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Association between sensory reactivity and feeding problems in school-aged children: InProS Study

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ABSTRACT

This study aimed to explore the association between sensory reactivity (SR) and feeding problems in children at 3–7 years of age. We analysed data from 589 Spanish children from the InProS project, a population-based cross-sectional study. SR was measured using the Short Sensory Profile (SSP) as a two-level categorical variable (SR or no SR) and feeding problems (food variety, texture problems, or both feeding problems) were collected using closed questions (yes or no). Multiple Poisson regression models were used to estimate associations adjusted for potential confounding variables. Results showed the following prevalence rates for SR: 29.0% (SSP total score <155), 11.4% (tactile sensitivity <30), 14.8% (taste/smell sensitivity <15), 22.1% (movement sensitivity <13), 49.1% (low responsiveness/seeking sensation <27), 43.6% (auditory filtering <23), 11.6% (low energy/weak <26), and 25.3% (visual/auditory sensitivity <19). Around a fifth of children (18.3%) consumed a limited variety of foods, 4.9% had difficulties in the transition/introduction of textures, and 3.9% had both feeding problems. The presence of taste/smell sensitivity was associated with difficulties in the transition/introduction of textures (PR = 1.17, 95%CI = 1.09–1.27), limited variety of foods (PR = 1.42, 95%CI = 1.31–1.53), and both feeding problems (PR = 1.31, 95%CI = 1.19–1.44). In addition, children with total SR or auditory filtering SR were associated with a higher prevalence of consuming a limited variety of foods (PR = 1.13, 95%CI = 1.06–1.20 and PR = 1.08, 95%CI = 1.02–1.15, respectively). These findings highlight the importance of considering SR as a potential predictor of feeding problems, especially in children with taste/smell sensitivity. However, further studies are needed to confirm these findings.

1. Introduction

Early childhood is a crucial period of life for establishing and consolidating eating behaviours and food preferences (Yang, 2017). Children during this stage may experience feeding problems, among which the most common are picky eating and neophobia (i.e., fear of trying new foods) (Brown et al., 2016). These difficulties often manifest in prolonged and stressful eating time, the need to provide distractions to increase intake (e.g., television or toys), the rejection of certain foods, textures and flavours, or failure to introduce advanced textures (Milano et al., 2019). In addition, it is known that if feeding problems persist for a prolonged period, they can significantly affect the child's nutritional status, physical growth, and cognitive development and cause stress to their primary caregivers (van Dijk et al., 2016). However, since feeding problems is an umbrella term including a great variety of eating behaviours, estimates of prevalence in children can substantially vary from 20% to 50% (Benjasuwantep et al., 2013; Yang, 2017).

A recent scoping review showed that there are many different factors that might influence the occurrence of feeding problems in childhood, including prematurity, breastfeeding difficulties, or sensory processing in infants, among others (Mudholkar et al., 2022). For instance, eating involves the correct integration of numerous sensory stimuli (olfactory,

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gustatory, tactile, auditory and visual), which, if not done correctly, can lead to the rejection of certain foods due to their sensory properties (Farrow & Coulthard, 2012). Children with sensory sensitivity and/or sensory reactivity (SR) show an inadequate response to different sensory stimuli (Schulz & Stevenson, 2020), thereby being more likely to be prone to present adverse reactions or higher food refusal.

The prevalence of SR in typically developing children is currently estimated to be around 5–30% (Kong & Moreno, 2018; Navarrete-Muñoz et al., 2019). To our knowledge, research on SR and feeding problems in typically developing children is scarce. However, the available evidence has shown SR could affect children's feeding behaviours, leading to food refusal and restrictive diets (Mudholkar et al., 2022). In this regard, a cross-sectional study suggested a possible association between tactile sensitivity and food neophobia in children aged 2–5 (Coulthard & Sahota, 2016). In addition, other studies observed that children with sensory hypersensitivities or sensory challenges displayed picky eating or food selectivity (Farrow & Coulthard, 2012; Steinsbekk et al., 2017; Tauman et al., 2017). Thus, considering the above, contributing to the development of research on SR and feeding problems in children in the general population would allow us to understand the origin of the avoidance behaviours of certain foods. Furthermore, from a clinical perspective, it would also help to address this problem early, establishing appropriate and effective strategies based on the child's sensory processing. Therefore, this study aimed to explore the association between SR and the prevalence of feeding problems in Spanish children at 3–7 years of age.

2. Materials and methods

2.1. Study design

The *Infancia y Procesamiento Sensorial* (InProS [Sensory Processing and Childhood], www.inteo.edu.umh.es/inpros) project is a cross-sectional population-based study that aims to determine the prevalence of RS and explore its factors in typically developing children aged 3–7 years. Detailed information on the study protocol has been published elsewhere (Fernández-Pires et al., 2020). In brief, participant recruitment was conducted between February and May 2016 from 21 randomly selected schools in the province of Alicante (Spain). Of 1700 initially eligible children invited to participate in the project, 620 returned parental consent and completed questionnaires, obtaining a response rate of approximately 37%. For the present study, the final sample consisted of 589 children with complete information for the variables of interest. All participants provided informed consent signed by parents/legal guardians and did not receive any incentive to participate in this study. The InProS study had the approval of the Research Ethics Committee of the Miguel Hernández University (DPC.ASP.02.16) and was conducted in accordance with the Declaration of Helsinki and current Spanish legislation on data protection (Ley Orgánica 3/2018, de 5 de diciembre, de Protección de Datos Personales y garantía de los derechos digitales).

