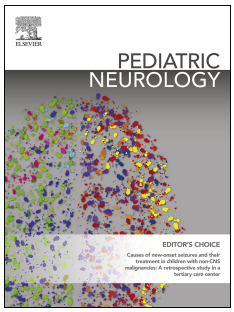


# Association between television viewing and sensory reactivity in childhood: the cross-sectional InProS study

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**Short running title:** Television and sensory reactivity in childhood

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**Association between television viewing and sensory reactivity in childhood: the cross-sectional InProS study**


## ABSTRACT

Current evidence suggests a potential detrimental effect of increased television viewing on children's health, including sensory processing issues. Therefore, this study examined the association between television viewing time and atypical sensory reactivity (SR) in children aged from 3 to 7 years. We evaluated data from the InProS cross-sectional study (n=545). Daily television viewing was categorized into tertiles: ≤ 1.5, 1.5-2.5, and ≥ 2.5 hours. SR was evaluated using the Short Sensory Profile (SSP). Children with atypical SR were those with the global SSP score below 155, 30 for tactile sensitivity, 15 for taste/olfactory sensitivity, 13 for movement sensitivity, 27 for under-responsive/seeks sensation, 23 for auditory filtering, 26 for low energy/weak, and 19 for visual/auditory sensitivity. We used multiple Poisson regression models with robust variance to explore associations. After adjusting for covariates, children who watched television 1.5-2.5 and ≥ 2.5 hours/day showed a higher prevalence of atypical global SR (PR:1.54; 95%CI: 1.03-2.30; PR:1.81; 95%CI: 1.19-2.76, respectively) and auditory filtering (PR:1.50; 95%CI: 1.15-1.96; PR:1.36; 95%CI: 1.01-1.83, respectively), compared to children who watched ≤ 1.5 hours/day. In addition, watching television ≥ 2.5 hours/day, compared to watching ≤ 1.5 hours/day, was associated with having atypical SR in movement sensitivity (PR:1.73; 95%CI: 1.06-2.83), under-responsive/seeks sensation (PR:1.31; 95%CI: 1.02-1.69), and low energy/weak (PR:2.02; 95%CI: 1.01-4.06). The findings showed that television viewing ≥1.5 hours/day was associated with a higher prevalence of atypical SR in childhood. However, further longitudinal studies are required to confirm these results.



## KEY WORDS

sensory reactivity; television viewing; children; sensory processing difficulties; sedentary behavior

## Introduction

In recent decades, children's media use, including smartphones, tablets, and other technological devices, has increased dramatically [1]. However, despite the predominance of these devices, television continues to represent the most widely used screen-based media among children aged 0-8 years [1-3]. According to the Spanish National Institute of Statistics, almost all Spanish children have at least one television in their homes [4]. Increased access to television and excessive exposure to television has raised serious concerns about its impact on child development [5,6]. Current evidence suggests that children who spend more hours in front of the television tend to present a higher prevalence of obesity [7], sleep difficulties [8-10], psychological and cognitive impairments [11-13], behavioral problems [14], language alterations [15] and sensory processing difficulties, including atypical sensory reactivity (SR) [16].

Atypical SR refers to difficulties in sensory processing within the central nervous system, leading to non-adaptive responses to sensory stimuli encountered in daily life, including tactile, olfactory, gustatory, auditory, visual, proprioceptive, and vestibular stimuli [17]. These unconventional responses may manifest as hyper-reactivity, also referred to as over-reactivity, characterized by adverse responses to sensory stimuli, and hypo-reactivity, or under-reactivity, which entails a lack of response or indifference to sensory stimuli [17, 18]. Additionally, individuals with atypical SR may experience sensory craving, characterized by an excessive desire for sensory input [17]. Such sensory difficulties seem to be related to inappropriate behavior, learning problems, difficulties in motor development, social skills, and autonomy among children [19-24]. According to previous studies, the prevalence of atypical SR in children typically developing ranges between 5 and 30% [20,25-32].

