PERIÓDICO TCHÊ QUÍMICA
ARTIGO ORIGINAL

PREFERÊNCIAS SENSORIAIS VARK DE ALUNOS DE ENSINO MÉDIO NA APRENDIZAGEM DE CIÊNCIAS: ELES SÃO CONFIÁVEIS?

SECONDARY STUDENTS' VARK SENSORY PREFERENCES IN SCIENCE LEARNING: ARE THEY RELIABLE?

PREFERENCIAS SENSORIALES VARK DEL ALUMNADO DE SECUNDARIA EN EL ESTUDIO DE CIENCIAS: ¿SON FIABLES?

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Received 21 August 2020; received in revised form 12 September 2020; accepted 28 September 2020

RESUMO

As preferências sensoriais dos alunos (SP), ou seja, as formas ou canais pelos quais preferem receber informações, têm sido propostas como um fator pessoal que influencia a aprendizagem de ciências. Existem estudos que relacionam a melhoria do aprendizado com a adaptação dos recursos instrucionais às SP individuais. Um instrumento amplamente utilizado para determinar SP é o questionário VARK. No entanto, os SP individuais devem ser confiáveis para serem considerados úteis para melhorar o ensino. Não há estudos suficientes sobre a confiabilidade deste questionário. O objetivo desta pesquisa foi avaliar a confiabilidade (estabilidade temporal) da SP, medida pelo instrumento VARK. Além disso, foi avaliada a confiabilidade da percepção subjetiva dos alunos sobre suas SP pessoais. Foi utilizada uma metodologia mista, quantitativa e qualitativa. A amostra foi composta por 582 alunos, do 1º ano do ESO ao 1º do ensino médio (7º ao 11º ano). O questionário foi aplicado duas vezes a uma subamostra de alunos, com diferença de aplicação de alguns meses. Um pequeno grupo de alunos também foi entrevistado. Na análise dos resultados por meio dos testes do qui-quadrado (X^2) e da MANCOVA de medidas repetidas, não foram encontradas mudanças permanentes na distribuição dos grupos de PS ao longo do ensino médio. Essa estabilidade permitiria aos professores adaptar materiais a essa distribuição. Os SP individuais permaneceram estáveis ao longo do tempo sob um critério permissivo, mas não quando um critério mais rígido foi usado. Além disso, a confiabilidade da percepção subjetiva do PS encontrada foi baixa.

Palavras-chave: *Aprendizagem, Preferências sensoriais, questionário VARK, Confiabilidade, Ensino médio*

ABSTRACT

Students' sensory preferences (SP), that is, the ways or channels they prefer to receive the information, have been proposed as personal factors influencing science learning. Some studies relate improvement in learning to the adequacy of instructional resources to individual SP. A widely used instrument to determine SP is the VARK questionnaire. However, the individual SP has to be reliable to be considered useful to improve instruction. There are not enough studies on the reliability of this questionnaire. This study aimed to assess the reliability (temporal stability) of SP, as measured by the VARK instrument. Also, the reliability of the student's subjective perception of his/her personal SP was evaluated. A mixed methodology was used, combining techniques for obtaining both quantitative and qualitative information. The sample was made of 582 male and female students, from 7th to 11th grades. The questionnaire was administered twice to a subsample of students, with a few months' delay. Besides, a small group of students was interviewed. In the analysis of the results, using chi-square tests (X^2) and a repeated measure MANCOVA, no massive permanent changes in the group distribution of SP were found along with secondary education. This would be useful for teachers to adapt learning materials to their students' preferences. The individual SP was stable enough under a permissive criterion, but not when a stricter standard was used. Besides, the reliability of students' self-perception of SP was low.

Keywords: *Learning, Sensory Preferences, VARK questionnaire, Reliability, Secondary Education*

RESUMEN

Las preferencias sensoriales de los estudiantes (SP), es decir, las formas o canales mediante los cuales prefieren recibir la información, se han propuesto como un factor personal que influye en el aprendizaje de las ciencias. Hay estudios que relacionan una mejora en el aprendizaje con la adecuación de recursos instruccionales a las SP individuales. Un instrumento muy utilizado para determinar las SP es el cuestionario VARK. Sin embargo, las SP individuales deben ser fiables para poder considerarse útiles con el fin de mejorar la enseñanza. No hay estudios suficientes sobre la fiabilidad de este cuestionario. El objetivo de esta investigación fue evaluar la fiabilidad (estabilidad temporal) de las SP, medida mediante el instrumento VARK. Además, se evaluó la fiabilidad de la percepción subjetiva del alumnado sobre su SP personal. Se ha empleado una metodología mixta, cuantitativa y cualitativa. La muestra se compuso de 582 estudiantes, de 1º de ESO hasta 1º de bachillerato (7º a 11º grado). El cuestionario se aplicó dos veces a una submuestra de estudiantes, con una diferencia de aplicación de algunos meses. También se entrevistó a un pequeño grupo de estudiantes. En el análisis de los resultados mediante pruebas chi cuadrado (X^2) y un MANCOVA de medidas repetidas, no se encontraron cambios permanentes en la distribución grupal de SP a lo largo de la educación secundaria. Esta estabilidad permitiría al profesorado adaptar materiales a dicha distribución. Las SP individuales fueron estables en el tiempo bajo un criterio permisivo, pero no cuando se utilizó un criterio más estricto. Además, la fiabilidad de la percepción subjetiva de la SP encontrada fue baja.

Palabras clave: *aprendizaje, cuestionario VARK, educación secundaria, fiabilidad, preferencias sensoriales*

1. INTRODUCTION:

Knowing students' preferences and individual difficulties dealing with instructional materials could help teachers improve their proposals and help students select resources, activities, and procedures to enhance their effectiveness (then, their self-efficacy) when studying science. Adapting the curriculum to students' differences has been suggested as a possible solution to learning difficulties (Bovill and Bulley, 2011; Rose, Meyer and Hitchcock, 2005; Tomlinson, 1999) instead of lowering the required levels in evaluation (Linnenbrink and Pintrich, 2002). Curriculum adaptations involve designing learning materials, activities, and teaching methodologies to meet individual students' capabilities and preferences (Snow, 1986; Triantafillou, Pomportsis, Demetriadis, and Georgiadou, 2004). These adaptations have to be made not only for disabled students (Bryant, Bryant, and Smith, 2015) but for any student. Students' learning styles (Cassidy, 2010) focused on many studies addressed to determine individual differences and concomitances in learning activities and to develop the curricular adaptations in a better way to students' characteristics and preferences.

