The sensory modality used for learning affects grades

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Ramirez BU. The sensory modality used for learning affects grades. Adv Physiol Educ 35: 270–274, 2011; doi:10.1152/advan.00010.2011.—Second-year undergraduate students from 2008, 2009, and 2010 cohorts were asked to respond to a questionnaire to determine their learning style preferences, the VARK questionnaire (where V is visual, A is aural, R is reading-writing, and K is kinesthetic), which was translated into Spanish by the author. The translated questionnaire was tested for wording comprehension before its application in the actual study. Using the results of the VARK questionnaire, students were classified as unimodal or multimodal and according to the first preferred sensory modality used for learning as V, A, R, or K learners. Multiple-choice questions (MCQs) and problems that required simple arithmetic calculations (arithmetic-type questions) were applied to the students. The relation between the main sensory modality used for learning and the grades obtained in each question type was analyzed both in unimodal and multimodal students. It was found that R unimodal students performed significantly better in arithmetic questions than A and K unimodal students (P < 0.001 by a Bonferroni multiple-comparison test after ANOVA). R unimodal students also performed better than R multimodal students in arithmetic questions (P = 0.02 by a Mann-Whitney U-test). However, no differences were observed after MCQs in either unimodal or multimodal students with different first sensory modalities used for learning. When MCQ scores between unimodal and multimodal students were compared, no differences were detected. It was concluded that the sensory learning style used for learning affects student outcome when students receive arithmetic questions but not when MCQs are applied.

VARK: learning styles; question types; student performance

RECENTLY, several studies have investigated the learning styles preferences in students interested in health professions. Despite the fact that there are many different learning style models that focus on aspects such as pesonality characteristics, information processing style, or instructional preferences (5, 13), many of the previous studies have focused on the sensory modality used by students to learn and have used the VARK questionnaire to assess it (2, 3, 4, 7, 10, 11, 15–17, 19, 21). The VARK questionnaire was developed by Neil Fleming (9), lies in the instructional preference category, and provides a profile of the preferred sensory learning style based on four modalities: visual (V), aural or auditory (A), reading-writing (R), and kinesthetic (K). The VARK questionnaire is available online (9a).

Although no student is restricted to only one sensory mode for learning, a stronger preference for one particular mode may exist. According to the VARK questionnaire, the first preference is the sensory modality that obtains the highest score, and, depending on the score distribution among the four sensory modalities, there are unimodal and multimodal (bimodal, trimodal, and tetramodal) students (9).

Fleming’s VARK questionnaire (English version) was recently validated (14), but potential problems related to item wordings were found. In this connection, students that received the VARK questionnaire in the present study speak Spanish as their native language, and a translated version of the VARK questionnaire was used. Because wording in Spanish has different meanings among different Latin American countries, the Spanish version of the VARK questionnaire that is available at Fleming’s website (9a) was not used here, and a new translation was done by the author. This translation was tested for meaning comprehension before being applied to the students in the present study.

The majority of VARK studies of students from different health-related careers have described the different learning style distributions between sex and/or unimodal versus multimodal proportions of the four sensory modalities (1, 2, 4, 11, 16, 19, 21). Only few and very recent studies have focused on the possible relation between the preferred sensory modality used for learning and student academic performance (3, 6–8, 10). These studies related course scores with sensory learning modalities and found either no relation (3) or that K students (6, 7), A students (10), or unimodal students (8) have the lower scores. Course scores usually are weighed mean data provided by several tests with different question types [multiple-choice questions (MCQs), open questions, problems, laboratory reports, or “other”], and they may have a different final value depending on the weight given to the different tests (or course activities). If student performance depends on the question type, then differences in the components of the final grades may be responsible for the differences reported by different authors. Therefore, this study focused on the possible relation between the preferred sensory modality used for learning, tested by VARK, and a specific question type. However, only two question types usually applied to the students that participated in this study were found to be specific and objective: MCQs and arithmetic questions. Therefore, although students received tests with other question types, only the relation between the sensory modality used to learn and MCQs or arithmetic-type questions was evaluated in the present study.