As far as we know, there has only been one study that has explored the relationship between sensory processing and screen time using different technological devices, including television. This study with 25 typically developing children aged 4 to 7 showed negative correlations between children's overall screen time and their visual, touch, body awareness, balance, planning

and global sensory processing skills [16]. Since television is the most commonly used screen-based media among children, and research regarding its potential effect on SR is limited, this study was conducted to provide more convincing evidence based on an epidemiological approach. The main aim of this study was to explore the association between television viewing time and atypical SR in children between the ages of 3 and 7.

## Methods

### *Study design, population, and ethics*

The Infancia y Procesamiento Sensorial Project (InProS [Sensory Processing and Childhood], www.inteo.edu.umh.es/inpros) is a cross-sectional population-based study conducted in typically developing children aged 3–7 from Alicante, Spain. Contributing to reproducible science, a protocol study with all the information on its methodology described has been previously published [33]. Briefly, participants were recruited between February and May 2016 from 21 randomly selected schools in the province of Alicante, Spain. Around 1700 eligible children were invited to participate in the study, of which 620 were finally included (response rate 37%). After excluding participants with missing data for the main variables, 545 children (87.9% of the total sample) were included in the present analysis. This study has been approved by the Ethics Committee of the Miguel Hernández University of Elche (DPC.ASP.02.16) and performed by the Declaration of Helsinki. In addition, all participants provided informed consent signed by their parents and did not receive any incentive for their participation.

### *Main study variables*

Television viewing in hours per day was collected by asking parents two *ad hoc* questions: 1) *"How many hours a day does your child watch television during the week?"*; and 2) *"How many hours a day does your child watch television during the weekend?"*. The mean daily hour of television viewing was calculated by averaging the time spent watching television during weekday and weekend: [((weekday television viewing × 5) + (weekend television viewing ×

2))/7]. The children's television viewing duration in hours per day was categorized according to tertiles: ≤ 1.5 hours/day, 1.5-2.5 hours/day, and ≥ 2.5 hours/day.

SR was measured using the Spanish cross-cultural translated and adapted version of the Short Sensory Profile (SSP) [34,35] based on the original tool developed by W. Dunn in 1999 [36].This questionnaire comprises 38 items, each describing sensory events in a child's daily life. Parents self-reported their child's behavioral reactions to specific sensory stimuli, which are divided into seven subscales: tactile sensitivity (7 items), taste/olfactory sensitivity (4 items), movement sensitivity (3 items), under-responsive/seeks sensation (7 items), auditory filtering (6 items), low energy/weak (6 items), and visual/auditory sensitivity (5 items). Each item can be scored on a Likert-type scale ranging from one ("always") to five ("never") points, enabling parents to record the frequency of their child's engagement in the described behaviors Data from the SSP reveal the responsiveness and reactivity patterns across these sensory systems. The global score and the score for each subscale are obtained by adding the values of the respective items. These scores facilitate the classification of children into three SR categories (typical performance, probable difference, or definitive difference) based on cut-off criteria proposed by Dunn [36]. In our study, children with atypical SR were classified into the "probable difference" and "definitive difference" categories. The cut-off points used for categorizing the children with atypical SR were below 155 points for the global score, 30 points for tactile sensitivity, 15 points for taste/olfactory sensitivity, 13 points for movement sensitivity, 27 points for under-responsive/seeks sensation, 23 points for auditory filtering, 26 points for low energy/weak, and 19 points for visual/auditory sensitivity. In our study, the internal consistency of the SSP was good (Cronbach's $\alpha = 0.72$-$0.76$ for all scales).