2.2. Study variables

2.2.1. Sensory reactivity

The child's SR was measured using the Short Sensory Profile (SSP), a questionnaire created by W. Dunn that has been cross-culturally adapted in Spanish children aged 3–10 years (Beaudry-Bellefeuille, 2015). The SSP is a parent self-reported questionnaire comprising 38 items organised in 7 sensory subscales (tactile sensitivity, taste/smell sensitivity, movement sensitivity, under-response/seeks sensation, auditory filtering, low energy/weak and visual/auditory sensitivity). Each item can be scored on a scale of 1–5 points (1-always and 5-never), where lower scores indicate the presence of RS. The SSP provides a total score and score for each subscale by summing the score of all the items or the individual items for the subscale, respectively. According to the cut-off points proposed by W. Dunn (Dunn, 1994), the SSP scoring (i.e., total and subscales) enables the classification of the children into three sensory processing profiles (typical performance, probable difference, or definitive difference). In the present study, we defined the children with SR as those classified into "probable difference" and "definitive difference") and created a dichotomous variable (i.e., no SR vs. SR) for the total SSP and subscales based on the following cut-off points: Total SSP <155, tactile sensitivity <30, taste/smell sensitivity <15, movement sensitivity <13, under-response/seeks sensation n $<$ 27, auditory filtering <23, low energy/weak <26, and visual/auditory sensitivity <19.

2.2.2. Feeding problems

Based on the Children's Feeding Assessment Questionnaire (CFAQ) (Whitehouse & Harris, 1998), we created two closed "yes/no" questions to assess feeding problems usually involving food fussiness and food refusal: (1) *Does your child encounter difficulty transitioning or introducing textures (from liquid to puree/puree to mashed or solid)?*, and (2) *Does your child tolerate only a very limited variety of foods, tastes and textures?* Then, we created the following two-level categorical variables from the responses to the two questions: texture problems (yes, no) and food variety (yes, no). Additionally, we built a new variable of both feeding problems, i.e., texture problems and food variety problems.

2.2.3. Covariates

We also included different variables as potential confounders for the analysis based on previous literature (Benjasuwantep et al., 2013; Fernández-Pires et al., 2021; Micali et al., 2016). Regarding the mother and father's characteristics, we considered age (years), country of birth (Spain, other) and employment status (employed, unemployed). Regarding the child's characteristics, we included age (years), sex (female, male), television viewing (hours per day), adherence to the Mediterranean diet measured with the Mediterranean Diet Quality Index (KIDMED) (Serra-Majem et al., 2004), sleep quality (good, poor) measured using the Spanish version of the Paediatric Sleep Questionnaire (PSQ) (Tomás Vila et al., 2007), sleep duration (hours per day), gestational age (weeks), birth weight (grams), and body mass index (kg/m^2).

2.3. Statistical analysis

All the analyses in this study were performed using R 4.1.1 statistical software (http://www.r-project.org). The statistical tests applied were bilateral, and the significance was set at 0.05. The normality of continuous variables was analysed using the Kolmogorov-Smirnov test with Lilliefors correction.

Socio-demographic and lifestyle characteristics of parents and their children by the child's feeding problems were described using frequencies (n) and percentages (%) for categorical variables and median and interquartile range (IQR) for quantitative variables. To check differences between the study's general characteristics according to having or not feeding problems, we applied the Chi-square (χ^2) or Fisher's Exact test for the categorical variables, and the Mann-Whitney *U* test for continuous variables due to they were asymmetrical. We also determined the prevalence of feeding problems (i.e., textures, food variety and both feeding problems) by the child's SR for the total and subscales of the SSP and compared if there were differences. In addition, we explored the association between SR and the prevalence of feeding problems using multiple Poisson regression models with robust variance based on Huber's sandwich estimation to calculate prevalence ratios (PR) and their respective 95% confidence intervals (CI). The models were adjusted for those variables previously identified in the literature that showed a p-value <0.20 in the bivariate analysis and, after inclusion in the model, produced $>10\%$ changes in the magnitude of the association.

Several sensitivity analyses were performed to assess the consistency

of the statistically significant associations. First, stratified models were run to determine the effects of the child's sex (male, female) and age in categories (3–5, 6–7). Second, we tested for changes in the effects when excluding the following characteristics: child's sleep duration (<10h/day), preterm infants (<37 weeks gestation), and low birth weight (<2500 g). Third, regarding SR, we assessed separately whether there were differences in the effect of the association on those children classified with "probable difference" and "definitive differences" in the SSP. Finally, the main models were adjusted for the following variables: father's age, country of birth, educational level and employment, and child's body mass index.