Throughout the last 40 years, the number of models and instruments about learning styles has been growing up in an almost exponential way (Geake 2008). Still, most of them have proved to be not reliable enough (Coffield, Moseley, Hall, and Ecclestone, 2004). Several reviews that span decades have revised these instruments (Arter and Jenkins, 1979; Kampwirth and Bates, 1980; Kavale and Forness, 1987; Kavale, Hirshoren, and Forness, 1998), and most of them suggested that there is not enough statistical evidence to support their outcomes. In his complete overview, Cassidy (2010) pointed out that it is necessary to provide evidence about the validity of the models underlying these instruments.

This criticism began a long time ago with the research conducted by Stumpf and Freedman (1981). Different researchers focused on the lack of accuracy of the instruments or inventories used to assess students' learning styles (Curry, 1990; Newstead, 1992), and some of them insisted on the importance of validating these inventories: this validation becomes a necessary step to adapt the instructional approach to students' learning styles in a significant way (Willingham, Hughes, and Dobolyi, 2015).

This is also the case of the VARK instrument. Fleming and Mills (1992) created this questionnaire (Appendix 1) to have a tool to classify people's sensory preferences (SP) about the learning resources. The basis of this SP today can be related to the research studies undertaken by Gilmore, McCarthy, and Spelke (2007), and Dekker, Lee, Howard-Jones, and Jolles (2012). These researchers obtained results that validate that visual, auditory, and kinaesthetic information is processed in different parts of the human brain.

The concept of Sensory Preferences (SP onwards), the kind of personal quality assessed by the VARK questionnaire, refers to a quite permanent individual factor created by a brain pattern, and not to a student's temporary whim. If SP were relatively stable over time, they could be

understood as a part of the students' individual differences influencing learning. Then SP would deserve specific attention in instructional design. Conversely, if SP were not steady for every student (at least in continuous, long enough intervals compared to the typical times needed to achieve educational goals), this construct wouldn't be useful to improve instructional effectiveness.

Even though the VARK questionnaire has been validated in its four-factor structural design (Leite, Svinicki, and Shi, 2009), up to our knowledge, there is no evidence of its reliability (understood as constancy or steadiness) in secondary school students. Most of the studies conducted using the VARK questionnaire involved university students. Therefore, this work focuses on the reliability of the sensory preferences of secondary school students, obtained as outcomes of the VARK questionnaire.

1.1. VARK Sensory Preferences

Fleming and Mills (1992; Fleming, 2001) elaborated on the concept of students' Sensory Preference when they found that many students pointed out as a learning obstacle the way (the channel through) teachers presented their learning material. The reason seemed to be associated with a particular sensory preference of each student. According to Fleming and Mills' (1992) idea, if a student's choice was not in tune with the sensory inputs needed to process the learning materials properly, some learning obstacles could appear associated with inappropriate attitudes towards the tasks or with low use of cognitive-metacognitive skills. These two types of factors, low motivation, indifference, and displeasure, or the perception of low self-efficacy (Koballa and Glynn, 2007; Osborne, Simon, and Collins, 2003), and the unproductive management of cognitive and metacognitive resources (Phan, 2009; Miñano, Castejón, and Gilar, 2012) had been pointed out as essential causes of learning obstacles in science education.

A student´s SP is understood as the individual sensitivity to the specific format of the information presented by the science teacher through a prominent, specific sensory channel. This is not a rigid or immovable preference in each student and discipline, and it does not exclude the possibility of learning through other sensory channels.

In the present paper, the VARK questionnaire was used (Fleming and Mills (1992; Fleming, 2001), assuming the particular way this instrument defines students' sensory preferences. The VARK questionnaire is an adaptation of the previous one designed by Stirling (1987) where only three categories were established: Visual, Aural, and Kinesthetic. Fleming and Mills (1992) considered these three categories insufficient. They decided to divide the Visual preference selected by Stirling (1987) into two different preferences that they called Visual and Reading/Writing because although the eyes are used to taking all the visual information, this information is different in itself. The presentation of the information given by the teacher was put on one side. It is based on visual representations of concepts through diagrammatic materials, graphics, symbols, hierarchy schemes, drawings, etc. On the other side, there were the materials, the information of which is mediated by texts. Then, reading is necessary to take benefit of them. These different materials were considered enough to differentiate the modes Visual, for the first type of material preference, and Reading/Writing, for the second.

Therefore, the VARK questionnaire considers four necessary preferences or "pure" modes: (V) Visual; (A) Aural; (R) Reading/Writing; (K) Kinesthetic. It is also considered any combination of these "pure" modes (i.e. VK, AR, ARK, etc.). These four "pure" modes can be related to different types of learning materials as follows (Fleming, 2001; Fleming and Mills, 1992):

- Visual (V): Visual students like to learn by representing information in tables, graphs, diagrams, drawings, and all the visual possibilities offered by new technologies.
- Aural (A): Aural students benefit from the information that is "heard". Students with this preference learn better through lectures, explanations from the teacher, devices that reproduce the information in a resonant way, and speaking with other students.
- Reading / Writing (R): The favorite learning materials for these students are notes, books, magazines, websites that offer written information, and the information supplied mainly as a text.
- Kinesthetic (K): Kinesthetic students prefer to learn through corporal experience (simulated or real). They like to manipulate any mechanism, device, or machine, and carry out tests and trials with them. They consider that practice is paramount for learning.

Two different versions of the VARK questionnaire have been proposed and used in educational research. The first one is made of 13 items. Still, a few years later, Fleming (2006)

added three extra items to balance the main pure preferences (V, A, R, K) in the questionnaire (4 situations X 4 pure preferences = 16 items). This second version was used to validate the 4-factor structure of the VARK model and to check the reliability of the four scales, which was considered good enough (Leite *et al*., 2009). However, Leite *et al*. (2009) found that the factor loadings of these three additional items in the four theoretical factors (V, A, R, and K) were of similar size, meaning that any of them especially contribute to any factor.