METHODS

Three cohorts (2008, 2009, and 2010) of second-year undergraduate medicine and sport science students that took one of my courses (Physiology or Research Methodology) for the first time participated in the study. Informed written consent was obtained from all students, and there was no incentive for participation.

The sensory modality used for learning was measured through scoring obtained by the application of a VARK questionnaire (9) translated by the author into Spanish, the students’ native language. In Spanish, words may have different meanings. Therefore, the translated VARK questionnaire was first tested for reading comprehension in a group of former students.
from my courses. The results of this preliminary study are not shown here, and these students were not part of the groups in the present study.

The translated version of the VARK test was applied as a self-reported multiple-choice questionnaire (hard copy) at the beginning of the semester in a class or seminar. The translated questionnaire maintained the original lettering order of the four choices in each question (see the APPENDIX), because the apparent disorder was intentional (9). Students were informed that there were no right or wrong answers. Other relevant explanations, such as “answers should represent what you would really do in the context of each question and not what you believe is expected to be done” were also given, despite the fact that instructions were written as an introduction in the questionnaire. The VARK questionnaire was analyzed using the stepping stone method explained in the website (9a).

The 312 students that participated in the study were classified according to their preferred sensory modality for learning as V, A, R, or K learners. The preferred sensory modality was the modality that obtained the highest score in each individual VARK questionnaire. The scoring also allowed discrimination between students that mainly use one sensory modality for learning (unimodal students) and those that use two or more sensory modalities (multimodal students) (9). In multimodal students, each of the used modalities gets a score. These scores may be equal or different. In this study, the first preference was used to classify multimodal students. When two or more sensory modalities got the same first score (tied), grades obtained in the tests by these multimodal students were not included in the statistical data analysis.

Two question types were used to test student learning outcomes: MCQs and problems that required an arithmetic solution (arithmetic questions). In MCQ tests, grades were the percentage of right answers. MCQ tests with 30–39 questions each were applied in the Physiology (2008 and 2009; 3 tests each) and Research Methodology (2008, 2009, and 2010; 1 test each) classes. MCQs were directed to mainly test understanding and were phrased as clearly and concisely as possible. The test difficulty was average. In arithmetic tests, grades were between 7.0 (perfect score) and 1.0 (all answers wrong), the grading system used at the Universidad de Santiago de Chile. Arithmetic questions were applied in the 2008 (4 questions) and 2009 (7 questions) Physiology classes and the 2010 (2 questions) Research Methodology class.

Since students have different learning styles, a variety of resources was offered in both courses: interactive lectures with PowerPoint presentations, blackboard drawings, oral discussion of right/wrong answers, and small-group tutorials for problem solving and case analysis. In addition, problems that required an arithmetic solution and MCQ tests were posted online on the corresponding course website for self-assessment.

A form with the equations required to solve the arithmetic problems covered in each course was handed out to the students during the tests, because the focus of the courses was not memorization but comprehension.

Data were analyzed using a two-tailed Mann-Whitney U-test or a Bonferroni multiple-comparison test after ANOVA. Statistical significance was set at $P < 0.05$.

RESULTS

Student participation in the study was high (88.6–100% per class). Most students were multimodal (68.9% of total students), and the proportion of unimodal students ranked from 26% to 37% in the different classes. The four sensory modalities were represented by both unimodal and multimodal students in all classes.

MCQs. In multimodal students, 62 of 215 students had tied first sensory modalities, and their data were not considered in the analysis of MCQ test results [48 students were bimodal (AR: 4, VK: 11, AK: 10, RK: 6, VR: 7, and VA: 10) and 14 students were trimodal (VRK: 3, ARK: 3, VAR: 4, and VAK: 4)].