3. Results

The prevalence of SR in children of this study was 29.0% (SSP total score <155), 11.4% (tactile sensitivity <30), 14.8% (taste/smell sensitivity <15), 22.1% (movement sensitivity <13), 49.1% (low responsiveness/seeking sensation <27), 43.6% (auditory filtering <23), 11.6% (low energy/weak <26), and 25.3% (visual/auditory sensitivity <19). Regarding feeding problems, 4.9% of the children had problems with the transition and/or introduction of textures, 18.3% consumed a limited variety of foods, tastes, or textures, and 3.9% had both feeding problems.

Table 1 shows the parents and their children's socio-demographic characteristics and lifestyles in the InProS study. Overall, the parents had a median age of around 40 years (38 for mothers, and 40 for fathers), were mainly Spanish (mothers = 85.1%, fathers = 84.3%), and nearly a third of the mothers were unemployed (30.4%). Children had a median age of 5 years, more than half (52.8%) watched television ≥2 h per day, had a median adherence to the Mediterranean diet of 8 points, and around a tenth had poor sleep quality (9.3%). However, some differences in the participant characteristics were observed according to whether or not children had feeding problems. Regarding texture problems, we observed that children with these problems had a statistically higher proportion of unemployed mothers (48.3 vs. 29.4%), poor sleep quality (20.7 vs. 8.8%), and a lower median adherence to the Mediterranean diet (6.0 vs. 8.0%). In addition, compared to children with no food variety problems, we found that there were a higher percentage of parents born in a foreign country (mothers = 28.3 vs. 11.9%; fathers = 30.1 vs. 12.7%), unemployed mothers (38.7 vs. 28.5%), children who watched television ≥2 h per day, and lower adherence to the Mediterranean diet (7.0 vs. 8.0%) in those who had food variety problems. Children with both feeding problems presented higher rates of mothers who were foreign (30.4 vs. 12.1%), unemployed (52.2 vs. 28.5%) and lower adherence to the Mediterranean diet (6.0 vs. 8.0%), in comparison with their counterparts who did not present these problems.

Table 2 shows the comparison of the prevalence of feeding problems according to having or not having SR for the SSP total and subscales scoring. Overall, a higher prevalence of feeding problems was observed in children with SR than in those without SR. Children who presented

Table 1
Sociodemographic and lifestyle characteristics of the parents and their children's according to feeding problems, InProS project (n = 589).

	All (n = 589)	Feeding Problems								
		Texture problems[a]			Food variety problems[b]			Both feeding problems[c]		
		Yes (n = 29)	No (n = 560)	p-value[d]	Yes (n = 108)	No (n = 481)	p-value[d]	Yes (n = 23)	No (n = 475)	p-value[d]
Maternal Characteristics										
Age (years), median (IR)	38.0 (35.0–41.0)	38.0 (35.0–42.0)	38.0 (35.0–41.0)	0.558	37.0 (35.0–41.0)	38.0 (35.0–41.0)	0.641	38.0 (35.0–41.5)	38.0 (35.0–41.0)	0.905
Country of birth, n (%)				0.176			<0.001			0.019
Spain	497 (85.1)	22 (75.9)	475 (85.6)		76 (71.7)	421 (88.1)		16 (69.9)	415 (87.9)	
Others	87 (14.9)	7 (24.1)	80 (14.4)		30 (28.3)	57 (11.9)		7 (30.4)	57 (12.1)	
Employment, n (%)				0.038			0.047			0.019
Yes	408 (69.6)	15 (51.7)	393 (70.6)		65 (61.3)	343 (71.5)		11 (47.8)	339 (71.5)	
No	178 (30.4)	14 (48.3)	164 (29.4)		41 (38.7)	137 (28.5)		12 (52.2)	135 (28.5)	
Paternal Characteristics										
Age (years), median (IR)	40.0 (37.0–43.0)	40.0 (36.0–42.0)	40.0 (37.0–43.0)	0.850	40.0 (36–42)	40.0 (37–43)	0.691	40.0 (36.0–42.7)	40.0 (37.0–43.0)	0.591
Country of birth, n (%)				0.169			<0.001			0.087
Spain	444 (84.3)	20 (74.1)	424 (84.8)		65 (69.9)	379 (87.3)		16 (72.7)	375 (87.4)	
Others	83 (15.7)	7 (25.9)	76 (15.2)		28 (30.1)	55 (12.7)		6 (27.3)	54 (12.6)	
Employment, n (%)				0.207			0.366			0.280
Yes	472 (88.9)	22 (81.5)	450 (89.3)		81 (86.2)	391 (89.5)		18 (81.8)	387 (89.6)	
No	59 (11.1)	5 (18.5)	54 (10.7)		13 (13.8)	46 (10.5)		4 (18.2)	45 (10.4)	
Child Characteristics										
Sex, n (%)				1.000			1.000			0.827
Male	289 (50.4)	14 (51.9)	275 (50.4)		52 (50.0)	237 (50.5)		10 (47.6)	233 (50.3)	
Female	284 (49.7)	13 (48.1)	271 (49.6)		52 (50.0)	232 (49.5)		11 (52.4)	230 (49.7)	
Age (years), median (IR)	5.0 (4.0–6.0)	5.0 (4.0–6.0)	5.0 (4.0–6.0)	0.265	5.0 (4.0–6.0)	5.0 (4.0–6.0)	0.227	5.0 (4.0–5.5)	5.0 (4.0–6.0)	0.258
TV viewing, n (%)				0.211			0.006			0.109
<2h/day	269 (47.2)	8 (33.3)	261 (47.8)		36 (35.5)	233 (49.9)		6 (30.0)	231 (49.9)	
≥2h/day	301 (52.8)	16 (66.7)	285 (52.2)		67 (65.0)	234 (50.1)		14 (70.0)	232 (50.1)	
Adherence to MD, median (IR)	8.0 (6.0–9.0)	6.0 (5.0–7.0)	8.0 (7.0–9.0)	<0.001	7.0 (6.0–8.0)	8.0 (7.0–9.0)	<0.001	6.0 (4.2–7.0)	8.0 (7.0–9.0)	<0.001
Sleep Quality, n (%)				0.043			0.276			0.431
Good	534 (90.6)	23 (79.3)	511 (91.2)		95 (88.0)	439 (91.3)		20 (87.0)	436 (91.8)	
Poor	55 (9.3)	6 (20.7)	49 (8.8)		13 (12.0)	42 (8.7)		3 (13.0)	39 (8.2)	

