The method of loci as a mnemonic device to facilitate learning in endocrinology leads to improvement in student performance as measured by assessments

Ayisha Qureshi,1 Farwa Rizvi,2 Anjum Syed,1 Aqueel Shahid,3 and Hana Manzoor3

1Department of Physiology, Rawal Institute of Health Sciences, Islamabad, Pakistan; 2Department of Community Medicine, Islamabad Medical and Dental College, Islamabad, Pakistan; and 3Rawal Medical College, Rawal Institute of Health Sciences, Islamabad, Pakistan

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Qureshi A, Rizvi F, Syed A, Shahid A, Manzoor H. The method of loci as a mnemonic device to facilitate learning in endocrinology leads to improvement in student performance as measured by assessments. Adv Physiol Educ 38: 140–144, 2014; doi:10.1152/advan.00092.2013.—Cognitive psychology has demonstrated that the way knowledge is structured in memory determines the ability to retain, recall, and use it to solve problems. The method of loci (MOL) is a mnemonic device that relies on spatial relationships between “loci” (e.g., locations on a familiar route or rooms in a familiar building) to arrange and recollect memorial content. In the present study, we hypothesized that the use of MOL leads to better understanding of the topic among students, which can be observed through better student performance on assessments. Students were divided into two groups: group 1 was taught insulin and diabetes mellitus through didactic lectures and a self-directed learning session, whereas group 2 was taught insulin and diabetes mellitus through didactic lectures and MOL. Memory palaces for insulin and diabetes mellitus were generated by students under supervision of the teacher and taught by students as well. A questionnaire survey and open-ended questions were given to the participants. Group 2, which underwent didactic lectures followed by a MOL interactive session, showed significantly improved performance on the assessments compared with group 1, which had been taught through didactic lectures and a self-directed learning session. Descriptive analysis showed that all students found MOL to be a helpful technique.

endocrinology; method-of-loci; memory palace; assessments

Mnemonics are strategies for encoding information with the sole purpose of making it more memorable (1). “What most mnemonics do is to impose meaning and structure to material that would otherwise be meaningless and unstructured,” says Fernand Gobet (University of Nottingham, Nottingham, UK), a psychologist who has studied expert memory extensively. “They do so by making associations between items to learn and items that are already stored in long-term memory. Mnemonics also force one to pay attention to relevant features of the material, and to ‘process’ the material more deeply than by simply rehearsing it. Various experiments have shown that these techniques are effective, although some of them can be hard and time consuming to learn” (5).

Eleanor A. Maguire and colleagues (15) observed that 9 of the 10 superior memorists used the mnemonics known as the “method of loci” (MOL). MOL is a mnemonic device that relies on spatial relationships between “loci” [e.g., locations on a familiar route or rooms in a familiar building called “memory palaces” (MPs)] to arrange and recollect memorial content (11). The origin of this ancient method, sometimes called the “journey” or “mental walk” technique (3), is attributed to the Greek poet Simonides of Ceos in 477 BC (26), and its efficacy is reflected in its continued use over 2.5 millennia in a virtually unchanged form. We discovered that there is a rich literature out there describing the efficacy of MOL as a means to superior memory (25).

Given the ease of use of MOL and its power as a mnemonic device to facilitate repeated access to memory, the present study explored its potential to help medical students recall concepts associated with insulin and diabetes mellitus (DM). There were several important questions to address: Is there any technique that can be used by all students to improve their memory? Can a student use MOL to facilitate access to the various concepts of physiology related to insulin and DM? Can a MP generated in advance using a setting familiar for all participants alike (e.g., the college campus) be equally effective? Will students using MOL perform better on assessments than control students who had not been exposed to MOL? With recall being such an important part of medicine, can such recollection improve with a small amount of training? Can MOL encourage a student’s interest and thus stimulate active learning?

With these thoughts in mind, we designed the present study using the hypothesis that the use of MOL leads to better understanding of the topic among the students, which can be observed through better student performance on assessments.

METHODS

This study was conducted with a class of 78 second-year medical students at Rawal Medical College, Rawal Institute of Health Sciences (Islamabad, Pakistan). The topic covered was insulin and DM. All students (n = 78) were taught insulin and DM in a didactic fashion, consisting of two traditional lectures. Each lecture spanned 60 min.

After the didactic lectures had been completed, 28 students were randomly selected and then taught insulin and DM through the MOL technique. Continued participation in the study was, in any case, entirely voluntary.

The rest of the class (n = 50) studied the same topics (insulin and DM) and completed in-class worksheets. Students were allowed open textbook reference and were allowed to take the completed worksheets home. This was a self-directed learning session under instructor supervision. The entire class was, thus, studying the same topic during the same time, albeit in different ways.