Each item in the questionnaire has multiple choice answer questions. Thus the participant can choose one option, two, or all of them to find the optimal match with their unique position in the proposed situation. Each option is associated with one of the four different modes considered: Visual (V), Aural (A), Reading (R), and Kinesthetic (K). Four different 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 SP is assigned to each participant by composing the different scores according to a (complicated) specific procedure.

Different daily-life situations are portrayed in VARK items: information-receiving situations, information sending circumstances, and contexts in which information has to be used to decide. These situations are easy to understand for students of different ages. In that way, possible erroneous individual interpretations are prevented. They invite participants to think-and-answer from their own daily life experience and not from purely hypothetical or unreal situations.

This questionnaire has been used in some studies aimed at characterizing student's sensorial preferences or at adapting instructional activities to students' characteristics. The samples were usually made up of university students (Dobson, 2009; El Tantawi, 2009; Kharb, Samanta, Jindal and Singh, 2013; Leasa and Batlolona, 2016; Slater, Lujan, and DiCarlo, 2007). VARK preferences have also been related to academic achievement, but usually in university students samples again (Dobson, 2009; El Tantawi 2009; Kharb *et al*. 2013; Awang, Samad, Faiz, Roddin, and Kankia, 2017; Horton, Wiederman, and Saint 2012).

In summary, the VARK-questionnaire administration has produced different outcomes in samples usually made of university students. However, if VARK was not reliable, conclusions could not be elaborated from these previous studies.

1.2. Aims, objectives, and rationale

First, the present study aimed at analysing the reliability of secondary school students' SP as assessed by the VARK questionnaire. The existence of SP as a real individual psychological factor influencing learning requires its stability in long periods. The stability of students' preferences can be assessed following synchronous or asynchronous procedures. Both procedures were used, and then data was analyzed to find whether they were convergent and showed a coherent picture or not.

The first objective was to obtain the distribution of students' SP throughout the years comprised in the compulsory secondary school education and then analyze whether massive changes occur in classroom groups of students (not in individuals). Group constancy (associated with prevalence) of the SP distribution could be important in educational contexts. Here, the stability of the VARK-assigned SP will be analyzed by conducting a cross-sectional synchronous study. The degree of stability will be obtained by comparing the outcomes of groups of students with different ages, but equivalent to other relevant factors.

The second objective was to assess the reliability of the VARK-assigned SP of each student by looking at their constancy in time. If the questionnaire provided reliable information, then two different administrations would give similar results for the same student. In this analysis, an asynchronous study was conducted as the VARK questionnaire was administered twice to the same (sub)sample at different times.

Second, this study also aimed at assessing the students' accuracy when they self-assigned a particular SP. This student's self-assignment was done independently from the VARK-assigned SP, and then both results could diverge.

If VARK-assigned SP were not reliable or continuously changed over time (as an effect of the students' development, for instance), then the SP construct would not be handy for teachers to improve instructional materials. Also, if students' subjective perceptions of their SP were not reliable, they should not attribute learning obstacles to their subjective feelings. In this case, teachers would help students to be aware of their real SP to use them properly.

The third objective was to test the reliability of student's self-perceived SP by comparing the self-assigned sensory preference with the VARK instrument (VARK-assigned SP). However, this

comparison implies considering the VARK questionnaire as reliable, and then, the possibility of meeting this third objective depends on the result of the previous purposes.

In most analyses, students' gender was considered a possible factor causing differences in students' preferences. Provide sufficient details to permit repetition of the experimental work. The technical description of methods should be given when such practices are new.

2. METHODOLOGY:

2.1. Participants

A total of 582 Spanish male and female students from the 7th year (1st of ESO in Spain)- to 11th year (1st of Baccalaureate in Spain)- completed the VARK questionnaire this study. They belonged to several intact groups in eight secondary schools of three different ownerships (public, private arranged-cooperative, private arranged-religious). All high-schools are located in a big Spanish city. There was not a sampling procedure, so participants were chosen according to their availability. However, biasing criteria in selecting participants - such as assigning students with high academic performance, poorer general aptitude - were avoided. The distribution of students in the different school years was not the same but ranged from 24 percent (2nd ESO-8th year) to 15 percent (3rd ESO-9th year) of the total sample. Table 1 provides the amount and percentage of students according to gender and grade level.

Table 1. *Distribution of the sample according to gender and academic year.*

	7th	8th	9th	10th	11th	Total
Average Age (y.o.)	12,7	13,4	14,2	15,1	16,5	
Boys. N=	74	78	46	74	54	326
Percent=	55%	56%	54%	54%	63%	56%
Girls. N=	61	61	39	63	32	256
Percent=	45%	44%	46%	46%	37%	44%
Total N	135	139	85	137	86	582

Incomplete data was from some participants (experimental mortality), so in some analyses, the sample size was smaller. To analyze the stability of the VARK-questionnaire, this instrument was administered again to a sub-sample of 128 participants. This sub-sample was obtained by selecting at random 20-30 boys and girls from every academic year.

To increase the reliability of students' comprehension of the VARK items and researchers' interpretations, a group of 10 students was selected for individual interviews after the first administration of the questionnaire. The selection of this sub-set of participants followed two criteria: (a) the most frequent SP resulting from the first administration of the questionnaire had to be represented; (b) the number of girls and boys had to be balanced according to their distribution in each academic year (see Table 1).

2.2. Variables, Instruments, and Measures

The shorter, 13-item version of the VARK questionnaire (Fleming and Mills, 1992) was used in the present study. This version was chosen, instead of the longer ones, for different reasons: a) As it was stated before, when participants are younger students, a shorter version implies a lower risk of random responses due to boredom; (b) This more concise version of the questionnaire does not need specific permissions, and it is available and free, and (c) According to the results obtained by Leite *et al.* (2009), there was not expected singular contributions from the three additional items included in the more extended version of the questionnaire.

The 13-item VARK questionnaire was used to (a) obtain the five scores for pure or elemental modes V, A, R, K, and for the total amount of options chosen by each student; and (b) to assign one of the 15 different types of SP to each participant:

- Unimodal: V, A, R, or K. In these cases, the student has a clearly defined preference for learning through only one of the sensory channels considered.
- Bimodal: AV, AR, VK, AR, AK, or RK. In these cases, the student benefits from materials given in any of two different channels or their combination.
- Trimodal: VAR, VAK, ARK, or ARK. Students having these sensory preferences benefit from any of the sensory channels except for one. Hence, VAR also means that the student does not prefer (or avoid) materials using the K channel, and so on.
- Tetramodal: VARK. This is the "neutral" preference, as any sensory channel is good for learning identically.