*Covariates*

Sociodemographic and lifestyle factors of the children and their parents were collected through different questions included in an *ad hoc* questionnaire and several standardized tests completed by the parents. After statistical exploration of our data and a review of the scientific literature [37-40], we selected parental covariates such as age (years), country of birth (Spain/other), education

(primary education or less/secondary education/university education), employment (yes/no), television viewing (hours per day) and sleep duration (hours per day). For the children, we considered age (years), sex (male/female), adherence to the Mediterranean diet measured by the KIDMED index (continuous variable), body mass index (BMI) (calculated as parent-reported weight in kilograms divided by parent-reported height in meters squared), sleep duration (hours per day) and sleep quality (poor/good) measured using the Spanish version of the Pediatric Sleep Questionnaire (PSQ) [41].

*Data analysis*

Statistical analysis was conducted using R software, version 4.1.0 (R Foundation for Statistical Computing, Vienna, Austria; http://www.R-project.org). Two-tailed statistical tests were applied, and the significance level was set at 0.05. In addition, the normality of the distribution of all quantitative variables was tested using the Kolmogorov-Smirnov test with Lilliefors correction.

The sociodemographic characteristics of children and their parents were described according to SR using frequencies and percentages (%) for categorical variables and median and interquartile range (IQR) for continuous variables (given that they presented a non-normal distribution). To compare the differences in the characteristics explored according to the response variable categories, the Chi-square test ($\chi^2$) or Fisher's Exact test was applied for categorical variables, and the Mann-Whitney U test for continuous variables.

The association between television viewing time and the prevalence of atypical SR was assessed using multiple Poisson regression models with robust variance based on Huber's sandwich estimation [42,403)] to estimate prevalence ratios (PR) and their respective 95% confidence intervals (CI). Because of the lack of convergence, Poisson regression with robust variance was used instead of log-binomial regression [44].

To control for potential confounders, all models were adjusted by those variables that had shown a p-value < 0.20 in the bivariate analysis and those that produced > 10% changes in association when building the core model. In addition, the models did not include parental variables and child

BMI to preserve maximum statistical power because of a large amount of missing data on these variables. Finally, the core model was adjusted by the following children's variables: sex (male/female), age (in years), adherence to the Mediterranean Diet (KIDMED score), and sleep quality (poor/good, according to the PSQ score), and mother's variables such as age (years), country of birth (Spain/others), employment (yes/no), and television viewing time (hours per day).

To assess the dose-response effect, linear trend tests were applied for tertiles of television viewing, coding the variable as 1, 2, and 3.

**Results**

According to the study sample distribution, 33.8% (n = 184) of the participating children spent ≤ 1.5 hours/day watching television, 35.7% (n = 195) watched between 1.5-2.5 hours/day, and 30.5% (n = 166) consumed television ≥2.5 hours/day. The prevalence of atypical SR was 28.4% for the global score (<155), 11.2% for tactile sensitivity (<30 points), 14.9% for taste/olfactory sensitivity (<15 points), 22.2% for movement sensitivity (<13 points), 48.4% for under-responsive/seeks sensation (<27 points), 42.6% for auditory filtering (< 23 points), 12.1% for low energy/weak (<26 points) and 25.5% for visual/auditory sensitivity (<19 points).

The main sociodemographic and lifestyle characteristics of InProS project participants according to global SR measured by the SSP are described in table 1. Compared to children with typical SR, mothers whose children were classified as having atypical SR were younger (median age 37 vs. 38), unemployed (38.7% vs. 24.9%), and spent more time watching television daily (median viewing hours of 2.3 vs. 1.9). Parents born in a foreign country (mothers= 25.2% vs. 10.5%; fathers= 26.5% vs. 13.0%) and with secondary education (39.5% vs. 30.9%) had a higher proportion of children with SR. Compared to their counterparts, children with atypical SR had worse eating habits as measured by the KIDMED index (median of 7.0 vs. 8.0 points), higher BMI (median of 16.0 vs. 15.7) and a poorer sleep quality according to the PSQ (19.4% vs 4.4%).