Address for reprint requests and other correspondence: A. Qureshi, Dept. of Physiology, Rawal Institute of Health Sciences, Lehtrar Rd., Khanna Dak, Islamabad, Pakistan (e-mail: ayisha.quireshi75@gmail.com).
Generation of the MP. In the case of our study, three MPs were generated on the following topics: the mechanism of action of insulin, actions of insulin, and DM.

MPs were generated by two second-year medical students under the supervision of the teacher. This procedure differs from the standard variants of MOL (3, 27), where the MOL is generated by the subject themselves. The rationales for this modification were twofold: 1) to reduce the inaccuracies of facts to be recalled as insulin and DM are relatively difficult topics to learn and students had attended only two didactic lecture on the topics before this session and 2) to facilitate the students, as it may be difficult for them to completely generate a MP independently after only a single introductory session to the mnemonic technique.

When a MP is generated, usually a personally familiar location, like an individual’s home, is used as the setting (14). In our study, a location familiar to all participants was the college campus. Three specific places in the college campus were selected: the college cafeteria, the dissection hall, and the main college entrance with faculty parking.

MOL training. The memory training comprised three face-to-face sessions apart from the introductory session, which were conducted by the same students who had generated the MPs.

The purpose behind the students teaching the MPs was to encourage peer learning. Joel Michael (17) has indicated two factors to foster meaningful learning: providing opportunities for peer teaching and encouraging students to “talk physiology.”

Upon entering the classroom for the introductory session, students were provided with a written protocol. This included an introduction to MOL as a mnemonic technique, its various aspects, a brief outline highlighting its significance as a technique preferably used by superior memorists, step-wise instructions, and a schedule for the sessions.

Students were introduced to the mnemonic technique of MOL and MP. To familiarize participants with the mnemonic technique, we used prompts to verbalize and discuss all aspects of image formation, image retrieval, image generation, assistance during recall, repetition, and elaboration of instructions. Various other forms of encouragement were emphasized (4).

Each of the next three sessions lasted ~60–90 min. The first two sessions were scheduled 4 days apart, whereas the third and the last session took place 1 wk later, so that students had time to review the MPs and become familiar with them. Any queries students had regarding the MPs were clarified during this last session. All students practiced recalling the loci several times by mentally journeying through them until they expressed confidence in remembering the various locations. (Remember that all participants were equally familiar and comfortable with the college campus as the setting for the MPs.)

We had no problem holding the students’ interest, and it was an exciting experiment for the medical students teaching the MOL as well.

It is also important to mention that a mediated learning experience stimulates metacognition in students. Metacognition was coined to label “learning about learning.” This includes the ability to learn to plan, monitor success, correct errors, recognize unsuccessful problem approaches, etc. (24). In this experience, students had the possibility of becoming more conscientious about their own learning style.

There were no added costs for the implementation of the activities; there was no requirement for extra rooms or additional instructors.

Assessments. The class (n = 78) underwent a single uniform assessment in the form of a quiz, which was composed of multiple-choice questions (MCQs). The result of the quiz was used to compare class performance.

Questionnaire. A questionnaire was distributed to the participants of the study (n = 28) during the last session. The MOL scale consisted of nine items regarding the effectiveness of MOL in physiology and other subjects and peer teaching. Each item was accompanied by a five-point Likert scale, ranging from 1 (strongly agree) to 5 (strongly disagree). Two open-ended questions were also included to provide feedback regarding the participants’ experiences concerning the MOL technique in general and the use of the MOL technique in learning physiology in particular.

Statistical analysis. All results for the MCQs are presented as mean scores with SDs. To determine the effect of MOL on student performance on the MCQs (mastery of the original material), we used an independent Student’s t-test to compare the scores.

Statistical significance was established at P < 0.05. Because the questionnaire was primarily descriptive, descriptive information was presented for numeric data analysis. Words or sentences provided by participants in answer to the open-ended questions are reported in a tabulated form.

RESULTS

The results of this study can be best described under three headings: student performance on the MCQs, the MOL scale, and open-ended questions.

Student performance on the MCQs. Students underwent a single objective test in the form of MCQs at the end of the session. The test comprised 10 questions. Student performance was evaluated by the number of correct responses given.

An independent Student’s t-test showed the dependence between MOL and student performance as measured by assessments (Table 1). We observed a highly significant increase (P < 0.003) in the number of correct responses on the questions when attempted by students who had been taught insulin and DM through didactic lectures and the MOL technique (mean: 9.31, SD: 1.12) compared with students who had been taught through didactic lectures and the self-directed learning session (mean: 8.10, SD: 1.85). Two participants of the MOL group did not appear for the quiz.

