including both stimulus (numbers and words), showed a downwards trend suggesting that children viewing TV >14 h per week performed worse in the test at a statistically significant level in the crude models. The same tendency is noted in HRT2 global. In adjusted models, regression coefficients were reduced to not statistically significant levels but slightly preserved the similar trends as crude models. Maternal social class seemed to have a notable effect in the regression coefficients (data not shown). Neither interactions with social class nor collinearity with the confounders were found between the exposure and the main outcomes (data not shown). Neither sex nor ADHD diagnosis were shown to materially change the results. SDQ and school performance did not show any adjusted association with TV viewing duration (Table 2).

We also examined the possible pathways leading to the association between TV viewing time and neuropsychological outcomes. Adjusted models by potential intermediate factors statistically related with the exposure and outcome are described in.

Table 4. Television viewing at 14 years old showed no coefficient changes with its inclusion and exclusion from the models (data not shown). Cultural activities at 9 years were not tested because of the lack of association with the exposure. Once we excluded physical activity, a moderate increase in the beta coefficient (30%) were noted in those children watching TV >14 h per week. No other coefficient changes were observed with the exclusion of sleep duration. However, as previous adjusted models showed in Table 3, none of the regression coefficients shown in Table 4 were statistically significant.

4. Discussion

In this longitudinal population-based study of children followed from birth to 14 years of age, average weekly TV viewing by children between 6 and 9 years of age was not associated with lower adolescent cognitive, behavioral and school performance scores. In our cohort, after adjustment for socio-demographical factors, there was no significant longitudinal association between children over passing AAP TV exposure threshold (>2 h/day) and adverse working memory outcomes. Meanwhile, some consistencies with adverse trends between crude and adjusted models were maintained, suggesting a need for more data on cognitive scores and this sedentary behavior in larger population-based cohort studies.

As opposed to our results, in the Longitudinal Survey of Youth-Child (NLSY) [14], investigators reported that TV and video viewing before the age of 3 was associated with lower Peabody Reading Achievement and Wechsler Memory for Digit Span scores at age 6 years, the latter being an indicator of working memory. Lower working memory is

Table 3
Crude and adjusted models of child television viewing duration at 6 and 9 years of age and neuropsychological outcomes at 14 years of age (Menorca, 1998–2012).

Child outcomes, ($n = 278$)		TV viewing time at 6 and 9 years (h/w)[c]			p-Trend
		Short duration (7–9, $n = 86$) coefficient (95% CI)	Medium duration (10–13, $n = 61$) coefficient (95% CI)	Long duration (≥14, $n = 43$) coefficient (95% CI)	
HRT1numbers (ms)	Crude[a]	−2.8 (−33.9–28.6)	2.4 (−31.6–36.4)	46.9 (8–85.7)**	0.044**
	Adjusted[b]	−11.6 (−44.3–21.1)	−3.3 (−38.7–32.1)	34.1 (−6.9–75.1)	0.171
HRT1words (ms)	Crude	16.5 (−10.2–43.3)	23.8 (−5.6–53.4)	21.5 (−12.5–55.6)	0.123
	Adjusted	−0.7 (−29.2–27.7)	19.6 (−11.5–50.7)	10.2 (−25.8–46.3)	0.295
HRT1_global (ms)	Crude	12.3 (−24.1–48.8)	24.8 (−15.1–64.8)	44.9 (−0.7–90.6)	0.043**
	Adjusted	−9.7 (−48.7–29.3)	17.8 (−24.3–60)	26.9 (−21.8–75.7)	0.173
HRT2numbers (ms)	Crude	−7.2 (−38.2–23.6)	−5.8 (−39.7–28)	6.7 (−31.9–45.4)	0.838
	Adjusted	−21.5 (−56.1–11.1)	−7 (−42.3–28.3)	−10.4 (−51.3–30.5)	0.731
HRT2words (ms)	Crude	29.7 (−4–63.6)	32.1 (−5.1–69.3)	49.7 (6.6–92.7)**	0.021**
	Adjusted	20.4 (−16.1–56.9)	14.1 (−25.5–53.8)	25.8 (−20.5–72.2)	0.315
HRT2_global (ms)	Crude	27.7 (−14.8–70.1)	25.7 (−20.7–72.1)	53 (0.002–106.8)**	0.060*
	Adjusted	8.3 (−36.9–53.6)	7.3 (−41.7–56.4)	18.9 (−37.8–75.7)	0.546