InProS, Infancia y Procesamiento Sensorial; TV, television; MD, Mediterranean Diet; IR, Interquartile Range.
[a] Does your child encounter difficulty while transitioning or introducing textures (liquid to puree/puree to solid)? (yes/no).
[b] Does your child tolerate only a very limited variety of foods, tastes and textures? (yes/no).
[c] This variable only included children with both feeding problems (i.e., texture problems and food variety) vs. children with no feeding problems.
[d] P-value was calculated by Fisher's exact test for categorical variables and by U Mann-Whitney test for continuous variables.

Table 2
Comparison of the prevalence of feeding problems according to having or not SR measured by the SSP in children from the InProS Project (n = 589).

	Feeding Problems								
	Texture problems[a]			Food variety problems[b]			Both feeding problems[c]		
	Yes n (%)	No n (%)	p-value[d]	Yes n (%)	No n (%)	p-value[d]	Yes n (%)	No n (%)	p-value[d]
SR items, n (%)									
Total score			0.001			<0.001			0.001
SR (38–154 points)	17 (9.9)	154 (90.1)		54 (31.6)	117 (68.4)		13 (10.3)	113 (89.7)	
No SR (155-90 points)	12 (2.9)	406 (97.1)		54 (12.9)	364 (87.1)		10 (2.7)	362 (97.3)	
Tactile sensitivity			0.011			0.001			0.005
SR (7–29 points)	8 (11.9)	59 (88.1)		23 (34.3)	44 (65.7)		7 (14.0)	43 (86.0)	
No SR (30–35 points)	21 (4.0)	501 (90.6)		85 (16.3)	437 (83.7)		16 (3.6)	432 (96.4)	
Taste/smell sensitivity			<0.001			<0.001			<0.001
SR (4–14 points)	21 (24.1)	66 (65.9)		34 (39.1)	53 (60.9)		19 (37.3)	32 (62.7)	
No SR (15–20 points)	8 (1.6)	494 (98.4)		55 (11.0)	447 (89.0)		4 (0.9)	443 (99.1)	
Movement sensitivity			0.062			0.014			0.015
SR (3–12 points)	11 (8.5)	119 (91.5)		34 (26.2)	96 (73.8)		10 (9.5)	95 (90.5)	
No SR (13–15 points)	18 (3.9)	441 (96.1)		74 (16.1)	385 (83.9)		13 (3.3)	380 (96.7)	
Under-responsive/seeks sensation			0.183			0.011			0.202
SR (7–26 points)	18 (6.2)	271 (93.8)		65 (22.5)	224 (77.5)		14 (6.0)	220 (94.0)	
No SR (27–35 points)	11 (3.7)	289 (96.3)		43 (14.3)	257 (85.7)		9 (3.4)	255 (96.6)	
Auditory filtering			0.701			0.002			0.517
SR (6–22 points)	14 (5.5)	242 (94.5)		62 (24.2)	194 (75.8)		11 (5.4)	191 (94.6)	
No SR (23–30 points)	15 (4.4)	318 (95.5)		46 (13.8)	287 (86.2)		12 (4.1)	284 (95.9)	
Low energy/weak			1.000			0.069			1.000
SR (6–25 points)	3 (4.4)	65 (95.6)		18 (26.5)	50 (73.5)		2 (3.9)	49 (96.1)	
No SR (26–30 points)	26 (5.0)	495 (95.0)		90 (17.3)	431 (82.7)		21 (4.7)	426 (95.3)	
Visual/auditory sensitivity			0.125			0.020			0.446
SR (5–18 points)	11 (7.4)	128 (92.6)		37 (24.8)	112 (75.2)		7 (4.2)	108 (95.8)	
No SR (19–25 points)	18 (4.1)	422 (95.9)		71 (16.1)	369 (83.9)		16 (6.1)	367 (95.8)	