MP scale. A total of 28 participants were recruited. Toward the end of the study, these participants were provided with a questionnaire consisting of nine items. Participants were asked to rate the extent to which they perceived each of the nine items (Table 2). Responses were from “strongly agree” to “agree” to “neutral” to “strongly disagree” and “disagree.” For the purposes of description only, responses to agree and strongly agree were combined as “agree” and those of disagree and strongly disagree were combined as “disagree.”

Table 1. Summary of end-of-course evaluations comparing student performance

<table>
<thead>
<tr>
<th>Description</th>
<th>n</th>
<th>Mean Score</th>
<th>SD</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Didactic lectures plus self-directed learning</td>
<td>52</td>
<td>8.10</td>
<td>1.85</td>
<td>0.003*</td>
</tr>
<tr>
<td>Group 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Didactic lectures plus MOL</td>
<td>26</td>
<td>9.31</td>
<td>1.12</td>
<td></td>
</tr>
</tbody>
</table>

n, number of students. In group 1, the endocrinological unit on insulin and diabetes mellitus was taught by didactic lectures and a self-directed learning session. In group 2, the endocrinological unit of insulin and diabetes mellitus was taught by didactic lectures and the method of loci (MOL) techniques, using memory palaces. *P value was very highly significant (0.003).
How We Teach

METHOD OF LOCI AND STUDENT PERFORMANCE IN ENDOCRINOLOGY

I would like to share the MOL technique. I performed better on my assessments on topics learned through MOL; one participant disagreed. I learned more during the session with MOL compared with my previous experience in physiology. I would like to continue using MOL to learn more topics in physiology. I was more comfortable with MOL because it was being taught by students themselves. I performed better on my assessments on topics that I learned using MOL. The experience was good; it made learning of the topics easier and more dynamic. The experience was good. I will use it in the future. It was a creative form of brainstorming; it definitely helps in understanding medical ideas in one’s imagination, thus making it fun and easier to recall. The experience was good; it made learning of the topics easier and helped me a lot in memorization of the details. It was a great experience to be part of the Memory Palace. The experience was good; it made learning of the topics easier and helped me a lot in memorization of the details. It was a very time consuming. I would not come up with a Memory Palace. I would rather use that time to try to memorize text, however, if a Memory Palace was provided by someone else, I would not mind using it. It can be helpful. I would recall the topics better when the Memory Palace was revised a couple of time. It helped me make a better connection with the topic and made me want to go more in depth and learn about Insulin. It was a good experience. I will use it in the future. It was a great experience to be part of the Memory Palace.

When asked to report whether they found the MOL helpful, all participants (100%) agreed. Most of the respondents (92.9%) were able to recall facts better after learning them with MOL, although one participant remained neutral and another participant disagreed. About 85.7% of the participants agreed that it helped them understand the topic better, whereas 14.3% were neutral. In response to the item “I learned more during the session with MOL compared with my previous experience in physiology,” 71.4% agreed, 17.9% remained neutral, and 10.7% disagreed. The majority of the participants (89.3%) agreed to “continue using MOL to learn more topics in physiology,” although 3.6% disagreed and 3.6% remained neutral. However, only 78.6% of the students agreed to use MOL to learn other subjects compared with 10.7% who disagreed and 3.6% who remained neutral.

Interestingly, only 64.3% of participants were “comfortable as the MOL was taught by students,” whereas 14.3% were not comfortable and 21.4% did not comment.

Most of the participants (85.7%) believed that they did better on assessments on topics learned through MOL; one participant disagreed, whereas 10.7% remained neutral.

Again, 85.7% of participants wanted to share the MOL technique with others, whereas 14.3% remained neutral.

Open-ended questions. Respondents were asked in two open-ended questions to comment on their experience regarding MOL and whether they would change anything about the way it was taught. Of note was the low response to these questions. For this reason, we tabulated the words and terms provided by the participants and analyzed them (Tables 3 and 4).

In Table 3, the responses included indicated that although for the majority of students the MOL helped immensely in better understanding and recall, there were, however, concerns regarding the amount of time that would be spend generating and memorizing the MPs in addition to the text that must be learned. It was interesting to note that one student was eager to use MOL if the MPs would be provided but was reluctant if he were to generate one himself as it appeared to be a time-consuming process. Usually, students are unlikely to appreciate the difficulty, time, and care required to devise a conceptual map (or, in this case, the MP) that they so easily and quickly develop with the help of their professor. Such misapprehension, however, is part of most educational stratagems (13).

As shown in Table 4, it was apparent that the students liked the way the MOL technique was taught and were inspired to make their own. However, there was one participant who had concerns about the MP being taught by the students, whereas two participants had concerns regarding the complexity of the MP being taught and suggested that it be simplified.