Figure 1 shows the distribution of grades (percentage of right answers) among the 97 unimodal and 153 multimodal students (with one preferred sensory modality) subjected to MCQ tests according to the preferred sensory modality used for learning. No significant differences (ANOVA test) were detected in the outcomes of students that used different sensory modalities for learning in either unimodal or multimodal students. In addition, when all MCQ test grades between the 97 unimodal (66.5 ± 12.2, mean ± SD) and 153 multimodal (65.4 ± 12.3, mean ± SD) students were compared, no significant differences were detected ($P = $ not significant by Mann-Whitney U-test).
In one class, unimodal students obtained slightly higher scores than multimodal students in each one of the three MCQ tests [unimodal students: 65.0 ± 12.6% (n = 42) and multimodal students: 62.1 ± 14.5% (n = 114), means ± SD of data from three MCQ tests, P = not significant] and in each of the other tests with different question types applied to them. Therefore, in this class, unimodal students obtained higher final scores than multimodal students [unimodal (n = 186) vs. multimodal (n = 501) overall data comparison in this class: P = 0.02 by Mann-Whitney U-test]. However, this was a particular situation not observed in other classes.

Arithmetic questions. Three of five classes that received MCQ tests also received questions that required simple arithmetic calculations to be solved. Examples of these questions are shown in Fig. 2. This group had 49 unimodal and 115 multimodal students (34 students with tied first sensory modalities, whose data were not considered in the following analysis).

As shown in Fig. 3, unimodal students that used the R modality for learning obtained significantly higher grades in arithmetic questions than A and K students (P < 0.001 by a Bonferroni multiple-comparison test after ANOVA).

Because the outcomes of one class may affect the statistical significance of the overall group ANOVA, each class was analyzed separately. Regarding unimodal student arithmetic grades, in each class, R students obtained much higher mean grades than students using any other sensory modality (means: 5.9–6.3). Students that used the A modality for learning obtained the lowest scores in two of three classes (means: 2.6 and 3.7), and V (means: 4.3–4.9) and K (means: 3.9–4.7) students obtained reasonable means. Therefore, it can be clearly seen that, in each class, unimodal students using the R sensory modality were the best students and A students were those having more difficulties in answering the questions that required arithmetic calculations.

In contrast, as shown in Fig. 3, there were no statistically significant differences between arithmetic grades in multimodal students (with one preferred sensory modality) that used different sensory modalities for learning (P = not significant by ANOVA).

When all groups were compared, a significant difference was detected (P = 0.004 by ANOVA for 8 groups). Therefore, arithmetic grades of unimodal students were compared with those of multimodal students that shared the same preferred sensory modality, and no statistically significant differences were found between unimodal and multimodal V and K students (Table 1). However, multimodal A students had significantly higher scores than unimodal A students (P = 0.04 by Mann-Whitney U-test) and multimodal R students had significantly lower scores than unimodal R students (P = 0.02 by Mann-Whitney U-test).

### Example 1.
A 70 kg man developed 1715 watts (mean value) during a 1.2 km run. At what speed (mean value) did he run?

### Example 2.
A new treatment (ligature) is compared to a standard surgical procedure. Patients were assigned to treatments at random. Ten months after surgery 18 out of 64 patients in the ligature group and 29 out of 65 patients in the control group were dead.

Based on relative risk reduction (RRR), which treatment is better?

Fig. 2. Arithmetic questions. Shown are examples of questions that required simple arithmetic calculations to be solved. Example 1 was applied in a Physiology course, and example 2 was applied in a Research Methodology class. Students did not have to memorize any equation required to solve the problems because a list of equations was handed out to them. Many problems had more than one possible solution (or answer); therefore, the process was always evaluated (it was mandatory to write all the arithmetic steps involved in the answer).

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**Table 1. Arithmetic scores of unimodal and multimodal students**

<table>
<thead>
<tr>
<th>Sensory Modality</th>
<th>Unimodal Students</th>
<th>Multimodal Students</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Means ± SD</td>
<td>No. of students</td>
</tr>
<tr>
<td>V</td>
<td>4.9 ± 2.4</td>
<td>32</td>
</tr>
<tr>
<td>A</td>
<td>3.7 ± 2.5</td>
<td>39</td>
</tr>
<tr>
<td>R</td>
<td>6.1 ± 1.9</td>
<td>37</td>
</tr>
<tr>
<td>K</td>
<td>4.5 ± 2.4</td>
<td>61</td>
</tr>
</tbody>
</table>

Students were separated by learning style preference [visual (V), aural (A), reading-writing (R), and kinesthetic (K)] by the VARK questionnaire. Statistical analysis was by the Mann-Whitney U-test. A significant difference was detected between unimodal and multimodal students that used the preferred A or R sensory modalities. NS, not significant.
DISCUSSION

This is the first attempt to analyze student performance by focusing on specific question types with respect to the preferred sensory modality used to learn. No significant differences were found when MCQs were used, but when arithmetic questions were solved, unimodal R students performed better than students using any other sensory modality or combination of different modalities.