* $p < 0.10$.
** $p < 0.05$. CI, confidence interval.
[a] Crude model adjusted for child age at 14 years test.
[b] Adjusted for child sex, BMI, having babysitter at 4 years of age, maternal social class, maternal education level, alcohol consumption during pregnancy, paternal social class and paternal education. The p for trend shown is the categorical value as a continuous one to see if there is a significant trend line within the variable and between the groups.
[c] Reference group included children watching TV <7 h/w ($n = 88$).

Table 4
Child television viewing duration adjusted models by potential intermediate factors and 14-year-old neuropsychological outcomes (Menorca, 1998–2012).

Child outcomes ($n = 278$)		TV viewing time at 6 and 9 years (h/w)[a]			p-Trend
		Short duration (7–9, $n = 86$) coefficient (95% CI)	Medium duration (10–13, $n = 61$) coefficient (95% CI)	Long duration (≥14, $n = 43$) coefficient (95% CI)	
HRT1_global					
Basic model	Model A	−9.7 (−48.7–29.3)	17.8 (−24.3–60)	26.9 (−21.8–75.7)	0.173
Collapsed model	Model B	−11.9 (−51.1–27.1)	11.3 (−32.3–54.9)	21.8 (−28.3–71.9)	0.301
Physical activity excluded	Model C	−8.4 (−47.6–30.6)	20.6 (−22–63.3)	30.5 (−18.9–79.9)	0.133
Sleeping duration excluded	Model D	−13 (−52–25.8)	8.8 (−34.2–51.7)	18.7 (−30.6–67.9)	0.361
HRT2_global					
Basic model	Model A	8.3 (−36.9–53.6)	7.3 (−41.7–56.4)	18.9 (−37.8–75.7)	0.546
Collapsed model	Model B	2.9 (−42.3–48.2)	-6.8 (−57.4–43.7)	5.8 (−52.3–63.9)	0.982
Physical activity excluded	Model C	8.4 (−37–53.9)	7.5 (−42.1–57.2)	19.2 (−38.4–76.8)	0.546
Sleeping duration excluded	Model D	3.3 (−41.7–48.3)	-6 (−55.8–43.7)	6.8 (−50.2–63.9)	0.952

[a] Reference group included children watching TV <7 h/w ($n = 88$). Model A adjusted for child age at 14 years test, sex, BMI, having babysitter at 4 years of age, parental social class, parental education level and alcohol consumption during pregnancy. Model B is additionally adjusted for physical activity at 6 and 9 years and sleeping duration at 6 and 9 years. Model C is like model B without physical activity at 6 and 9 years. Model D is like model B without sleeping duration at 6 and 9 years. The p for trend shown is the categorical value as a continuous one to see if there is a significant trend line within the variable and between the groups.*$p < 0.10$; **$p < 0.05$. CI, confidence interval.

linked to lower general cognitive functioning and lower learning achievement [15]. A cross-sectional study by Nathanson et al. [16], found that several indicators of television exposure such as cumulative hours viewing television or the age at which children first began watching TV were significantly related to executive function. However, Schmidt et al. [8], reported that television viewing before 3 years was not associated with lower language and visual motor skills at age 3 after adjusting for maternal, child and household characteristics. They suggested that the effects of TV on infants may not be apparent until children are older than 3 years old. Johnson et al. [17] and Haconx et al. [18] found that television viewing in childhood and adolescents were associated with poor education achievement by 22 and 26 years of age, respectively, suggesting that is possible that the effects of TV on school achievement are not apparent until children are older than 14 years old. In addition, some analysis found when looking closely at the data and its relation to other covariates, particularly maternal and social factors, no association is found except when looking at the most at risk, high use group of child television viewers [19].

