



SECONDARY STUDENTS' SENSORY PREFERENCES AND THEIR INFLUENCE ON SCIENCE ACADEMIC ACHIEVEMENT

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ABSTRACT

Evidence has been found that some students seem to have learning obstacles associated with particular sensory preferences when dealing with instructional materials. Therefore, knowing students' sensory preferences could help teachers improve instructional resources. Our objectives were: (1) to describe Secondary students' sensory preferences according to gender and age; (2) to analyse the possible association between students' sensory preferences and their general academic achievement in science. We conducted a synchronic, cross-sectional descriptive study in a sample of 582 male and female students from 7th to 11th grade using the VARK questionnaire. There was a significant predominance of sensory preferences containing the Kinesthetic mode, and the preferences containing the Visual mode were the least frequent. Girls or boys showed similar distributions of sensory preferences. Using linear regression to predict students' general academic achievement from VARK scores, we obtained a significant contribution of the Kinesthetic score, and a minor but still significant single contribution of the Reading/Writing score.

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INTRODUCTION

Teachers could have the possibility of more effective teaching if they knew what piece of students' mental mechanisms is causally associated to the observed students' learning difficulties or success. Most students' learning obstacles in science education are related to a priori task-avoiding attitudes associated with low motivation, indifference, displeasure or perceived low self-efficacy (Sha et al., 2016; Wan et al., 2021). One possible cause of these demotivation and undesired attitudes is difficulty in taking advantage of learning materials (Urdu & Schoenfelder, 2006). Thus, designing learning materials to better fit students' capabilities, preferences and individual differences, as a part of curriculum adaptations,

seems a promising way to improve students' motivation and self-efficacy and education efficacy (Bovill & Bulley, 2011; Arbutnott & Krätzig, 2015). For years, different authors have worked on the concept of students' learning styles (Cassidy 2004) as a complex construct integrating personal factors as motivation, self-regulation, self-efficacy, and learning strategies, paying special attention to self-efficacy (Bandura, 2012) and its perception.

The central claim of the learning styles theory is that tailoring teaching strategies and materials to accommodate students' learning styles will greatly improve students' learning (Hsieh et al., 2011). Some evidence supporting this claim was obtained. Silva & Andrade's paper (2009) illustrated how ICT allows teachers to adjust teaching methodologies to students' learning styles, supporting their selection of strategies to

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improve teaching and learning. Connected with this idea, recently Shanmugam and Balakrishnan (2019) showed the importance of using ICT for motivation in learning science. In the same vein, Ramirez (2011) showed that sensory preferences affects the results of students learning arithmetic. Students' learning styles were a significant predictor of second language achievement (Soodmand Afsar & Bayat 2018), and were also related to differences in attitudes towards science learning (Wang & Tseng 2015), and even to the effectiveness of contemporary educational technologies (Akbulut & Cardak 2012). On the other hand and following on science education, Lehman (2011) found that some instructional methods were rated as most favorable by a sample of 173 students of an introductory biology without connection with their learning styles.

The theoretical basis of the learning styles and their influence on learning improvement has received less attention. Mayer's (2005) multimedia learning assumed that the human brain assigns different cognitive resources for incoming inputs having different physical format (images, texts, sounds, textures, body language, etc.). Specific combinations of input formats, under some principles, can enhance learning effectiveness. More recent studies in Neuroscience have reported similar conclusions. For instance, Pishghadam et al. (2021) concluded that: "to boost comprehension and reduce the cognitive load during the integration and reinterpretation process, multisensory properties of the input need to be enriched" (p. 100962). These recent neural-based studies and Mayer's work are in tune with Fleming (2011) older proposal on students' sensory modality preference and with Kurilovas et al.'s (2015) study, who showed that personalising learning based on students' needs in terms of their learning styles improves students' learning results. These authors found that many students referred to the way teachers presented their learning material as a learning obstacle. The reason seemed to be associated with a particular sensory preference of each student, i.e. an individual sensitivity to the format of the information provided by the science teacher due to the student's higher or lower cognitive facility processing and integrating visual, aural, textual or kinesthetic information. If this individual preference towards specific format(s) of the learning materials existed and were relatively stable over time, it could be understood as a part of the student's learning style.