To obtain independent evidence of the

students' self-assigned SP, before administering the VARK questionnaire, students were asked to self-assign the most relevant sensory preference, under their own criteria. An explanation preceded this question about the meaning of Fleming and Mills' SP, and of each of the V, A, R, and K main sensory preferences. The possible answers to this question were only the four pure modes V, or A, or R or K, and only one of them could be chosen.

The interviews were performed by one of the researchers after the first administration. The structure was based on the following stages:

1. Connecting the interview with the VARK questionnaire fulfilled some weeks ago. The meaning of each sensory preference V, A, R, K was explained again.
2. Asking the interviewees to self-assign the main unimodal preference again, to verify the students' constancy in this self-evaluation.
3. Finding out the student's interpretation and justification of the self-assigned SP. Participant's understanding of the real meaning of each unimodal SP and its coherence with the self-assignation was verified by using different examples.
4. Using some VARK items to ask for the meaning the student gave to each item and option, and also to compare the answers given in the interview and in the questionnaire administration.

2.3. Data collection procedure

The first administration of the VARK questionnaire to the whole sample took place in the last third of the academic year. The individual interviews were conducted two to four months later. The second administration to a subsample was done from three to six months after the first administration.

The questionnaire was translated from English into Spanish and Catalan. The science teacher in each school was instructed in the VARK model and in the correct administration of the questionnaire. Permissions were obtained and then, sessions were scheduled for data collection.

The science teacher conducted the data collection session in each school. Written instructions were read aloud to explain the objectives and possible benefits of the study to the participants. First, the teacher explained the meaning of SP, solved out students' doubts, and then, students were asked to self-assign a unimodal SP. Second, the VARK questionnaire was administered. Particular emphasis was put on: (a) centering attention to science learning only; and (b) the possibility of choosing more than one option in each VARK item. Afterward, students' doubts and worries were met. Students individually fulfilled the questionnaire in a typical time of 45-55 min.

The completed questionnaires were evaluated by one of the researchers, according to the particular procedure established for the VARK instrument (a description of the course can be found at Appendix 1). The SPSS 22.0 TM program was used for all data analyses.

For the individual interviews, one of the researchers visited the schools and asked some additional collaboration participants. The interviews took place in a small meeting room. In the introduction, the researcher referred to the VARK questionnaire previously completed by the students and explained the objectives of the interview: to clarify students' answers and to assure the comprehension of items. The interviews lasted approximately 20 minutes per student.

3. RESULTS AND DISCUSSION

3.1. Distribution of SP in the Secondary School

In the whole sample, the Type of School did not produce significant differences in the distribution of VARK scores, V, A, R, K, and Total responses (Pillai's trace: $F(6,1136)= 1.578$; $p> .10$). The distribution of the VARK-assigned SP, obtained by compounding these scores in a specific way, was not significantly associated with the Type of School (Chi-square: $X^2(28) = 30.312$; $p= .348$). Thus, the type of school was collapsed in further analyses. Figure 1 shows the distribution of the VARK-assigned SP in the sample after the first administration.

There were less unimodal (35 percent) than multimodal students (bimodal: 33 percent; trimodal: 24 percent; tetramodal: 8 percent). This distribution was not different from the expected at random (unimodal: 27 percent, bimodal: 40 percent; trimodal: 27 percent and tetramodal: 7 percent) according to X^2 test ($X^2(3) = 4.07$; $p> .05$). The "pure", unimodal SP appeared in frequencies significantly different from the expected at random ($X^2(3) = 29.89$; $p> 0.001$): 22 percent of K, 9 percent of A, 3 percent of R and only 1 percent of V ($X^2(3) = 29.89$; $p> 0.001$). The K preference was clearly more frequent, and R and V were less

frequent than expected at random. Only 10 percent of students showed strong unimodal sensory preferences.

Six types of SP accumulated 80 percent of the sample. These "most frequent SP" were: K, AK, ARK, A, VARK, and VAK. The remaining "less frequent SP" (each under 5 percent of the sample) were RK, AR, R, VK, VRK, V, VA, VAR, VR, and together made 20 percent of the participants. As the pure modes concern, there appeared a significant predominance of SPs containing the K mode (81 percent of participants) in the unimodal SP or the different multimodal combinations (as AK or ARK, for instance). Conversely, the V mode was the least frequent in unimodal or multimodal combinations (22 percent).

3.2. Changes in the group distribution of Sensory Preferences along with Secondary School

To test SP stability along with Secondary School, the data of the initial period was compared with the data of the final one in these academic years. Two years were considered together (so their data were collapsed) for a period to guarantee a period long enough in academic terms. In this way, the influence of minor and not permanent changes due to maturation adjustments would be minimized. The "Initial Stage" or period was defined as 7th and 8th years; and the "Final Stage" as 10th and 11th years.

First, the set of more or less frequent SP was the same in both academic stages. The academic stage was not significantly associated to the percentage of students in the set of more or in the set of less frequent SP (Initial stage: 80.7 percent; Final stage: 80.3 percent; $X^2(1) < 1$). Selecting only the most frequent SP (K, AK, ARK, A, VARK, VAK) there was not a significant association between academic stage and SP ($X^2(5) = 6.04$; p= .303), neither for girls (X^2 (5) = 4.093; p= .536) nor for boys ($X^2(5) = 8.36$; p= .137). Thus, the most frequent SP distribution was similar in the first two years and the two last years. The same applied when only the less frequent SP were selected and associated with the academic stage ($X^2(8) = 8.03$; p= .430). As the "pure" SP concerns (V, A, R, K), their distributions did not vary with the stage either (Global: $X^2(3) =2.95$; p= .399; Girls only: $X^2(3) < 1$; Boys only: $X^2(3) = 3.42$; p= .332). Figure 2 shows the relevant data for the initial to final stage comparison.

The possible impact of gender on VARK sensory preferences was also analyzed. There was not a significant association between SP and gender ($X^2(14) = 16.07$; p= .309). Independent X^2 tests were performed for each academic year, and none of them showed a significant association SP-gender (p> 0.10 in any year). These data suggest that the distributions of SP for girls or for boys were statistically similar.