SSP, Short Sensory Profile; InProS, Infancia y Procesamiento Sensorial; SR, Sensory Reactivity.
[a] Does your child encounter difficulty while transitioning or introducing textures (liquid to puree/puree to solid)? (yes/no).
[b] Does your child tolerate only a very limited variety of foods, tastes and textures? (yes/no).
[c] This variable only included the children with both feeding problems (i.e., texture problems and food variety) vs. children with no feeding problems.
[d] P-value was calculated by Fisher's Exact Test.

either texture, food variety, or both feeding problems showed statistically higher rates of SR in SSP total score, tactile sensitivity, and taste/smell sensitivity. Moreover, children with food variety problems, or both feeding problems, i.e., texture and food variety problems co-occurred, had a higher prevalence of SR in movement sensitivity than their counterparts with no feeding problems. The results also displayed that those children with food variety problems had statistically significant higher rates of SR in under-responsive/seek sensation, auditory filtering, and visual/auditory sensitivity SSP subscales.

Table 3 displays the association between SR for the total score and subscales of the SSP and the prevalence of feeding problems in the children of this study. Having SR in the SSP total score was significantly associated with a higher prevalence of food variety problems (PR = 1.13, 95%CI = 1.06–1.20; $p < 0.001$). The results also showed that SR in the taste/smell sensitivity subscale was significantly associated with having problems with texture problems (PR = 1.17, 95%CI = 1.09–1.27; $p < 0.001$), food variety problems (PR = 1.42, 95%CI = 1.31–1.53; $p < 0.001$) and both feeding problems (PR = 1.31, 95%CI = 1.19–1.44; $p < 0.001$). Finally, SR on the auditory filtering subscale was associated with a higher prevalence of a limited variety of foods in children (PR = 1.08, 95%CI = 1.02–1.15; $p = 0.004$).

The results of the sensitivity analyses are presented in Tables 4 and 5. Overall, no substantial changes in the main associations between SR and feeding problems were observed, except when only including children with definitive atypical performance, where the effect was slightly higher.

4. Discussion

In the present study, we identified that a considerable proportion of

Table 3
Association between SR for the total and subscales of the SSP and prevalence of feeding problems in children from the InProS Project.

	Texture problems (n = 559)			Food variety problems (n = 559)			Both feeding problems (n = 474)		
	PR [a]	CI 95%	p value	PR [b]	CI 95%	*p* value	PR [b]	CI 95%	p value
Total score (SR; SSP <155 points)	1.03	0.99–1.07	0.106	1.13	1.06–1.20	<0.001	1.05	0.99–1.11	0.058
Tactile sensitivity (SR; SSP <30 points)	1.04	0.95–1.11	0.334	1.09	0.99–1.21	0.066	1.07	0.99–1.16	0.130
Taste/smell sensitivity (SR; SSP <15 points)	1.17	1.09–1.27	<0.001	1.42	1.31–1.53	<0.001	1.31	1.19–1.44	<0.001
Movement sensitivity (SR; SSP< 13 points)	1.02	0.98–1.06	0.357	1.06	1.00–1.13	0.109	1.04	0.97–1.09	0.192
Under-responsive/seeks sensation (SR; SSP <26 points)	1.00	0.98–1.02	0.914	1.05	0.99–1.11	0.052	1.01	0.97–1.05	0.571
Auditory filtering (SR; SSP <23 points)	1.00	0.96–1.04	0.816	1.08	1.02–1.15	0.004	1.00	0.96–1.04	0.829
Low energy/weak (SR; SSP <27 points)	0.98	0.94–1.02	0.351	1.03	0.95–1.11	0.557	0.97	0.92–1.03	0.259
Visual/auditory sensitivity (SR; SSP <19 points)	1.01	0.97–1.05	0.659	1.04	0.98–1.10	0.179	1.01	0.97–1.05	0.801

SSP, Short Sensory Profile; InProS, Infancia y Procesamiento Sensorial; SR, Sensory Reactivity; PR, Prevalence Ratio; CI, Confidence Interval.
[a] Models were adjusted for mother's country of birth (Spain or others), mother's employment status (working or not working), child's television viewing (<2 h/day or ≥ 2 h/day), child's sleep quality (good or bad) and child's adherence to the Mediterranean diet (continuous).
[b] Models were adjusted for mother's country of birth (Spain or others), mother's employment status (working or not working), child's television viewing (<2 h/day or ≥ 2 h/day) and child's adherence to the Mediterranean diet (continuous).