The effects of more television watching may come to a head later in life in an amplification of the trend that we see in our analysis of lower cognitive outcomes and more television watching. Our analysis shows a moderate correlation between the three time exposures suggesting that early high exposure to television viewing may predict high television viewing years later. The continuous elevation of time watching television along with the proportional amplification of television and screen time during the life course may result in a poor cognitive performance in later years.

In our study there was no association between television viewing and the behavioral outcomes as tested by the SDQ or any association with school marks. This finding is in contrast with other studies that have reported a negative association with school marks and television viewing and worse behavioral outcomes with more television watching. It is possible that the content of the television watching is important in relation to beneficial effects of educational television programs on the educational outcomes such as school performance. [14].

In the current literature there are a few proposed potential explanatory pathways. In one study, cultural or extracurricular activities, such as musical education and being bilingual, were associated to cognition outcomes [20,21].We did not find support for this explanatory pathway. Sleep duration and physical activity have long been associated with both television viewing and mental health outcomes [4,22–27]. Sleep duration and physical activity were associated with both exposure and outcome but only child physical activity seemed to suggest a mediation effect in the final model, however with inconclusive results, due to the lack of independent association between the exposure and the outcome. Physical activity could plausibly mediate the relationship between television viewing and neurocognitive outcomes through the time-displacement theory which suggests that television viewing displaces or takes time away from such intellectually demanding activities as reading or homework, creative and imaginative activities, physical activities and social interaction [14,28–29]. On the other hand, new evidence has suggested an independent association between physical activity and sedentary behavior, meaning that time spent in sedentary activity does not affect the time spent doing physical activity [30]. Possibly physical activity itself is a protective factor when it comes to cognitive outcomes. Hillman et al. [31] conclude in their review that physical activity alone can lead to better overall brain health and cognition in the lifespan.

Our study had several strengths; firstly, the study is based on a longitudinal birth cohort, based on prospectively collected data up to age 14 years and the cohort's participants were successfully recruited from the general population making the results appropriate to generalize. The quality and quantity of different types of data points collected allows us to reduce reporting bias. Considering our exposure measure of parental reported television viewing, Anderson et al. [32] found that parental report of television exposure was an adequate measure when compared with parental diary estimates assessed by videotape observations. In relation to the complexity of the phenomenon studied, our analyses included the ability to control for a large variety of socio-demographic variables at 6 and 9 years of age and psychosocial factors such as maternal IQ that could otherwise lead us to draw wrong conclusions. The results suggest that social class and other covariates have a relevant confounding effect on television viewing and neuropsychological test outcomes. A larger sample size with detailed analysis will be able to look into this effect and conclude if the cofounding effects are the primarily reasons for the outcomes found.

A main limitation is that the content of the TV viewed was not available. An emerging body of evidence suggests that content is an important mediator of the effects of TV on infants [30,33–35]. For example, there is evidence that children who watch more adult content television, as opposed to educational programming created for children have worse executive function outcomes [16]. We have no data on television viewing before age of 6 years and are unable to assess whether preschool television viewing might also be related with cognitive outcomes collected later in life. We also did not have data on using computers, tablets, mobile phones, game consoles, etc. At the time of data collection these devices were not ubiquitous, but to make conclusions about modern media usage these other forms of media consumption must be considered.

In our description of missing data we found a potential for bias in regards to the maternal educational status. There was a non-random loss to follow up with children whose mothers had less educational experience. This should also be kept in mind as we had changes in our significance when we controlled for social variables and this potential bias

could have consequences in our results. Lastly our sample size can make suggestion about tendency but does not have the power to make strong conclusions about neurocognitive test outcomes at age 14. A larger sample size and a controlled experimental study can give clearer answers on the association tendencies we see here.