3.3. Reliability VARK-assigned sensory preference

Different outcomes from two different administrations in a subsample (N= 128). were used to analyze the stability of VARK-assigned SP. The analysis focused on the four scores, but also on the compounded SP.

3.3.1 Score Analysis

When the four scores were taken into account, constancy analyses followed standard procedures, as the test-retest method. Usually, two conditions are required when comparing two different administrations of a particular instrument to be considered stable enough: a) there will not be significant differences; b) a significant correlation is expected to appear.

A repeated measure MANCOVA was performed with two within-subjects factors: Administration (first/second) and type of Score (V/A/R/K). The main effect of the type of Score was significant with a large effect size (Pillai's trace: F(3,124) =142.55; p< 0.001; η^2= .78), but there was not a significant effect of the Administration factor (F< 1), and there was not a significant interaction Administration X type of Score (F(3,124)= 2.46; p= .066). Therefore, globally, there were no significant differences between the first and the second administration of the VARK-questionnaire when the four scores were taken into account. Post-hoc pre-post comparisons for every type of score were performed. After the Bonferroni correction (i.e. stating 0.05/4 = .0125 as the limit of significance), none of them were significant.

The correlation between the first and the second administration were significant for V (r= 0.30; p= 0.001), R (r= 0.34; p< 0.001) and K (r= 0.24; p= 0.006) scores, and also for the Total responses score (r= 0.30; p= 0.001), but reached only marginal significance for the A score (r= 0.17; p=0.06).

3.3.2 VARK-assigned SP analysis

Next, the VARK-assigned SP, obtained by compounding the scores, was analyzed. Due to the different possible pure-mode combinations in the assigned SP (uni, bi, tri, and tetra-modal), comparisons to assess the stability can be made using strict or more permissive criteria.

In the stricter case, if the SP assigned to the same

student were not exactly the same combination of pure modes in both administrations, it would be considered that both VARK-assigned SP differs each other. Using the more permissive criterion, if the first and second SP for the same student shared at least one pure mode, it would be considered that both assignations do not differ.

According to the stricter criterion, only 17 percent of participants obtained precisely the same assignation from both VARK administrations. Nonetheless, when the permissive criterion was adopted, 89 percent of students shared at least one pure mode in both administrations, i.e., only 11 percent of students completely changed their combination of pure modes from the first to the second administration. Each administration was considered a "judgement" made by the VARK-questionnaire on every participant. Then, it computed the Cohen's Kappa to obtain a quantitative indicator for the agreement between both administrations keeping apart random effects. The value was K= 0.78, meaning a good agreement between both administrations (under the more permissive criterion).

3.4. Reliability of students' self-assigned Sensory Preferences

When the more permissive criterion expressed before was assumed, the VARK instrument could be considered as reliable enough to determine students' sensory preferences. Thus, these (reliable) assigned SP can be compared to the self-assigned students' preferences. Remember that the self-assigned SP was necessary unimodal SP (i.e. V, or A, or R, or K).

The self-assigned SP was considered coherent when this (pure) mode was included in the VARK-assigned SP (usually, a combination of pure modes). Otherwise, the self-assigned preference was considered incoherent. For instance, if a participant considered him/herself as K but the instrument assigned him/her the (bimodal) type VA, the student's self-perception was considered as incoherent because VA does not contain the mode K.

In this way, the self-assigned SP and the VARK-assigned SP were coherent only in 61 percent of the participants in the first administration (N= 582). The percentages of incoherent self-assignments ranged from 72 percent of those students' self-considered V, to 14 percent of those self-considered K. Figure 3 shows the proportions of participants with coherent or incoherent self-assignments.

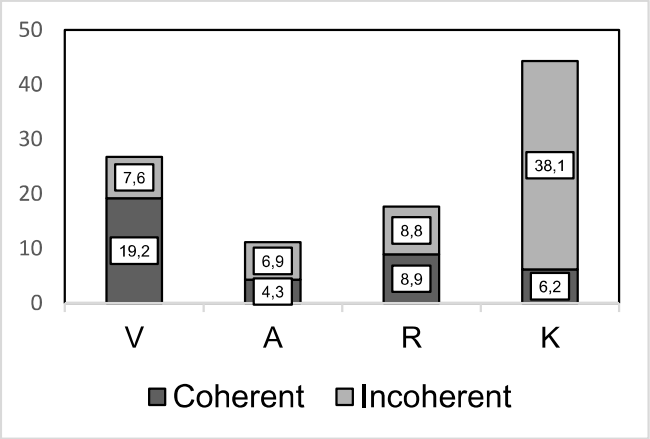

Figure 3. Students' proportions with a self-assigned sensory preference, which is coherent or incoherent with the VARK-assigned sensory preference. The height of the bars represents the percentage concerning the total number of participants.

Therefore, even using the most permissive criterion, 39 percent of students in the sample self-assigned a sensory preference in full disagreement with the VARK-assigned SP. This percentage of disagreement reached 49 percent when the same agreement was computed for the second administration of the questionnaire in the subsample.

If the questionnaire was considered reliable, then the students' self-perceptions wouldn't be considered reliable enough. Opposite, if the reliability of the VARK questionnaire was considered low (for example, assuming the stricter criterion exposed before), then independent evidence would be required to assess the reliability of students' self-assignations.

The stability of the self-assigned SP in the subsample (N=128) was also assessed comparing their first and second self-assignments. As students could self-assign just a pure mode, the probability of concordance diminished (only a strict criterion is possible). The obtained Cohen's Kappa was K= 0.30. Therefore, the students' self-assignations appeared to have low reliability, at least when periods of few months were considered.

3.5. Participants' Interviews

The interviewed students had correct interpretations of the VARK SP. They seemed to understand the meaning of their preference and clearly explain the differences with other preferences. These few passages seem to support these conclusions:

S96 [1:00] (...) in my case, when I see an image of science I can understand it better. For example, when the teacher tells us about an animal, about a special feature it has, when she shows a picture, I can see better this quality in the image than when it is explained by the teacher using her own words (#96 student explaining his Visual preference)

S3 [12:56] I like auditory classes, auditory explanations because I have this auditory memory. When I listen to something, later on, when I have to study it, I can remember that (#S3 student explaining their Auditory preference)

Half of the interviewed students changed their self-assignation from the first administration of the questionnaire (the added question) in the interview. Among the students who maintain their first self-assignation, half of them differed from the VARK-assigned SP according to the more permissive criterion. Therefore, the researcher formulated some VARK items again to these "coherent" students, and, surprisingly, no one repeated the same answer given in the first administration.