Fleming & Mills (1992) proposed a model (VARK model) that categorizes students based on the sensory modality in which they prefer to have

information presented to them. In this model, four basic preferences or "pure" modes are considered: V, Visual; A, Aural; R, Reading/Writing; and K, Kinesthetic. The model also considers any combination of these "pure" modes (i.e., VK, AR, ARK, VARK, etc.) as a different sensory preference. Therefore, there are 15 different possible sensory preferences. The four "pure" modes can be related to different types of learning materials. Visual students (V) like to learn through the representations of information in tables, graphs, diagrams, drawings and all the visual possibilities offered by new technologies. Aural students (A) benefit from information that is "heard". Students with this preference learn best through lectures, explanations from the teacher, devices that reproduce the information in a sonorous way and speaking with other students: The favourite learning materials for Reading/Writing students (R) are notes, good books, magazines, websites that offer written information, and, in general, the information supplied mainly as text. Finally, Kinesthetic students (K) prefer to learn through corporal experience (simulated or real). They like to manipulate any type of mechanism, device or machine and put it to the test. They consider that practice is fundamental for learning.

Based on this model, the VARK questionnaire was elaborated to assess individual sensory preferences. VARK items propose different daily-life situations. Different options are offered in each item, and the participant can choose one option, two, or all of them in order to better match with their personal position. Each option is associated with one of the four different modes considered. Four different scores for V, A, R and K-type responses are obtained (the number of options chosen in all items corresponding to each sensory mode). The final type of sensory preference is assigned to each participant (onwards referred to as SP) by composing the different scores according to a specific procedure (a summary of this can be seen in <http://mercury.educ.kent.edu/database/eureka/documents/LearningStylesInventory.pdf>)

This questionnaire has been used in some studies usually with samples made of university students. In the field of science education different distributions of SP have been obtained in varying degrees. In the studies of Kharb et al. (2013) K was the most frequent SP. Ding et al. (2012) reported most students (85,7%) having multiple learning preferences in different combinations, and the most prevalent SP was "VARK" (50,09 %), followed by trimodal options (19,4%).

The VARK questionnaire has also been used to assess possible gender differences in sensory preferences. Most studies did not reveal any difference between male and female students. In a recent study Shrestha et al. (2020) did not find significant differences working with undergraduate dental students. Also, Urval et al. (2014) did not find significant differences between the 415 female and male undergraduate medical training students in terms of unimodal or multimodal learning preferences. Mean VARK scores for individual sensory modalities were not significantly different. In a previous study carried out by Breckler et al. (2009) no significant differences were found between male and female students. VARK sensory preferences have been related to academic achievement too, usually in university students. Both Dobson (2009) in a study with physiology students, and El Tantawi (2009) in a study with biostatistics students, obtained a significant relationship between SP and academic performance. However, Awang et al. (2017) obtained a non-significant relationship between SP and academic achievement in a sample of international business-course students. Also, Wright & Stokes (2015) suggested that the application of a teaching and learning approach including the different VARK learning preferences was well received by economic grade students and improved their course scores.

Even though learning styles have been widely researched, their existence as a real psychological construct is now in doubt (Dekker et al., 2012; Willingham et al., 2015). However, in the present work we adopted a pragmatic position: we did not discuss whether the learning styles are satisfactory psychological constructs. Instead, we used studies and instruments to investigate the way instructional effectiveness can be enhanced by designing better learning. Being part of learning styles or not, students' sensory preferences likewise deserve attention because of their potential influence on students' -objective or subjective-perception of their learning difficulties. In educational contexts, we will refer to the format with which a student better process the information provided as "the student's sensory preference", and we will consider this concept as an individual differentiating learning factor.

This research aimed at describing the sensory preferences of secondary students; and at assessing whether they are significantly associated to science learning. More specifically, the first objective was to describe in some detail, and using the VARK questionnaire, the distribution of SP in secondary school, according to gender and academic year. The second objective was to ex-

amine to what extent VARK sensory preferences are related to academic achievement in science. These objectives are defined to delve into the current situation of science education that seeks new methods to improve learning (Osborne, 2014). Knowing the sensory preferences of students is important to better define new instructional resources (Ortega-Torres et al., 2020a) at a time when these resources are changing rapidly as a consequence of technological-pedagogical development.