5. Conclusions

In this prospective study, long-term association with early life TV viewing and adolescent working memory functioning was not found in a model adjusted for potential confounders, such as maternal social class level. Since the association trends were slightly preserved, we cannot discard the possibility to find an independent association with a larger sample size. This result has been supported in other studies but further research on large population-based birth cohort studies including TV and other types of media exposure are required, this is in order to confirm whether or not there is an association and further investigate the potential explanatory pathways or confounding effects of TV-related socio-demographic characteristics on long-term child and adolescent neuropsychological development.

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Conflict of interests

All authors have no conflicts of interest to disclose.

Transparency document

The Transparency document associated with this article can be found, in online version.

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Appendix A. Supplementary data

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References

Roberts, D., Foehr, U., Rideout, V., 2005. Generation M: Media in the Lives of 8–18 Years-old.
Rhoades, B.L., Greenberg, M.T., Lanza, S.T., Blair, C., 2011. Demographic and familial predictors of early executive function development: contribution of a person-centered perspective. J. Exp. Child Psychol. 108 (3), 638–662.
Hoyos Cillero, I., Jago, R., 2010. Systematic review of correlates of screen-viewing among young children. Prev. Med. (Baltim) 51 (1), 3–10.
Nuutinen, T., Ray, C., Roos, E., 2013. Do computer use, TV viewing, and the presence of the media in the bedroom predict school-aged children's sleep habits in a longitudinal study? BMC Public Health 13 (1), 684.
Anand, V., Downs, S.M., Bauer, N.S., Carroll, A.E., 2014. Prevalence of infant television viewing and maternal depression symptoms. J. Dev. Behav. Pediatr. 35 (3), 216–224.
Christakis, D., 2014. Interactive media use at younger than the age of 2 years: time to rethink the American Academy of Pediatrics Guideline? JAMA Pediatr. 98121, 2–3.
Gingold, J., Simon, A.E., Schoendorf, K.C., 2014. Excess screen time in US children: association with family rules and alternative activities. Clin. Pediatr. (Phila) 53 (1), 41–50.
Schmidt, M.E., Rich, M., Rifas-Shiman, S.L., Oken, E., Taveras, E.M., 2009. Television viewing in infancy and child cognition at 3 years of age in a US cohort. Pediatrics 123 (3), e370–e375.
Takeuchi, H., Taki, Y., Hashizume, H., et al., 2015. The impact of television viewing on brain structures: cross-sectional and longitudinal analyses. Cereb. Cortex 25 (5), 1188–1197.
Intusoma, U., Mo-Suwan, L., Ruangdaraganon, N., Panyayong, B., Chongsuvivatwong, V., 2013. Effect of television viewing on social-emotional competence of young Thai children. Infant Behav. Dev. 36 (4), 679–685.
Guxens, M., Ballester, F., Espada, M., et al., 2012. Cohort profile: the INMA—INfancia y Medio Ambiente—(environment and childhood) project. Int. J. Epidemiol. 41 (4), 930–940.
Forns, J., Esnaola, M., López-Vicente, M., et al., 2014. The n-back test and the attentional network task as measures of child neuropsychological development in epidemiological studies. Neuropsychology 28 (4), 519–529.
Goodman, R., 1997. The strengths and difficulties questionnaire: a research note. J. Child Psychol. Psychiatry 38 (5), 581–586.
Zimmerman, F.J., Christakis, D.A., 2005. Children's television viewing and cognitive outcomes: a longitudinal analysis of national data. Arch. Pediatr. Adolesc. Med. 159 (7), 619–625.