Table 2 shows the prevalence of SR for the global and different subscales of the SSP according to children's television viewing in tertiles (low ≤1.5 hours/day, medium 1.5-2.5 hours/day, and high ≥2.5 hours/day). Overall, a statistically significant higher prevalence of atypical SR was observed in children with medium and high television viewing than in those classified as having a lower exposure to television viewing, except for the subscales of tactile sensitivity (p = 0.165) and visual/auditory sensitivity (p = 0.055), where statistical significance was not reached.

**Table 1.** Sociodemographic and lifestyle characteristics of the study participants by the children's global sensory reactivity.

| | | Global SR [b] | | |
|---|---|---|---|---|
| | **All** | **SSP < 155 Typical SR** | **SSP ≥ 155 Atypical SR** | ***p* value [a]** |
| n (%) | 545 (100) | 390 (71.6) | 155 (28.4) | |
| **Maternal characteristics** | | | | |
| Age (years), median (IR) | 38.0 (35.0 – 41.0) | 38.0 (35.0 – 41.0) | 37.0 (34.0 – 41.0) | **0.013** |
| Country of birth, n (%) | | | | **< 0.001** |
| Spain | 465 (85.3) | 349 (89.5) | 116 (74.8) | |
| Others | 80 (14.7) | 41 (10.5) | 39 (25.2) | |
| Education level, n (%) | | | | 0.111 |
| Primary or less | 122 (22.4) | 82 (21.0) | 40 (25.8) | |
| Secondary studies | 188 (34.5) | 129 (33.1) | 59 (38.1) | |
| University studies | 235 (43.1) | 179 (45.9) | 56 (36.1) | |
| Employment, n (%) | | | | **0.002** |
| Yes | 388 (71.2) | 293 (75.1) | 95 (61.3) | |
| No | 157 (28.8) | 97 (24.9) | 60 (38.7) | |
| TV viewing (hours/day), median (IR); (n *missing* = 10) | 2.0 (1.3 – 2.6) | 1.9 (1.3 – 2.6) | 2.3 (1.3 – 2.9) | **0.008** |
| Sleep duration (hours/day), median (IR); (n *missing* = 12) | 7.6 (7.0 – 8.0) | 7.6 (7.0 – 8.0) | 7.6 (7.0 – 8.0) | 0.763 |
| **Paternal characteristics [c]** | | | | |
| Age (years), median (IR) | 40.0 (37.0 – 43.0) | 40.0 (37.0 – 43.0) | 40.0 (36.0 – 43.0) | 0.397 |
| Country of birth, n (%) | | | | **< 0.001** |
| Spain | 409 (83.3) | 309 (87.0) | 100 (73.5) | |
| Other country | 82 (16.7) | 46 (13.0) | 36 (26.5) | |
| Education level, n (%) | | | | **0.033** |
| Primary or less | 162 (32.5) | 107 (30.3) | 48 (35.6) | |
| Secondary | 167 (33.6) | 113 (32.0) | 53 (39.3) | |
| University studies | 169 (33.9) | 133 (37.7) | 34 (25.2) | |
| Employment, n (%) | | | | 0.509 |
| Yes | 446 (89.4) | 320 (90.1) | 118 (88.1) | |
| No | 53 (10.6) | 35 (9.9) | 16 (11.9) | |
| TV viewing (hours/day), median (IR); (n *missing* = 28) | 2.0 (1.3 – 2.6) | 2.0 (1.3 – 2.6) | 2.3 (1.3 – 3.1) | 0.126 |
| Sleep duration (hours/day), median (IR); (n *missing* = 29) | 7.3 (7.0 – 8.0) | 7.3 (7.0 – 8.0) | 7.6 (7.0 – 8.0) | 0.072 |
| **Child characteristics** | | | | |
| Sex, n (%) | | | | **0.017** |
| Male | 271 (49.7) | 181 (46.4) | 90 (58.1) | |
| Female | 274 (50.3) | 209 (53.6) | 65 (41.9) | |
| Age (years), median (IR) | 5.0 (4.0 – 6.0) | 5.0 (4.0 – 6.0) | 5.0 (4.0 – 6.0) | 0.444 |
| Adherence to Mediterranean Diet, median (IR); (n *missing* = 7) | 8.0 (6.0 – 9.0) | 8.0 (7.0 – 9.0) | 7.0 (6.0 – 9.0) | **0.004** |
| Body mass index, median (IR); (n *missing* = 113) | 16.0 (14.5 – 17.4) | 15.7 (14.3 – 17.4) | 16.0 (15.0 – 17.3) | 0.101 |
| Sleep duration, median (IR); (n *missing* = 4) | 10.0 (9.3 – 10.3) | 10.0 (9.3 – 10.3) | 10.0 (9.3 – 10.3) | 0.284 |
| Sleep quality, n (%) | | | | **< 0.001** |
| Poor | 47 (8.6) | 17 (4.4) | 30 (19.4) | |
| Good | 498 (91.4) | 373 (95.6) | 125 (80.6) | |