However, all the students interviewed, except for one, showed a high coherence to justify their present self-assignations, even when this self-assignment differs from the previous self-assigned ones. It suggested that in brief periods (a few minutes), students did not change their criteria, concepts, and feelings about themselves. Opposite, in a few months, most students changed their perceptions, feelings, and conceptions about themselves.

3.6. Discussion

VARK model was developed by Fleming and Mills (1992) after a perception: the mismatch between students' sensory preferences (SP) and the type of instructional materials offered by teachers seem to cause students' learning obstacles. This mismatch may be objective or subjective. In the first case, it is assumed that real individual sensory preferences influence the effectiveness of students' harnessing of particular instructional materials. These real individual sensory preferences are supposed to be obtained from the VARK questionnaire. In the second case, subjective perception of a mismatch can occur when a student feels that he/she learns better using particular formats that imply sensory channels that are different from the ones implied in the instructional materials offered by the teacher. In this subjective case, the mismatch is based on a student's self-assessment, not on an objective assessment.

From an educational perspective, the study of the causal relationship between the aforementioned mismatch and students' learning difficulties is welcomed (Awang *et al*., 2017; Dobson, 2009; El Tantawi 2009; Kharb *et al*. 2013). However, the reliability of the sensory preference understood as a personal construct influencing learning is a pre-requisite to take educational advantage of these studies.

The present work aimed at analyzing the reliability (understood as stability over time) of both, the objective and the subjective assessment of the students' sensory preferences. The objectives in the present work were: (a) to obtain the distribution of VARK sensory preferences in Secondary education; (b) to assess the reliability, understood as stability over time, of the VARK sensory preferences assigned by the VARK questionnaire (objective assessment); (c) to assess the reliability of the students' (subjective) self-perceived sensory preferences.

VARK questionnaire was analyzed by Leite *et al*. (2009), and the supposed 4-factor structure (V, A, R. K) was confirmed. However, stability over time is also necessary for the reliable use of the questionnaire. Results in the sample made up of secondary school students from 7th to 11th academic years are not conclusive, as different conclusions can be elaborated from others, but sensible, criteria.

First, in a cross-section study, group distribution of SP was not different at the beginning or the final stages in secondary school, and this was true for girls or for boys. Second, the distribution of the VARK scores was statistically similar in both the different administrations of the questionnaire using the same subsample of students. Third, when the VARK-assigned SP after the first administration of the questionnaire were compared with the SP assigned after the second administration (with a few months of the interval between them), only 17 percent of participants obtained exactly the same SP. However, in 89 percent of students, both assignments shared at least one pure mode (V, or A, or R or K).

The reliability of the subjective students' self-assigned sensory preferences was also analyzed. These self-assignations were first compared to the VARK-assignations. The obtained percentages of share were not high: 61 percent and 51 percent of participants, in the 1st and 2nd administrations, self-assigned a unimodal SP that was included in

their VARK-assigned SP. Next, it was compared to the first and second self-assigned SP in the subsample of participants who asked twice the specific question. Again the match was not good (Kappa= 0.30).

4. CONCLUSIONS:

To conclude, data from this study suggested that, although secondary school students seem to be coherent in their feelings along with a personal interview (lasting 20 min), their perceptions about their sensory preferences when studying science were not reliable enough, at least when relatively large periods (months) are considered. The results obtained in the present study did not facilitate knowing whether or not the personal sensory preference can be considered as a real construct. Nevertheless, based on the results of this study, it cannot be concluded that VARK-assigned SP is not reliable. Simply, the SP obtained after two different applications of the VARK questionnaire were not as convergent as desired. Conclusions strongly depended on the criterion used to assess the convergence, and then the results did not show an explicit scene. Therefore, additional studies are needed to conclude on the reliability of students' sensory preferences as personal constructs. On the other side, and despite the SP were real individual characteristics or not, results suggest that students' group distributions of SP are stable enough. The group distribution of students' SPs did not significantly change from the initial to the final two-years stages of Secondary school, and this was true when distributions for girls or boys were considered apart. Thus, science teachers could still benefit from instructional changes addressed to meet secondary students' SP, especially the most frequent ones (in this study, K, AK, ARK, A, VARK, VAK).

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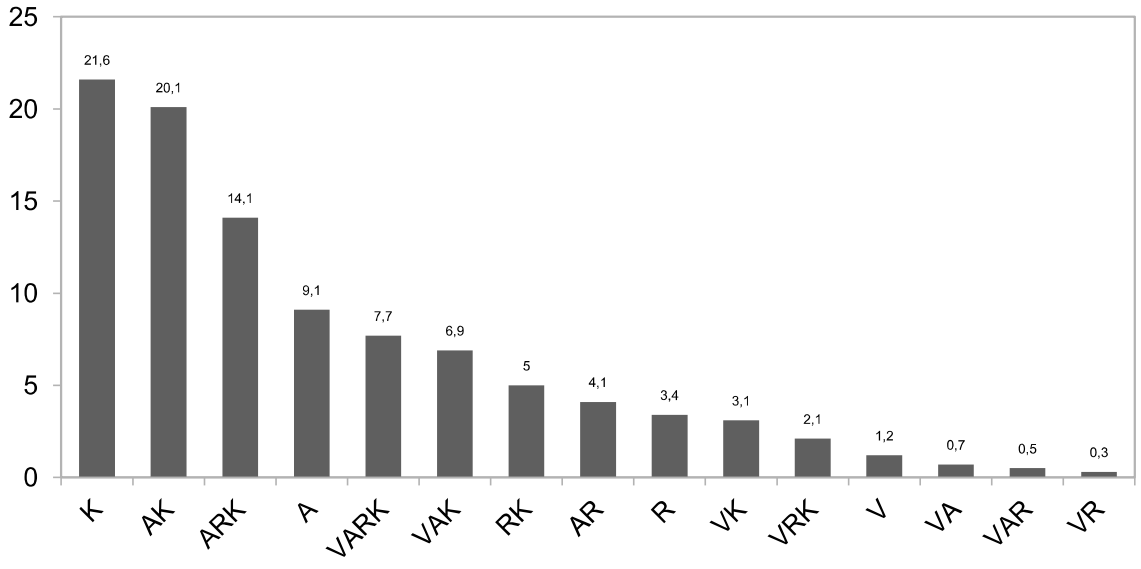