METHODS

This study used an ex post facto, cross-sectional, descriptive research to analyse the results of testing in secondary students' sensory preferences and their relationship with general academic achievement in science. The study focused on secondary education due to the importance of this age for the choice of future studies, a total of 582 male and female Spanish students from 7th grade to 11th grade participated in this study. They belonged to several intact groups in 8 secondary schools of different ownership (public, private-arranged-cooperative, and private-arranged-religious) located in one of the big Spanish cities. There was not a sampling procedure and participants were chosen according to their availability. The selection of the participants avoided biasing criteria, such as academic performance, general aptitude, etc., and attempted at obtaining enough representation of gender in each academic year considered. Table 1 shows the distribution of the sample according to gender and grade.

Table 1. Number and Percentage of Participants According to Gender and Academic Grade

Grade	Age (Average)	Boys	Girls	Total
7th	12.7	74	61	135
		55%	45%	100%
8th	13.4	78	61	139
		56%	44%	100%
9th	14.2	46	39	85
		54%	46%	100%
10th	15.1	74	63	137
		54%	46%	100%
11th	16.5	54	32	86
		63%	37%	100%
Total		326	256	582
		56%	44%	100%

We obtained incomplete data from some participants. Nonetheless, the smallest sample size in any analysis was N = 554.

The shorter, 13-item version of the VARK questionnaire (Fleming & Mills, 1992) is used in the present research study because a shorter version implies a lesser risk of random responses due to boredom. This shorter version does not need specific permissions, it is available and free, and according to the results obtained by Leite et al. (2010), in this research study we did not expect singular contributions from the three additional items included in the longer version of the questionnaire. The 13-item VARK questionnaire was used to assign just one type of SP to each participant among the 15 different possible types: 4 unimodal (V, A, R, or K); 6 bimodal (AV, AR, VK, AR, AK, or RK), 4 trimodal (VAR, VAK, ARK, or ARK) and 1 tetra-modal (VARK) considered as the “neutral” preference, as any sensory channel is good for learning in an equivalent way. In the present study we focused on the following variables: gender, grade, global level of achievement in science, the four scores for V, A, R and K-type responses, and the resultant questionnaire-assigned SP. We also analysed its validation for secondary school students in a previous research “Secondary students’ VARK sensory preferences in science learning: Are they reliable?” (Ortega-Torres et al., 2020b).

In order to collect the data, first, the original VARK questionnaire was translated from English into Spanish and Catalan, the participants’ mother tongues. Then, the questionnaire was transferred to an on-line format (Google-Form) in order to facilitate its administration and data collection. Instructions were elaborated to explain the aims and possible benefits of the study to the participants, and to focus their attention on science learning throughout secondary school. Science teachers were met in every school to explain them the objectives of the study and to ask for their collaboration. Teachers were instructed in the VARK model and in the procedure to correctly administrate the questionnaire. Permissions were obtained and then, days and times were determined for the data collection sessions. The data collection session took less than 60 min. The global level of performance in school science was obtained from the science teachers in each secondary school. Teachers were asked to assign an average mark to every participant in four levels, from A (the highest one) to D, corresponding to scores that range from 8 to 10; 6 to 7.9; 4 to 5.9; 0 to 3.9 respectively in a 0-10 points scale (usual assessment scale at Spanish schools).

The returned questionnaires were evaluated according to the instrument instructions, and the four scores (V, A, R K) were obtained. From

these scores, an individual SP was assigned to each participant (the “resultant SP”). Excel software was used in most descriptive analyses. SPSS 22.0 TM program was used to statistically assess the influence of different factors on the distribution of students’ SP, and also to study the possible influence of SP on the students’ academic performance in science. ANOVA was used in most tests. When sphericity was not obtained, multivariate methods were used based on the Pillai’s trace.