SR, Sensory reactivity; SSP, Short Sensory Profile; IR, Interquartile range.

[a] p value was calculated by Chi-square test or Fisher's exact test for categorical variables and, U Mann–Whitney test for continuous variables. [b] Children's sensory profile was determined following the cut-off points proposed by W. Dunn for total Short Sensory Profile score to classify

**Table 2.** Comparison between TV viewing time and having or not having sensory reactivity according to Short Sensory Profile scores in children from the InProS Project (n = 545).

| | All | TV viewing time [a] | | | *p* value [b] |
|---|---|---|---|---|---|
| | | Low (≤ 1.5 h/d) | Medium (1.5 – 2.5 h/d) | High (≥ 2.5 h/d) | |
| n (%) | 545 (100.0) | 184 (33.8) | 195 (35.7) | 166 (30.5) | |
| **Global SSP (Item 1-38), n (%)** | | | | | < 0.001 |
| Typical SR (155-190 points) | 390 (71.6) | 152 (82.6) | 139 (71.3) | 99 (59.6) | |
| Atypical SR (38-154 points) | 155 (28.4) | 32 (17.4) | 56 (28.7) | 67 (40.4) | |
| Tactile sensitivity (Items 1-7), n (%) | | | | | 0.165 |
| Typical SR (30-35 points) | 484 (88.8) | 170 (92.4) | 170 (87.2) | 144 (86.7) | |
| Atypical SR (7-29 points) | 61 (11.2) | 14 (7.6) | 25 (12.8) | 22 (13.3) | |
| Taste/smell sensitivity (Items 8-11), n (%) | | | | | 0.002 |
| Typical SR (15-20 points) | 464 (85.1) | 167 (90.8) | 168 (86.2) | 129 (77.7) | |
| Atypical SR (4-14 points) | 81 (14.9) | 17 (9.2) | 27 (13.8) | 37 (22.3) | |
| Movement sensitivity (Items 12-14), n (%) | | | | | 0.002 |
| Typical SR (13-15 points) | 424 (77.8) | 156 (84.8) | 153 (78.5) | 115 (69.3) | |
| Atypical SR (3-12 points) | 121 (22.2) | 28 (15.2) | 42 (21.5) | 51 (30.7) | |
| Under-responsive/seeks sensation (Items 15-21), n (%) | | | | | < 0.001 |
| Typical SR (27-35 points) | 281 (51.6) | 110 (59.8) | 107 (54.9) | 64 (38.6) | |
| Atypical SR (7-26 points) | 264 (48.4) | 74 (40.2) | 88 (45.1) | 102 (61.4) | |
| Auditory filtering (Items 22-27), n (%) | | | | | 0.002 |
| Typical SR (23-30 points) | 313 (57.4) | 125 (67.9) | 102 (52.3) | 86 (51.8) | |
| Atypical SR (6-22 points) | 232 (42.6) | 59 (32.1) | 93 (47.7) | 80 (48.2) | |
| Low energy/weak (Items 28-33), n (%) | | | | | < 0.001 |
| Typical SR (26-30 points) | 479 (87.9) | 170 (92.4) | 178 (91.3) | 131 (78.9) | |
| Atypical SR (6-25 points) | 66 (12.1) | 14 (7.6) | 17 (8.7) | 35 (21.1) | |
| Visual/auditory sensitivity (Items 34-38), n (%) | | | | | 0.055 |
| Typical SR (19-25 points) | 406 (74.5) | 147 (79.9) | 145 (74.4) | 114 (68.7) | |
| Atypical SR (5-18 points) | 139 (25.5) | 37 (20.1) | 50 (25.6) | 52 (31.3) | |