Table 4
Sensitivity analysis of the association between sensory reactivity and food variety problems in children aged 3–7 from InProS Project (Alicante, Spain).

	n	Food variety problems					
		Total SSP score		Taste/Smell sensitivity		Auditory filtering	
		PR (CI 95%)	p value	PR (CI 95%)	*p* value	PR (CI 95%)	*p* value
Main model[a]	559	1.13 (1.06–1.20)	<0.001	1.42 (1.31–1.53)	<0.001	1.08 (1.02–1.15)	0.004
Including only boys	269	1.11 (1.02–1.20)	0.015	1.39 (1.24–1.56)	<0.001	1.07 (0.99–1.16)	0.051
Including only girls	278	1.15 (1.04–1.27)	0.005	1.43 (1.29–1.58)	<0.001	1.08 (1.00–1.17)	0.057
Including only children aged 3–5	358	1.11 (1.02–1.20)	0.013	1.44 (1.30–1.58)	<0.001	1.09 (1.03–1.16)	0.013
Including only children aged 6–7	200	1.19 (1.05–1.33)	0.002	1.37 (1.19–1.56)	<0.001	1.08 (0.97–1.18)	0.124
Excluding children sleeping <10h/day	349	1.13 (1.04–1.22)	0.003	1.43 (1.30–1.58)	<0.001	1.08 (1.02–1.15)	0.019
Excluding preterm children	447	1.13 (1.04–1.22)	<0.001	1.42 (1.31–1.53)	<0.001	1.09 (1.03–1.16)	0.006
Excluding low weight at birth	488	1.12 (1.03–1.21)	0.001	1.44 (1.33–1.55)	<0.001	1.08 (1.02–1.15)	0.008
Adjusted for child body mass index	439	1.11 (1.01–1.18)	0.012	1.36 (1.26–1.47)	<0.001	1.05 (0.99–1.11)	0.143
Adjusted for father's age, education, employment, and country of birth	495	1.12 (1.06–1.20)	<0.001	1.43 (1.33–1.55)	<0.001	1.06 (1.00–1.13)	0.046
Including only definitive atypical sensory processing[b]	466	1.13 (1.03–1.26)	0.011	1.49 (1.38–1.61)	<0.001	1.06 (1.00–1.13)	0.059
Including only probable atypical sensory processing[c]	493	1.13 (1.04–1.22)	0.002	1.45 (1.31–1.60)	<0.001	1.08 (1.02–1.15)	0.010

InProS, Infancia y Procesamiento Sensorial; SR, Sensory Reactivity; PR, Prevalence Ratio; CI, Confidence Interval.

[a] Main model was adjusted for mother's country of birth (Spain or others), mother's employment status (working or not working), child's television viewing (<2 h/day or ≥ 2 h/day) and child's adherence to the Mediterranean diet (continuous).

[b] Children with definite difference as measured by the SSP were classified as follows: Total SSP (≤141), taste/smell sensitivity (≤11) and auditory filtering (≤19). These children were compared with their respective peers classified as having typical sensory performance (i.e., ≥155, ≥15, ≥23, respectively).

[c] Children with probable difference as measured by the SSP were classified as follows: Total SSP (154-142); taste/smell sensitivity (14-12) and auditory filtering (22-20). These children were compared with their respective peers classified as having typical sensory performance (i.e., ≥155, ≥15, ≥23, respectively).

Table 5
Sensitivity analysis of the adjusted prevalence ratios between sensory reactivity and feeding problems in children aged 3–7 from InProS Project (Alicante, Spain).

	Texture problems			Both feeding problems		
	Taste/Smell sensitivity			Taste/Smell sensitivity		
	n	PR CI 95%	*p* value	n	PR CI 95%	*p* value
Main model[a]	559	1.17 (1.09–1.27)	<0.001	474	1.31 (1.19–1.44)	<0.001
Including only boys	269	1.13 (1.00–1.27)	0.037	228	1.23 (1.08–1.42)	0.002
Including only girls	278	1.22 (1.11–1.35)	<0.001	236	1.36 (1.19–1.56)	<0.001
Including only children aged 3–5	358	1.19 (1.09–1.32)	<0.001	300	1.35 (1.20–1.52)	<0.001
Including only children aged 6–7	200	1.13 (1.01–1.28)	0.033	173	1.22 (1.04–1.43)	0.012
Excluding children sleeping <10h/day	349	1.16 (1.05–1.28)	<0.001	295	1.29 (1.15–1.46)	<0.001
Excluding preterm children	447	1.19 (1.10–1.28)	<0.001	376	1.34 (1.21–1.47)	<0.001
Excluding low weight at birth	488	1.21 (1.12–1.31)	<0.001	413	1.37 (1.24–1.50)	<0.001
Adjusted for child body mass index	439	1.13 (1.04–1.22)	0.002	374	1.22 (1.11–1.35)	<0.001
Adjusted for father's age, education, employment, and country of birth	495	1.24 (1.14–1.33)	<0.001	427	1.35 (1.22–1.49)	<0.001
Including only definitive atypical sensory processing[b]	466	1.24 (1.12–1.36)	<0.001	403	1.40 (1.25–1.58)	<0.001
Including only probably atypical sensory processing[c]	493	1.20 (1.09–1.32)	<0.001	427	1.34 (1.17–1.53)	<0.001

InProS, Infancia y Procesamiento Sensorial; SR, Sensory Reactivity; PR, Prevalence Ratio; CI, Confident Interval.