López-Vicente, M., Forns, J., Suades-González, E., et al., 2016. Developmental trajectories in primary schoolchildren using n-back task. Front. Psychol. http://dx.doi.org/10.3389/fpsyg.2016.00716.
Nathanson, A.I., Aladé, F., Sharp, M.L., Rasmussen, E.E., Christy, K., 2014. The relation between television exposure and executive function among preschoolers. Dev. Psychol. 50 (5), 1497–1506.
Johnson, J.G., Cohen, P., Kasen, S., Brook, J.S., 2007. Extensive television viewing and the development of attention and learning difficulties during adolescence. Arch. Pediatr. Adolesc. Med. 161 (5), 480–486.
Hancox, R., Milne, B., Poulton, R., 2005. Association of television viewing during childhood with poor educational achievement. Arch. Pediatr. Adolesc. Med. 159 (7), 614–618.
Foster, E.M., Watkins, S., 2010 Jan–Feb. The value of reanalysis: TV viewing and attention problems. Child Dev. 81 (1), 368–375.
Moradzadeh, L., Blumenthal, G., Wiseheart, M., 2014 Oct. Musical training, bilingualism, and executive function: a closer look at task switching and dual-task performance. Cogn. Sci. 7, 1–29.
Slevc, L.R., Davey, N.S., Buschkuehl, M., Jaeggi, S.M., 2016 Jul 31. Tuning the mind: exploring the connections between musical ability and executive functions. Cognition 152, 199–211.
Marinelli, M., Sunyer, J., Alvarez-Pedrerol, M., et al., 2014 May. Hours of television viewing and sleep duration in children: a multicenter birth cohort study. JAMA Pediatr. 168 (5), 458–464.
Feng, Q., Zhang, Q., Du, Y., Ye, Y., He, Q., 2014. Associations of physical activity, screen time with depression, anxiety and sleep quality among Chinese college freshmen. PLoS One 9 (6), e100914.
Cespedes, E.M., Gillman, M.W., Kleinman, K., et al., 2014. Television viewing, bedroom television, and sleep duration from infancy to mid-childhood. Pediatrics 133 (5), e1163–e1171.
Curcio, G., Ferrara, M., De Gennaro, L., 2006. Sleep loss, learning capacity and academic performance. Sleep Med. Rev. 10 (5), 323–337.
Hamer, M., Stamatakis, E., Mishra, G., 2009. Psychological distress, television viewing, and physical activity in children aged 4 to 12 years. Pediatrics 123 (5), 1263–1268.
Penedo, F.G., Dahn, J.R., 2005. Exercise and well-being: a review of mental and physical health benefits associated with physical activity. Curr. Opin. Psychiatry 18 (2), 189–193.
Strasburger, V.C., Jordan, A.B., Donnerstein, E., 2010. Health effects of media on children and adolescents. Pediatrics 125 (4), 756–767.
Anderson, D.R., Huston, A.C., Schmitt, K.L., Linebarger, D.L., Wright, J.C., Larson, R., 2001. Early childhood television viewing and adolescent behavior: the recontact study. Monogr. Soc. Res. Child Dev. 66 (1).
Biddle, S.J.H., et al., 2004. Physical activity and sedentary behaviours in youth: issues and controversies. J. R. Soc. Promot. Heal. 124 (1), 29–33.
Hillman, C.H., Kamijo, K., Scudder, M., 2011. A review of chronic and acute physical activity participation on neuroelectric measures of brain health and cognition during childhood. Prev. Med. 52S, S21–S28.
Anderson, D., Field, D., Collins, P., 1985. Estimates of young children's time with television: a methodological comparison of parent reports with time-lapse video home observation. Child Dev. 1345–57.
Lillard, A.S., Peterson, J., 2011. The immediate impact of different types of television on young children's executive function. Pediatrics 128 (4), 644–649.
Carson, V., Kuzik, N., Hunter, S., et al., 2015. Systematic review of sedentary behavior and cognitive development in early childhood. Prev. Med. 78, 115–122.
Thakkar, R.R., Garrison, M.M., Christakis, D.a., 2006. A systematic review for the effects of television viewing by infants and preschoolers. Pediatrics 118 (5), 2025–2031.