SSP, Short Sensory Profile; SR, sensory reactivity; h/d, hours per day; TV, television. [a] TV viewing time (hours/day) was categorized into tertiles: first tertile (≤ 1.5 hours/day), low TV viewing; second tertile (1.5-2.5 hours/day), medium TV viewing; and third tertile (≥ 2.5 hours/day), high TV viewing. [b] *p* value was calculated by Chi-square test.

children's level of sensory processing performance as having SR (<155 points) or not having SR (≥155 points). [c] Paternal information is available for 491 parents.

The association between children's television viewing in hours per day and the prevalence of atypical SR is shown in Table 3. Multiple regression models revealed that children who watched television 1.5-2.5 hours/day exhibited a 50% or more higher prevalence of atypical SR in total SSP (PR:1.54; 95%CI: 1.03-2.30), and auditory filtering (PR:1.50; 95%CI: 1.15-1.96), compared

to those watching ≤1.5 hours/day. Furthermore, children who watched television for ≥2.5 hours/day had an 81% (PR:1.81; 95%CI: 1.19-2.76) and a 36% (PR:1.36; 95%CI: 1.01-1.83) higher prevalence of atypical SR in these sensory domains, respectively, compared to their counterparts watching ≤1.5 hours/day. Moreover, children who spent ≥2.5 hours/day watching television showed a 73% higher prevalence of atypical SR in movement sensitivity (PR:1.73; 95%CI: 1.06-2.83),31% in under-responsive/seeks sensation (PR:1.31; 95%CI: 1.02-1.69), and 102% in low energy/weak (PR:2.02; 95%CI: 1.01-4.06), compared to those watching ≤1.5 hours/day.

The results of the p-trend analysis showed a significant dose-response relationship between television viewing duration and atypical global SR (p=0.021) and auditory filtering (p=0.23). This suggests that as the number of hours of television viewing per day increased, there was a corresponding increase in the prevalence of atypical SR in these sensory domains.

**Table 3.** Association between TV viewing time and prevalence of atypical sensory reactivity measured using global and subscales scores of S Sy Pe in children from the InProS Project (n = 545).