Although the Spanish version of the VARK test used here has not yet been validated, it maintained the questions, question number, and option order in each question and was analyzed as proposed by Fleming (9a) to classify the sensory modality used to learn. The VARK questionnaire is available online in many languages (9a), and other authors have also used translated versions of the VARK questionnaire applied to students whose native language was not English (3).

Although students can use all sensory modes for learning, one mode may be dominant and preferred. There are also students with no clear preference for any one mode and others that have equally strong preferences for two or three modes. According to Fleming, multimodal students have choice and flexibility and can use the mode that best suits them, the teacher, or the subject (9).

Do unimodal students perform better than multimodal ones? The present results are not enough to answer the question. As far as MCQs are concerned, El Tantawi (8) described that multimodal students in one course (from one cohort) performed significantly better than unimodal students. In contrast, I found that unimodal students in one class performed better than multimodal students in all the applied tests. However, this was a particular situation found in only one of the five classes, and in the whole group (three cohorts with students from two different scientific careers) there were no significant differences between unimodal and multimodal students. So, a study with a number of students from more than one cohort would be needed to confirm if the results of El Tantawi (8) are not another example of a special situation.

Unimodal R students were significantly better than A and K students in solving arithmetic questions. These results are in the same line as reported by others: unimodal A students (10) and self-assessed K students (7) are among those with the lower course scores. However, the low arithmetic score obtained by unimodal A students was improved in multimodal A students. This suggests that multimodal A students, which, by definition, use two or more sensory modalities, may have used another mode (V or R) better suited to solve arithmetic problems. These results support Fleming’s proposal that multimodal students are flexible and can use the mode that best suits the subject (9).

Accordingly, the K multimodal arithmetic average was higher than the K unimodal arithmetic average, but this difference was not statistically significant. A larger sample may determine if K multimodal students also improve their arithmetic skills compared with their unimodal peers.

The better results of unimodal R students compared with multimodal students that shared the same first sensory modality may be due to a better focus (concentration) of the strength for solving problems associated with the preferred use of the R modality in unimodal students. The relation observed between the R sensory modality used for learning and arithmetic capacity may also exist for other question types not analyzed here, and A or K students may have strengths in other areas.

Significant differences between students using different sensory modalities for learning were found only in unimodal students. This was probably due to the presence of “interference” among the different modalities because, despite the fact that students had one preferred sensory modality, they were multimodal. A statistical analysis applied on a much larger number of multimodal students considering the outcomes of each of the sensory combinations used for learning (each bimodal, trimodal, and tetramodal combination) may determine a difference. Such a study could throw interesting results, since, in addition to the present study, most studies have shown that the majority of students that are interested in health careers are multimodal (1, 3, 4, 7, 8, 15, 17).

MCQs are widely used among all education levels. They are considered objective questions and are easy to score or mark, the scoring is objective and reliable, results are quantifiable, and statistics on the tests are easily obtainable (particularly if the tests are computer scored) (12). In addition, in contrast to other assessment instruments in which feedback is laboriously and dependent on individual answers, the closed answer range of MCQs makes it easy for a tutor to provide feedback (20). Provision of feedback is essential in formative assessment, and the format of MCQs is well suited for delivery via a web-based learning environment where students can complete assessments and obtain immediate feedback. Feedback on student performance may significantly increase their outcome (18). The major drawback of MCQs is that they cannot test oral or written skills (20) but still offer ample scope to test much of the knowledge and skills required by many programs (from school to postgraduate).

All students that participated in this study had large experience with MCQs and may have learned some strategy to improve their performance. Anyway, no differences in the outcome after MCQs were detected between students that used different sensory modalities to obtain new information in either unimodal or multimodal students. Also, there were no differences between unimodal and multimodal students. Therefore, MCQs appear not to discriminate against students with any particular sensory modality preference.