RESULTS AND DISCUSSION

The type of school (public, private-arranged-cooperative, and private-arranged-religious) did not produce significant differences in the distribution of VARK scores, V, A, R, K and Total responses, (multivariate analysis based on Pillai’s trace: $F(2,570)= 1.58$; $p > 0.10$) or in the distribution of the resultant SP assigned to each participant ($X^2(28)= 30.31$; $p= 0.35$). Thus, the type of school was collapsed in further analyses. Table 2 shows the averaged (per student) V, A, R and K scores, according to academic grade and gender (note that the total amount of responses may exceed 13 because several options can be chosen in each item). The higher average scores were obtained for K and A modes, followed by R and V modes. Repeated measures MANOVA revealed significant differences among the four modal scores, with a large effect size ($F(3,570)= 290.52$; $p > 0.001$; $\eta^2= 0.61$; $P=1.0$). Post-hoc pair comparisons showed significant differences between any couple of modal scores ($p < 0.001$ for any comparison).

We analysed the scores throughout the academic grades. The total responses score (Table 2) was significantly influenced by the academic grade ($F(4,568)= 13.20$; $p < 0.001$; $\eta^2= 0.09$; $P=1.0$). Therefore, we performed a mixed 4 (mode) X 5 (grade) MANCOVA with the total responses as a co-variable. In this way, the influence of the total responses on the differences among the modal scores were controlled. The main effect of the mode factor was still significant ($F(3,565)= 4.55$; $p < 0.01$; $\eta^2= 0.02$; $P= 0.89$). More interestingly, the mode X grade interaction was significant ($F(12,556)= 3.68$; $p < 0.001$; $\eta^2= 0.03$; $P= 1.0$) pointing to different SP distribution in different grades. A closer inspection revealed that the interaction effect was entirely due to the scores in 9th grade. When the 9th grade was excluded from the analysis, the mixed 4 X 4 MANCOVA did not show a significant mode X year interaction ($F(9,474)= 1.31$; $p > 0.10$). Therefore, in statistical terms the way the four scores were distributed in 7th, 8th, 10th and 11th grades in our sample was similar, once the total amount of responses was taken into account.

Table 2. Mean Score and Standard Deviation for Modes V, A, R, and K Per Academic Grade and Gender

		VARK Scores									
		V		A		R		K		Total	
Grade	Gender	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
7th	Girls	3.1	1.6	5.7	2.3	3.6	1.5	6.1	2.1	18.5	4.6
	Boys	2.4	1.4	4.9	1.9	3.8	2.1	5.3	2.0	16.4	4.2
	Total	2.7	1.5	5.3	2.1	3.7	1.8	5.7	2.1	17.4	4.5
8th	Girls	3.0	1.8	5.8	2.2	3.7	2.1	6.3	2.3	18.9	4.6
	Boys	2.7	1.9	5.0	2.2	3.5	1.9	5.6	2.3	16.8	4.8
	Total	2.8	1.8	5.3	2.2	3.6	2.0	5.9	2.3	17.7	4.8
9th	Girls	4.9	2.3	6.2	2.4	5.3	2.5	6.8	1.8	23.1	4.9
	Boys	3.9	1.8	6.0	2.4	4.1	1.9	5.8	1.8	19.7	4.7
	Total	4.4	2.1	6.1	2.4	4.7	2.3	6.2	1.9	21.3	5.1
10th	Girls	2.9	1.5	5.9	2.4	3.7	2.2	6.7	2.1	19.2	4.7
	Boys	3.3	1.6	5.4	2.2	3.9	2.1	6.0	2.1	18.6	4.6
	Total	3.1	1.6	5.6	2.3	3.8	2.1	6.4	2.1	18.9	4.6
11th	Girls	2.8	1.7	5.5	2.0	3.7	2.1	6.4	1.9	18.4	4.5
	Boys	2.9	1.6	4.1	2.2	3.8	1.9	5.9	2.4	16.7	4.3
	Total	2.9	1.6	4.6	2.2	3.8	2.0	6.0	2.3	17.3	4.4
Global	Girls	3.3	1.9	5.8	2.3	4.0	2.2	6.4	2.1	19.6	4.9
	Boys	3.0	1.7	5.0	2.2	3.8	2.0	5.7	2.1	17.5	4.7
	Total	3.1	1.8	5.4	2.3	3.9	2.1	6.0	2.1	18.4	4.9