Figure 1. *Percentage of participants having different sensory preferences according to the VARK questionnaire.*

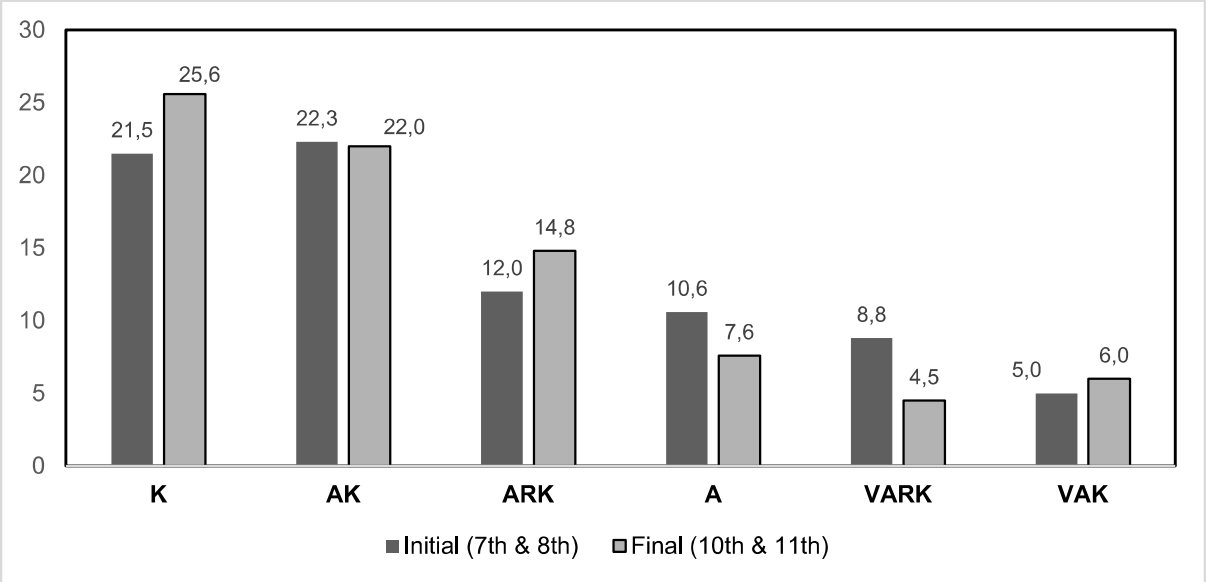


Figure 2. *Percentages of students with the most frequent VARK-assigned sensory preferences in the initial of final academic stages.*

APPENDIX 1

All information of the Appendix 1 has been taken from http://mercury.educ.kent.edu/database/eureka/documents/LearningStylesInventory.pdf

The VARK Questionnaire: How Do I Learn Best?

This questionnaire aims to find out something about your preferences for the way you work with information. You will have a preferred learning style and one part of that learning style is your preference for the intake and output of ideas and information.

Choose the answer which best explains your preference and circle the letter next to it. Please circle more than one if a single answer does not match your perception.

Leave blank any question which does not apply, but try to give an answer for at least 10 of the 13 questions. When you have completed the questionnaire, use the marking guide to find your score for each of the categories, Visual, Aural, Read/Write and Kinesthetic. Then, to calculate your preference, use the Scoring sheet.

1. You are about to give directions to a person who is standing with you.
She is staying in a hotel in town and wants to visit your house later.
She has a rental car. I would:
a. draw a map on paper
b. tell her the directions
c. write down the directions (without a map)
d. collect her from the hotel in my car

2. You are not sure whether a word should be spelled 'dependent' or 'dependant'. I would:
a. look it up in the dictionary.
b. see the word in my mind and choose by the way it looks
c. sound it out in my mind.
d. write both versions down on paper and choose one.

3. You have just received a copy of your itinerary for a world trip. This is of interest to a friend. I would:
a. phone her immediately and tell her about it.

b. send her a copy of the printed itinerary.
c. show her on a map of the world.
d. share what I plan to do at each place I visit.

4. You are going to cook something as a special treat for your family. I would:
a. cook something familiar without the need for instructions.
b. thumb through the cookbook looking for ideas from the pictures.
c. refer to a specific cookbook where there is a good recipe.

5. A group of tourists has been assigned to you to find out about wildlife reserves or parks. I would:
a. drive them to a wildlife reserve or park.
b. show them slides and photographs
c. give them pamphlets or a book on wildlife reserves or parks.
d. give them a talk on wildlife reserves or parks.

6. You are about to purchase a new stereo. Other than price, what would most influence your decision?
a. the salesperson telling you what you want to know.
b. reading the details about it.
c. playing with the controls and listening to it.
d. it looks really smart and fashionable.

7. Recall a time in your life when you learned how to do something like playing a new board game. Try
to avoid choosing a very physical skill, e.g. riding a bike. I learnt best by:
a. visual clues -- pictures, diagrams, charts
b. written instructions.
c. listening to somebody explaining it.
d. doing it or trying it.

8. You have an eye problem. I would prefer the doctor to:
a. tell me what is wrong.
b. show me a diagram of what is wrong.
c. use a model to show me what is wrong.

9. You are about to learn to use a new program on a computer. I would:
a. sit down at the keyboard and begin to experiment with the program's features.
b. read the manual which comes with the program.
c. telephone a friend and ask questions about it.

10. You are staying in a hotel and have a rental car. You would like to visit friends whose address/location you do not know. I would like them to:
a. draw me a map on paper.
b. tell me the directions.
c. write down the directions (without a map).
d. collect me from the hotel in their car.

11. Apart from the price, what would most influence your decision to buy a particular textbook:?:
a. I have used a copy before.
b. a friend talking about it.
c. quickly reading parts of it.
d. the way it looks is appealing.

12. A new movie has arrived in town. What would most influence your decision to go (or not go)?
a. I heard a radio review about it

b. I read a review about it.
c. I saw a preview of it.