| | TV viewing time | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Low (≤ 1.5 h/d)** | **Medium (1.5 – 2.5 h/d)** | | | **High (≥ 2.5 h/d)** | | | ***p*-trend [a]** |
| | **n cases** | **n cases** | **PR (IC95%) [b]** | ***p* value** | **n cases** | **PR (IC95%) [b]** | ***p* value** | |
| **SHORT SENSORY PROFILE** | | | | | | | | |
| Atypical SR in Global SSP (<155 points) | 32 | 56 | 1.54 (1.03; 2.30) | **0.035** | 67 | 1.81 (1.19; 2.76) | **0.006** | **0.021** |
| Atypical SR in tactile sensitivity (<30 points) | 14 | 25 | 1.29 (0.66; 2.49) | 0.458 | 22 | 0.93 (0.44; 1.95) | 0.840 | 0.692 |
| Atypical SR in taste/smell sensitivity (<15 points) | 17 | 27 | 1.37 (0.76; 2.47) | 0.294 | 37 | 1.81 (0.97; 3.37) | 0.061 | 0.149 |
| Atypical SR in movement sensitivity (<13 points) | 28 | 42 | 1.24 (0.78; 1.97) | 0.353 | 51 | 1.73 (1.06; 2.83) | **0.027** | 0.153 |
| Atypical SR in under-responsive/seeks sensation (<27 points) | 74 | 88 | 1.10 (0.86; 1.40) | 0.441 | 102 | 1.31 (1.02; 1.69) | **0.033** | 0.297 |
| Atypical SR in auditory filtering (<23 points) | 59 | 93 | 1.50 (1.15; 1.96) | **0.003** | 80 | 1.36 (1.01; 1.83) | **0.040** | **0.023** |
| Atypical SR in low energy/weak (<26 points) | 14 | 17 | 1.06 (0.52; 2.15) | 0.871 | 35 | 2.02 (1.01; 4.06) | **0.048** | 0.310 |
| Atypical SR in visual/auditory sensitivity (<19 points) | 37 | 50 | 1.20 (0.81; 1.77) | 0.356 | 52 | 1.29 (0.84; 1.97) | 0.246 | 0.328 |

SSP, Short Sensory Profile; SR, sensory reactivity; h/d, hours per day; TV, television; PR, prevalence ratio; CI, confidence interval. [1] To calculate *p-trend*, the values 0, 1, and 2 were assigned to low, medium, and high categories of the TV viewing time in order to enter the variable into the model as a continuous term. [2] Prevalence ratio adjusted for children: sex (female; male), age (in years), adherence to the Mediterranean diet (KIDMED score), sleep quality (good; poor) and for mother's characteristics: age (in years), country of birth (Spain; other country), employment (no; yes) and TV viewing (in hours by day).

**Discussion**

This study supports that a higher daily television viewing is associated with the prevalence of atypical SR in a population-based sample of school-aged children. The main results suggest that children who spent ≥1.5 hours/day watching television compared to those who spent <1.5 had a higher prevalence of atypical global and auditory filtering SR. In addition, we also observed that children in the highest tertile of television viewing (≥2.5 hours/day) showed a higher prevalence of atypical movement sensitivity, unresponsiveness/sensation seeking, and low energy/weak SR. To our knowledge, this is the first time that an association between television viewing and atypical SR has been explored in a population-based sample of school-aged children.

Recently, Dadson and colleagues conducted a study with 25 typically developing children aged 4 to 7 years to investigate the relationship between screen time and children's sensory processing skills [16]. Their study assessed two types of screen time: interactive screen time, involving tactile interaction, and watching screen time, focusing on screen viewing. Their findings showed a negative and significant correlation between watching screen time and children's sensory skills across various subscales, including visual, tactile, body awareness, and total score subscales. Although our study may partly support these findings, particularly in the subscales related to the proprioceptive system, it is important to be cautious when comparing the results because of differences in sensory processing assessment tools and statistical analysis.

Our data showed a positive association between television viewing and a higher prevalence of atypical SR in the auditory filtering subscale. To our knowledge, there are no previously published studies regarding this finding; however, it is important to consider potential underlying mechanisms. One plausible explanation could be related to the concept of selective attention in hearing. Children with atypical auditory filtering SR may experience challenges in selectively attending to relevant auditory cues amidst background noise, such as television sound [45]. However, for children with atypical auditory filtering SR, difficulties in selective attention may result in a heightened sensitivity to auditory stimuli, leading them to seek higher intensity auditory input to discern and comprehend environmental cues. In this context, previous research has

suggested a nuanced relationship between television exposure and attentional dynamics in children. While television content may initially captivate children's attention, leading to heightened response time to any auditory stimuli, prolonged exposure has been associated with a paradoxical decline in attention and concentration capacity [46,47]. This paradoxical effect may be exacerbated by the presence of background noise, such as television sound, which can contribute to increased distractibility and reduced sustained attention over time.