In the present study, similar VARK SP distributions were obtained at the starting and the final grades of secondary school. However, the distribution in 9th grade was different from the rest of grades. The reason is not clear and it beyond the means of the present study (we did not control variables as personal academic records, for instance). Of course, developmental factors could explain (part of) these differences (again beyond the present study). Another explanation could come from the way the educational laws are usually applied in Spain: students having persistent academic difficulties tend to accumulate in 9th grade, just before leaving the compulsory education system at 16 years old. Thus, many classroom groups at 9th grades have biased characteristics compared to other grades where students have yet to give up (7th and 8th grades), or where apprentices clearly decided to go on studying (from 10th grade onwards). We also analysed the distribution of the VARK scores according to gender. The total responses score was significantly higher for girls than for boys ($F(1,571) = 26.65$; $p < 0.001$; $\eta^2 = 0.05$; $P = 1.0$). A mixed MANCOVA with the total responses as a co-variable did not show a significant mode X gender interaction ($F(3,568) = 1.39$; $p > 0,10$).

Finally, a 2 X 5 X 4 mixed gender X academic grade X mode ANOVA for the VARK scores showed a non-significant two-way interaction gender X academic grade ($F(4,563) = 1.29$; $p > 0.10$) and also a non-significant interaction gender X year X mode ($F(12,1689) = 1.52$; $p > 0.10$). Thus, in every academic grade (including 9th grade), the distribution of VARK scores for girls or for boys did not differ significantly.

Secondary students have not been considered in most research on gender differences in VARK preferences. In statistical terms, we did not find girls-boys' differences in sensory preferences, as found in most studies involving students in diverse academic specialities (Breckler et al., 2009; Urval et al., 2014). Our analysis has been conducted using the four different VARK scores, as in the Urval et al. (2014), and also using the composed, resultant SP, as in the mentioned studies. The convergence in our results obtained by these two ways increase their reliability. The similarity between the results obtained in this study and others already cited within the field of science education in diverse geographic contexts shows a pattern that can help make planning decisions for science education.

The four modal scores and the total amount of responses have to be combined in a specific way to obtain the resultant SP assigned

of each student. Figure 1 depicts the distribution of the resultant SP in the sample.

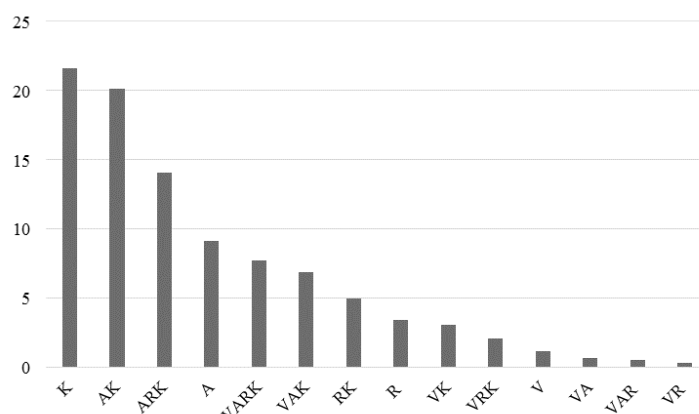


Figure 1. Percentage of Participants Having Different VARK Sensory Preferences

There were fewer unimodal than multimodal students (35% and 65% respectively). Among the multimodal ones, the percentages were diminishing as the modality became more complex (bimodal: 33%; trimodal: 24%; tetramodal: 8%). The obtained distribution was not different from the expected at random (unimodal: 27%, bimodal: 40%; trimodal: 27% and tetramodal: 7%) according to chi-squared test ($X^2(3) = 4.07$; $p > 0.05$). Higher differences unimodal-multimodal distribution were the results obtained by Ding et al. (2012) with a sample of 98 students with and 14.3% of unimodal preferences and 85.7% multimodals, and also a similar result (31% and 69% respectively) was obtained by Urval et al. (2014) in a sample of 415 medical students. Kharb et al. (2013) also reported comparable values with a sample of 100 medicine students. Breckler et al. (2009) identified 60% of students with multimodal preferences in a Human Physiology course (31% of tetramodals, 10% of trimodals and 19% of bimodals). Prithishkumar & Michael (2014) reported another high difference unimodal-multimodal distribution (24% vs. 86%) with 91 first-year medicine students.