[a] Main model was adjusted by mother's country of birth (Spain or others), mother's employment status (working or not working), child's television viewing (<2 h/day or ≥ 2 h/day), child's sleep quality (good or bad) and child's adherence to the Mediterranean diet (continuous) for feeding problem textures; and complete model was adjusted for mother's country of birth (Spain or others), mother's employment status (working or not working), child's television viewing (<2 h/day or ≥ 2 h/day) and child's adherence to the Mediterranean diet (continuous) for the both feeding problems.

[b] Children with definite difference as measured by the SSP were classified as follows: Taste/smell sensitivity (≤11). These children were compared with their respective peers classified as having typical sensory performance (≥15).

[c] Children with probable difference as measured by the SSP were classified as follows: taste/smell sensitivity (14-12). These children were compared with their respective peers classified as having typical sensory performance (SSP ≥15).

Spanish children aged 3–7 years manifested feeding problems. Approximately 1 out of 5 school-aged children had a diet with a limited variety of foods, while around 1 out of 25 children presented problems with the introduction/transition of textures or had both feeding problems. The main findings showed a statistically significant association between several SR outcomes and feeding problems. Children with taste/smell SR were more likely to present issues with the introduction/transition of textures, a variety of foods in the diet, or both feeding problems. Furthermore, an association was observed between having SR in the SSP total score and auditory filtering score and a higher prevalence of a diet with a limited variety of foods.

The finding observed in our study on the association between taste/smell SR and feeding problems in children aged 3–7 years aligns with preliminary results from a study of typically developing British children of 5–10 years of age (Farrow & Coulthard, 2012). This study showed that taste/smell SR was significantly correlated with food selectivity. In addition, our results may partly be supported by a recently published systematic review of 27 studies suggesting a relationship between sensory processing sensitivities and feeding problems in children with autism spectrum disorder (ASD) (Elsayed et al., 2022). Research has also shown that children with more taste/smell sensitivity may reject foods because of their smell before tasting them or avoid those with intense flavours (Monnery-Patris et al., 2015). Moreover, it has been observed that these children are more likely to refuse foods that have more significant variations in texture, smell and taste, such as fruits and vegetables (Coulthard & Blissett, 2009). Conversely, it has also been suggested that children with higher taste/smell sensitivity have a higher perception of the palatability of foods, thereby being more prone to consume only very tasty foods, such as ultra-processed foods (Naish & Harris, 2012), and probably having a nutritionally poorer diet. On the

other hand, we also observed that taste/smell RS was associated with difficulties in the transition/introduction of textures (from liquid to puree or from puree to mashed or solid). Children with sensory processing issues, mainly with taste sensitivity, may find it challenging to transition from foods such as purees, which have uniform texture and flavours, to solid foods with much more savoury flavours (Harris & Coulthard, 2016). In this regard, some research has suggested that difficulties transitioning food textures in infancy or toddlerhood may indicate later food selectivity (Coulthard et al., 2009), leading children to eat more restricted diets with a smaller range of foods. Interestingly, the association between these sensory issues and problematic feeding practices is consistent with previous results from the InProS study. We found that children with taste/smell sensitivity had lower adherence to the Mediterranean diet (Navarrete-Muñoz et al., 2019) indicating a poorer quality dietary intake.

This study found that the children with SR in the SSP total score had a higher probability of having a diet with a limited variety of foods. This finding is consistent with the evidence reported in previous European studies. A British study showed that selective feeding correlates significantly with higher total sensory sensitivity in children aged 5–10 years (Farrow & Coulthard, 2012). Another study of two cohorts of Norwegian children reported that children who are more sensory sensitive at 4 years have a higher risk for pickiness at 6 years (Steinsbekk et al., 2017). Our results may be explained by the fact that eating is a multisensory experience that involves processing and integrating the visual (colour and shape), auditory, tactile (textures and temperatures), gustatory and olfactory characteristics of food. As such, children who over- or under-respond to sensory stimuli, either in one or more sensory aspects, may reject certain foods that they internally classify as aversive, especially novel foods that have unfamiliar sensory characteristics (Blissett & Fogel, 2013).

This study also observed that children with SR in the SSP auditory filtering subscale were more likely to have food variety problems. Noises from food preparation, handling and use of utensils and conversations that may occur during mealtimes may result in reduced food intake in children with auditory SR (Nadon et al., 2011). Our results are in line with a study of typically developing children aged 7–36 months reporting that those with feeding problems showed lower auditory processing scores (Tauman et al., 2017). Similarly, a recent study in children with ASD found that children with feeding problems had a higher prevalence of SR in multiple sensory domains, including the auditory filtering subscale (Panerai et al., 2020).

Some studies have also suggested tactile SR may be associated with food neophobia or selectivity in typically developing children (Coulthard & Sahota, 2016; Nederkoorn et al., 2015). In the present study, we observed in the descriptive analysis that children with tactile sensitivity disclosed a higher prevalence of feeding problems. However, this association lost statistical significance when we controlled for confounding factors due to the limited sample size. Nevertheless, the marginally significant association we found may support the hypothesis of a possible association between tactile SR and food selectivity.