Similarly, this study found an association between television viewing and a higher prevalence of atypical SR in the under-responsive/seeks sensation SSP subscale. According to the sensory processing model, children with atypical SR on this subscale are characterized by a constant search for opportunities to increase sensory input in all activities of daily living [48]. Children that show this pattern tend to be very active and prone to explore their environment intensively, which can sometimes be overwhelming and tiring for their caregivers. These children are likely to be perceived as "difficult" or short-tempered, and it is possible that their caregivers expose them to more television hours as a relief [49]. Indeed, previous research showed that those infants that were perceived by their mothers as more active or demanding were exposed to higher levels of daily television time [50].

The SSP movement sensitivity and low energy/weak subscales of SSP encompass a diverse array of sensorimotor skills that are integral to the vestibular, tactile, and proprioceptive systems [36,48, 51]. These skills, including postural control, balance, coordination, and motor planning, undergo crucial development during infancy and serve as the cornerstone for fundamental activities such as walking, running, and object manipulation [52]. Dysfunction in these sensorimotor skills can manifest as difficulties in maintaining upright posture, navigating the environment safely, and executing precise movements [48,51]. It is plausible that children with atypical SR in the movement sensitivity and low energy/weak subscales may exhibit a reluctance to engage in sensorimotor exercises, potentially leading to a preference for sedentary behaviors, such as prolonged television viewing. This tendency towards sedentarism could partially account for the observed association in our study for these specific SSP subscales. Notably, we verified that a

considerable proportion of children displaying atypical SR in these subscales (62.7% for movement sensitivity and 65.7% for low energy/weak subscale), particularly those spending ≥ 2.5 hours/day watching TV, predominantly led sedentary lifestyles or engaged in moderate-low levels of physical activity compared to their counterparts with typical SR in the respective SSP scales.

This study presents several limitations that should be recognized. First, the cross-sectional design of the InProS project does not allow us to establish cause-effect relationships between the explored variables. However, the findings of this study could serve as a basis for further longitudinal epidemiological research. Second, SR and television viewing variables were measured using parent-reported questionnaires, leading to a misclassification bias. However, the SSP is a valid and reliable assessment tool [20,27], so any inaccuracies should be non-differential. Although the evidence shows that parent-reported data on children's television viewing appears accurate [53], a misclassification bias should not be ignored. In addition, the questions used to collect information on television viewing in this study have been also used in several previous studies [10,54]. Finally, although we ran multiple statistical models adjusted by confounding factors, there is the possibility of residual confounding because of variables that have not been accounted for.

In conclusion, this study is the first to explore the association between television viewing time and SR prevalence in children aged 3-7 years. In this population-based study, we observed that television viewing ≥ 2.5 hours/day was statistically associated with a higher prevalence of atypical SR. However, further prospective studies are needed to confirm these findings. Finally, we would like to emphasize the importance of reinforcing messages towards the compliance of the institutional recommendations on television viewing during childhood.

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**Data availability**: The raw data supporting the conclusions of this article will be made available by the authors if requested.

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**Ethical approval:** The studies involving human participants were reviewed and approved by Ethics Committee of Miguel Hernandez University of Elche (protocol code DPC.ASP.02.16 approved on 20th December 2016). Written informed consent to participate in this study was provided by the participants' legal guardian.

**Declarations of interest:** None.

**Contributors' statement:** EMNM, DVG and PFP contributed to the conceptualization, methodology, formal analysis, and visualization. EMNM provided resources, data curation and oversight throughout the development process. PFP performed the literature search and the analyses. EMNM, DVG and PFP were responsible for the writing—original draft preparation and project administration. All authors critically reviewed this and previous drafts. All authors approved the final draft for submission, with final responsibility for publication.

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**Declaration of interests**

☐ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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