As the four unimodal SP concerns, they appeared in frequencies 22% of K, 9% of A, 3% of R and only 1% of V. These frequencies were significantly different from the ones expected at random ($X^2(3) = 29.89$; $p < 0.001$). Thus, the K preference was clearly more frequent, and R and V were less frequent than expected at random. Six types of SP accumulated 80% of the sample. These “most frequent SP” were K, AK, ARK, A, VARK and VAK. The remaining “less frequent SP” (each under 5%) were RK, AR, R, VK, VRK, V, VA, VAR, VR and together made 20% of participants. Regarding the pure modes, there was a significant predominance of SP containing the K mode (81% of participants), in the unimodal SP

or in the different multimodal combinations (as AK or ARK for instance). On the contrary, the V mode was the least frequent, in unimodal or multimodal SP (22% of participants).

Leasa et al. (2016) obtained similar results with 6th grade students: the K preference was also the most common in their sample. The same result reported Kharb et al. (2013). In the Urval et al. (2014) and in the Prithishkumar & Michael’s (2014) investigations AK and ARK were very frequent, as happened in the present study. However, the A mode, not the K mode, was the most repeated one. Most of these studies have been developed with university students. To our knowledge, little research has been done with secondary students, but we found a recent study on middle schools performed by Rahadian & Budiningsih (2018) using a different instrument. A total sample of 307 middle school students completed the Index of Learning Styles questionnaire (ILS) to assess preferences on the four scales of the Felder-Silverman model. Results showed that 72% of students were active on the processing dimension of learning and 28% were passive. This active preference can be linked to the Kinesthetic sensorial preference found on our research if we follow Fleming & Mills (1992) description “it was defined as the perceptual preference related to the use of experience and practice (simulated or real)”. Therefore, the high prevalence of the active dimension in the Rahadian & Budiningsih study can be related to the high prevalence of the K modality in the present study. Recent studies like the one carried out by Ballen et al. (2017) with STEM students showed the importance to improve self-efficacy by the effect of applying active-methods, which is an interesting connection with the K preference found in this research.

Analyses of the resultant compounded SP were coherent and qualitatively similar to the analyses made for the four modal scores. There was not a significant association between the resultant SP and gender, in general ($X^2(14) = 16.07$; $p = 0.31$) or in each academic grade ($p > 0.10$ in any grade). When the most frequent resultant SP was selected (K, AK, ARK, A, VARK, VAK), and once the 9th grade was excluded, there was not a significant association between preference and academic year ($X^2(15) = 24.15$; $p > 0.05$).

The global average mark for the academic achievement in the sample was 2.58 (standard deviation: $SD = 1.04$) in a 1-4 point scale (D level=1; A level=4). It did not follow a normal distribution and was significantly influenced by gender (Mann-Whitney $U = 27093.0$; $p < 0.001$): girls ($M_g = 2.9$; $SD = 1.0$; A: 35%; B: 26%; C: 31%; D: 8%) had higher marks than boys ($M_b = 2.4$; $SD = 1.0$; A: 18%; B: 20%; C: 40%; D: 22%). However, the result was not significantly influenced by the academic grade (Kruskal-Wallis test: $X^2(4) = 4.39$; $p > 0.10$). We did not obtain significant differences when pairs of academic grades were compared ($p > 0.10$). Students having a trimodal or tetramodal SP show higher academic scores in average than students having a unimodal or bimodal SP ($M_{3&4} = 2.72$; $SD = 1.04$; $M_{1&2} = 2.52$; $SD = 1.04$), according to Mann-Whitney U-test ($U = 29652.5$; $p = 0.03$). However, uni- and bimo-

dal students did not differ ($p > 0.80$) and neither did tri- and tetramodal students ($p > 0.90$).

Finally, we tried to predict students' academic achievement from the V, A, R, K, and the total response score using a linear regression. When the back-step method was used to eliminate non-significant predictors, only the K score ($\beta = 0.15$; $p < 0.001$) and the R score ($\beta = 0.09$; $p < 0.05$) were significant ($F(2,570) = 8.75$; $p < 0.001$). In general, the group of participants having SP which do not include the K mode (A, R, V, AR, AV, VR, VAR); had lower average academic levels ($M_{\text{not-K}} = 2.34$; $SD = 0.97$) than the group of students with SP including the K mode ($M_K = 2.64$; $SD = 1.05$). Moreover, when the R mode was added to the K mode in the SP (RK, ARK, VRK, VARK), the average achievement increased ($M_{R\&K} = 2.75$; $SD = 1.08$) with respect to the SP including K but not R (K, AK, VK, VAK) ($M_{K\&\text{not-R}} = 2.58$; $SD = 1.03$).