The amount of unimodal students with any particular sensory preference is variable among different studies, and the majority of students interested in health professions have multimodal learning preferences. It would be interesting to assess if the better students in different scientific areas belong to a specific unimodal group.

APPENDIX

The Vark Questionnaire

Nombre:
Curso:
Año:

El propósito de este cuestionario es aprender como usted maneja la información. Como todos, usted tiene un estilo de aprendizaje preferido y una parte de ese estilo es su forma favorita de adquirir y entregar ideas e información.

Lea las preguntas siguientes y marque la respuesta que mejor refleje su preferencia (haga un círculo, una X o alguna señal sobre la letra correspondiente). Puede seleccionar más de una opción en cada pregunta, si una sola no refleja la que usted cree que es su mejor
How We Teach

SENSORY LEARNING MODALITY AFFECTS GRADES

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resposta. Deje en blanco cualquier pregunta que no se aplique en su caso.

No existen respuestas buenas y respuestas malas a las preguntas de este cuestionario. Sus respuestas sólo permitirán identificar cual es su forma preferente de administrar la información.

1. Cuando tiene unos pocos minutos libres sin nada mejor que hacer, usted prefiere:
   A. Mirar alrededor, perder la mirada en el vacío
   B. Hablar consigo mismo o con otras personas
   C. Buscar algo para leer
   D. Hacer algo práctico, como arreglar algo, hacer aseo, ordenar su pieza

2. Usted no está seguro(a) de cómo se deletrea una palabra (Ejemplo: trascendente o trascendente). ¿Qué haría?
   A. Busca la palabra en un diccionario
   B. Visualiza la palabra en su mente y escoge según como la ve
   C. La dice en voz alta o imagina como suena
   D. Escribe diferentes versiones de la palabra en un papel y escoge una

3. Usted quiere organizar una fiesta de cumpleaños para un buen amigo. Usted:
   B. Habla de esto por teléfono con sus otros amigos
   C. Hace listas de lo que hay que comprar, o mira revistas que traen ideas para hacer fiestas
   A. Se imagina las actividades de la fiesta
   D. Invita amigos y deja que la fiesta se desarrolle
   4. Va a hacer (o preparar) algo muy especial para su familia. Usted:
   D. Hace (o prepara) algo que le es familiar y que no requiere instrucciones
   A. Mira revistas o libros para buscar ideas e inspirarse
   B. Se basa en un libro que tiene una buena descripción e instrucciones
   C. Lo conversa con algunos amigos
   5. Usted decide participar en unas actividades de verano que lo(a) tienen muy entusiasmado(a). Dos de sus amigos también quieren participar. Usted:
   A. Lleva a sus amigos a conocer el lugar donde se desarrollarán las actividades
   B. Les muestra los folletos y la información que usted tiene
   C. Comienza a practicar las actividades que se van a desarrollar en el programa
   D. Le describe a sus amigos las actividades diarias del programa
   6. Usted está por comprar un nuevo equipo de música. ¿Cuál de los siguientes factores, además del precio, influirá en su decisión?
   B. El vendedor le dice todo lo que usted quiere saber
   C. Lee los detalles sobre el equipo
   D. Usa los controles y escucha el sonido del equipo
   A. El equipo se ve muy moderno y atractivo y le gustaría tenerlo en su pieza

7. Recuerde un momento de su vida cuando aprendió a hacer algo como jugar un nuevo juego. Trate de evitar escoger una habilidad muy física, como andar en patines. ¿Cómo aprendió mejor?
   A. Mirando primero como otros lo hacían
   B. Leyendo las instrucciones
   C. Escuchando a alguien explicarlo
   D. Haciéndolo o tratando de hacerlo usted

8. ¿Cómo es su respuesta a la pregunta en el cuestionario anterior?
   B. Comienza a practicar las actividades que se van a desarrollar en el programa
   C. Les muestra los folletos y la información que usted tiene
   A. Se imagina las actividades de la fiesta
   D. Invita amigos y deja que la fiesta se desarrolle

REFERENCES