This research has several limitations that must be acknowledged. First, it is essential to recognise that this study employs a cross-sectional design, which inherently limits the ability to establish causality or determine the directionality of the associations observed. AS such, we cannot infer a cause-and-effect relationship between SR and feeding problems A more extensive and prospective study would be required to explore these associations in greater depth and elucidate their temporal aspects. Second, we acknowledge the limitation related to our approach to assess feeding problems. The information on the feeding problems was collected through non-validated questions reported by parents, suggesting that the presence of classification bias cannot be ruled out. However, it is worth noting that our study sought to mitigate this limitation by basing our questions on the validated measure CFAQ (Whitehouse & Harris, 1998). Moreover, the prevalence of feeding problems in our study is comparable to that reported in other studies (Brown et al., 2016; Nederkoorn et al., 2015; Steinsbekk et al., 2017). The closed "yes/no" question used for identifying texture problems included the "transition" and "introduction" of textures as important milestones in a child's development to ensure safe and healthy eating habits. Yet, this question did not allow us to distinguish between these different aspects. From an epidemiological approach, this question can be served as a global screening to classify children with feeding problems, which can be interpreted in terms of groups at risk. This ad hoc classification allowed us to examine associations that can provide an insight into the determinants and health-related outcomes or events that could be linked to the health problem of interest (in this case, feeding problems). Thus, based on the hypothesis that atypical sensory performance is linked to feeding problems, the present study was aimed at estimating a measure of association (i.e., prevalence ratio) that allowed to quantify the magnitude of the effect (i.e., SR) on health outcomes (i.e., feeding problems). However, the use of more standardised instruments in future research could provide a more comprehensive assessment of feeding problems, enhancing the reliability and validity of the results. Furthermore, future studies should consider incorporating socioeconomic data and accessibility to local food stores into their analyses, as these factors could contribute to predicting feeding problems as, e.g., food selectivity. Another limitation to acknowledge is that the use of the Short Sensory Profile (SSP) as a self-reported measure to assess SR. While there could be potential variations in the measurement process, however, any implied classification bias is likely to be non-differential. Finally, despite our efforts to adjust for a comprehensive range of potential confounding variables, we acknowledge the possibility of residual confounding or reporting bias stemming from uncollected data or unmeasured factors. Nevertheless, the strength of our study lies in the random selection of centres for participant recruitment, which enhances the representativeness and of our sample and supports the potential extrapolation of our findings to the broader population. In sum, while our study may make significant contributions to the exploration of associations between SR and feeding problems in children, it is essential to interpret these findings with caution. We recognise the need for more extensive and prospective investigations to provide a deeper understanding of these complex relationships, considering the limitations inherent in our study design and methodology. However, our study may serve as a valuable foundation for future research in this area, aiming to refine our understanding of the intricate interplay between SR and feeding behaviours in children.

In conclusion, this population-based study showed that feeding problems might affect children aged 3 to 7. Main findings suggest that children with SR, especially taste/smell sensitivity problems, were more likely to manifest food issues related to textures, variety/acceptance or both feeding problems. While these findings suggest meaningful links, it is essential to acknowledge our study's limitations, notably its cross-sectional design, which limits causal inferences. Future research with a prospective approach is essential for a more comprehensive exploration of SR as a potential predictor of childhood feeding problems. However, as an initial stepping stone, we believe this study paves the way for further research into the relationship between SR and childhood feeding problems, offering potential insights for more effective interventions. These results highlight the need for early intervention led by occupational therapy professionals to detect and potentially mitigate SR's impact on feeding behaviours. These preventive actions would facilitate children's and their families' involvement in successful feeding experiences, ultimately leading to improved children's health and quality of life.

Ethics declaration

The study received full ethical approval from the Research Ethics Committee of the Miguel Hernández University (DPC.ASP.02.16) and was conducted in accordance with the Declaration of Helsinki and current Spanish legislation on data protection (Ley Orgánica 3/2018, de

5 de diciembre, de Protección de Datos Personales y garantía de los derechos digitales). Informed consent was obtained from parents and assent was taken from child participants.

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Author contributions

EMNM and DVG contributed to the design of the study. PFP and EMNM collected the data and created the dataset. ICS and RMS conducted the data analyses and wrote the first draft of the manuscript with support from EMNM and DVG, who provided advice and reviewed and edited the manuscript. All authors (ICS, RMS, EMNM, MSMI, MHP, PFP, ASP, DPB, IJL, PPG, CES and DVG) have revised and approved the final version of the manuscript.

Ethical statement

All participants provided informed consent signed by parents/legal guardians and did not receive any incentive to participate in this study. The InProS study had the approval of the Research Ethics Committee of the Miguel Hernández University (DPC.ASP.02.16) and was conducted in accordance with the Declaration of Helsinki and current Spanish legislation on data protection (Ley Orgánica 3/2018, de 5 de diciembre, de Protección de Datos Personales y garantía de los derechos digitales).

Declaration of competing interest

None.

Data availability

Data will be made available on request.

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