Finally, as suggested by the analyses, we grouped SP as: (a) those containing the K&R combination; (b) those including K but not R; (c) Other SP. These groups were significantly associated to the level of academic achievement (Kruskal-Wallis: $X^2(2) = 10.278$; $p < 0.01$). Table 3 shows the cross data of SP and students' academic achievement.

Table 3. VARK Sensory Preferences and Students' Academic Achievement

Sensory Preferences		Percentage in Each Level of Academic Achievement				Mean Score (1-4 Scale)
Most Frequent SP		A	B	C	D	
K&R included:	ARK, VARK	33.9	26.6	25.8	13.7	2,8
K included & R excluded:	K, AK, VAK	25.9	22.2	37.2	14.7	2,6
Other:	A	13.7	25.5	41.2	19.6	2,3
Less Frequent SP		Percentage in Each Level of Academic Achievement				
		A	B	C	D	
K&R included:	VRK, RK,	30.8	15.4	33.3	20.5	2,6
K included & R excluded:	VK	18.8	18.8	43.8	18.8	2,4
Other :	VR,VAR,VA R, AR & V	16.9	20.3	42.4	20.3	2,3

Among the most frequent SP (accumulating 80% of participants), those students having ARK and VARK preferences averaged significant higher academic scores in science than the remaining frequent SP, A, K, AK, VAK (Mann-Whitney $U = 16920.5$; $p < 0.05$).

In the present study, the detailed analysis conducted revealed a weak but significant relationship between secondary students' VARK preferences and their academic achievement: SP

including K and R seemed to be associated to higher academic scores than the other SP. Most international research did not obtain such a significant association. Using samples of students in scientific university degrees, the studies by Horton et al. (2012), Urval et al. (2014), and Awang et al. (2017) found a non-significant relation between SP and academic performance. However, the analysis performed in the present study is more detailed than these previous studies. More

recently, Ishartono et al. (2021) did not observe significant differences among Visual, Auditory, and Kinesthetic students' ability to solve PISA math problems. In addition, in the present study trimodal and tetramodal students together averaged higher academic scores than unimodal and bimodal students. This is not a surprising result, as tri- and tetramodal SPs allow the student benefit from more diverse learning materials. Some other results encourage science educators to engage students in inquiry-based science learning activities (Lin & Tsai, 2013) and other active methods connected with kinesthetic mode.

CONCLUSION

The present study analysed the VARK sensory preferences in a sample of male and female Spanish secondary students of different academic years, from 7th to 11th grades. The possible relationship of the VARK preferences and academic achievement in science was analysed as well. Despite the lack of similar studies on secondary students' VARK preferences, our results show some similarities to most of the results obtained with university students. In the limits of the present study, the results showed that the prevalence of the different sensory preferences in the classroom is similar at the beginning and the end of the Secondary level. The SP containing the K mode are the most common, followed by the A mode. In the present study we found a weak but significant link between Sensory Preferences and academic achievement in science. Students having the ARK and VARK preferences (containing A, and R and K together) had higher academic marks than the other students. On the other hand, students having A, R, V, AR, VR, VAR, or VA preferences had the lowest academic marks. Thus, it would be important to consider students' sensory preferences to implement science teaching plans. However, other international research studies showed a non-significant relationship between students' VARK preferences and their academic performance. In addition, no gender differences were obtained in the present study, so girls and boys could equally benefit from learning materials designed in the light of the VARK model in science education. However, other international studies obtained gender differences. The VARK questionnaire administration seems to produce different outcomes in different samples and ultimate conclusions cannot be elaborated yet. Additional studies in a diversity of samples must be developed and more data collected to shed light on the SP construct and its educational utility. Although the studies

carried out using the VARK model need to increase their reliability, the convergence in some issues let us suppose that the learning materials offered by teachers to their students would be more efficient if they were designed from knowledge of students' sensory preferences. In the case of scholar science, it seems that the most prevalent preference at Secondary school is the kinesthetic mode. In this school context, learning materials mixing academic (Reading/writing) and body-handling (kinesthetic) sensory modes could lead to better students performances.

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