13. Do you prefer a lecturer or teacher who likes to use:?
a. a textbook, handouts, readings
b. flow diagrams, charts, graphs.
c. field trips, labs, practical sessions.
d. discussion, guest speakers.

- **The VARK Questionnaire Scoring Chart**

Use the following scoring chart to find the VARK category that each of your answers corresponds to.

Circle the letters that correspond to your answers

e.g. If you answered b and c for question 3, circle R and V in the question 3 row.

Scoring Chart

Question	A	B	C	D
1	V	A	R	K
2	R	V	A	K
3	A	R	V	K
4	K	V	R	-
5	K	V	R	A
6	A	R	K	V
7	V	R	A	K
8	A	V	K	-
9	K	R	A	-
10	V	A	R	K
11	K	A	R	V
12	A	R	V	-
13	R	V	K	A

- **Calculating your scores**

Count the number of each of the VARK letters you have circled to get your score for each VARK category.

Total number of **V**s circled =
Total number of **A**s circled =
Total number of **R**s circled =
Total number of **K**s circled =

- **Calculating your preferences**

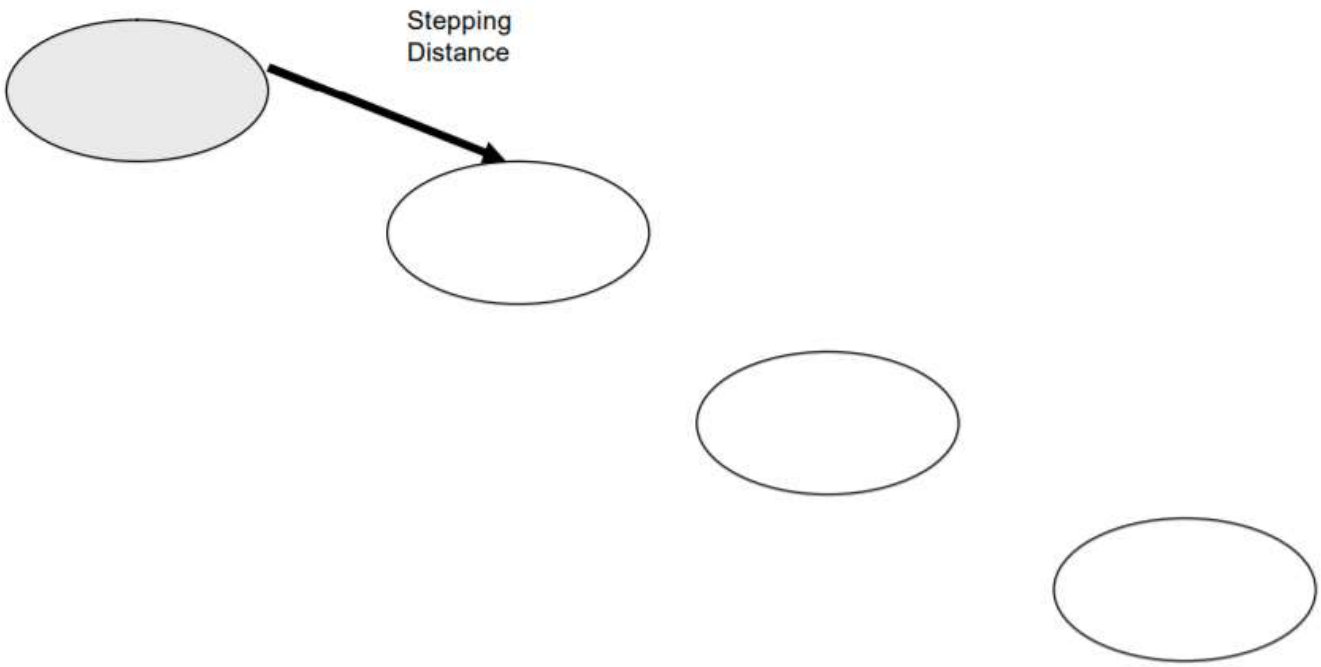
Use the “Scoring Instructions” sheet to work out your VARK learning preferences.

- **Scoring Instructions**

Because respondents can choose more than one answer for each question the scoring is complex. It can be likened to a set of four stepping-stones across

water.

1. Add up your scores, **V + A + R + K =**
2. Enter your scores from highest to lowest on the stones below, with their V, A, R, and K labels.



3. Your stepping distance comes from this table.

Total of my four VARK scores is	**My stepping distance is**
10-16	1
17-22	2
23-26	3
More than 26	4

3. Your first preference is your highest score so check the first stone as one of your preferences and enter its label on the stone.

4. If you can reach the next stone with a step equal to or less than your stepping distance then check that one too.

Once you cannot reach the next stone you have finished defining your set of preferences.

Administering the questionnaire

When you are instructing others to fill in the questionnaire they should be verbally advised to make a selection (a, b, c or d) for each question, but they may omit a question or choose two or three options if appropriate. Some may contest the meaning of words in the questionnaire and others may ask for additional contextual or situational information before they choose their answers. Avoid giving further information, as it may prejudice responses to the questions. Encourage them to choose more than one response if they think the context is not clear. Some may want to discuss the purpose of the questionnaire or its validity or reliability. Ask them to hold such questions till later when they can be more appropriately answered.

Stress, in whatever ways you can, that the results indicate their preferences but are not necessarily their strengths. This reduces the anxiety for respondents who may express the view

that the questionnaire says they are not good readers or not visually strong.

You should make the point that some strong preferences may lessen as individuals mature. Work experiences and life experiences will blur differences the between preferences as people learn to use aural, visual, read/write and kinesthetic modes equally well. Preferences may also be masked by experiences.

No one mode is superior and there is no superior profile. Although our academic institutions may be strongly read/write, life is much more varied. And you can be successful with almost any combination. You may be different but you are not dumb. Students and teachers can investigate the preferences shown and explore their own views about whether the preference fits. For example, a student with a strong visual (V) preference could be asked: "How important is colour in your life?" "Do you consider yourself a visual person?" "Are there aspects of your life where your visual preference is obvious?" "Do you think you have a strong sense of space or shape or position or location?" "Do the study strategies fit with what you do now?"

Finally, some may ask questions about output preferences rather than input preferences. "How is it that I like reading but I hate writing?" Research indicates that those who have a strong preference for "taking in the world" in any particular mode (V, A, R, or K) will want to output in the same mode.