Sample MCQs from the assessment quiz. A few MCQs representative of the assessment quiz taken at the end of the unit have also been included (Table 5). They are mostly recall-type questions. (For further comment on the type of MCQs, see the DISCUSSION.)

Table 2. Responses of the participants to the MOL questionnaire

<table>
<thead>
<tr>
<th>Item</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
<th>Missing System</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. MOL was a very helpful technique.</td>
<td>13</td>
<td>46.4</td>
<td>15</td>
<td>53.6</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2. I was able to recall the facts better after learning with MOL.</td>
<td>14</td>
<td>50</td>
<td>12</td>
<td>42.9</td>
<td>1</td>
<td>3.6</td>
</tr>
<tr>
<td>3. MOL helped me understand the topic better.</td>
<td>11</td>
<td>39.3</td>
<td>13</td>
<td>46.4</td>
<td>4</td>
<td>14.3</td>
</tr>
<tr>
<td>4. I learned more during the session with MOL compared with my previous experience in physiology.</td>
<td>11</td>
<td>39.3</td>
<td>9</td>
<td>32.1</td>
<td>5</td>
<td>17.9</td>
</tr>
<tr>
<td>5. I would like to continue using MOL to learn more topics in physiology.</td>
<td>13</td>
<td>46.4</td>
<td>12</td>
<td>42.9</td>
<td>1</td>
<td>3.6</td>
</tr>
<tr>
<td>6. I would like to continue using MOL to learn other subjects as well.</td>
<td>12</td>
<td>42.9</td>
<td>10</td>
<td>35.7</td>
<td>3</td>
<td>10.7</td>
</tr>
<tr>
<td>7. I was more comfortable with MOL because it was being taught by students themselves.</td>
<td>8</td>
<td>28.6</td>
<td>10</td>
<td>35.7</td>
<td>6</td>
<td>21.4</td>
</tr>
<tr>
<td>8. I performed better on my assessments on topics that I learned using MOL.</td>
<td>10</td>
<td>35.7</td>
<td>14</td>
<td>50</td>
<td>3</td>
<td>10.7</td>
</tr>
<tr>
<td>9. I would like to share the MOL technique with friends and family.</td>
<td>15</td>
<td>53.6</td>
<td>6</td>
<td>32.1</td>
<td>4</td>
<td>14.3</td>
</tr>
</tbody>
</table>

n, number of students.

Table 3. Words or phrases that participants used to describe their experience of learning physiology through the MOL technique

1. It helped me make a better connection with the topic and made me want to go more in depth and learn about Insulin.
2. It is useful in remembering the concepts, but in exams it will be difficult to remember the entire story.
3. It was a great experience to be part of the Memory Palace.
4. Slide shows/clips will help students to imagine more dynamically. The session should be made more interactive.
5. It was a good experience. I will use it in the future.
6. The experience was good; it made learning of the topics easier and helped me a lot in memorization of the details.
7. It was a creative form of brainstorming; it definitely helps in understanding medical ideas in one’s imagination, thus making it fun and easier to recall.
8. I think its very time consuming. I would not come up with a Memory Palace. I would rather use that time to try to memorize text, however, if a Memory Palace was provided by someone else, I would not mind using it. It can be helpful.
9. I would recall the topics better when the Memory Palace was revised a couple of time.
10. If we will study the topics in Memory Palace first, before studying in class, I think it will be more helpful.
Fourth, during the generation of a MP, opportunities arise for the clarification of those fundamental psychological concepts that, one discovers, students do not fully understand. Discussing, justifying, or explaining their answers with one another is a powerful way to encourage meaningful learning. Although students have not prepared the MPs themselves, still, it is making sense of what is placed before them, by their peers, that is the stimulus: to break it down into pieces and, in the process, clarify so many concepts and processes.

Interestingly, it was not a problem to encourage students to exploit their newly learned skill in other subjects as well, as evidenced by their eagerness as shown in the descriptive analysis; in fact, one participant immediately generated a MP for the branches of the brachial plexus in anatomy using a familiar route, from home to college, and started teaching it to the rest of his peers.

The fact that students using MOL were able to perform better on assessments than students solving worksheets is a clear indicator that the use of MOL leads to better memory and recall. All of the participants in the study agreed that it was, indeed, a very helpful technique. What was interesting was the majority of students that implied that their understanding of physiology improved. There can be multiple reasons for this “better” understanding: 1) the interactive classroom, 2) the opportunity to “talk” physiology (17) and “talking to themselves” (7) and, of course, 3) peer teaching.

Students who are actively involved in the learning process will learn more than students who are passive recipients of knowledge (6, 10) because active involvement enhances students’ levels of understanding and their ability to integrate and synthesize material (2, 12, 18). An interactive classroom where students “talk to themselves” to generate self-expression without the fear of being penalized and grapple with specific information related to the topic (9) is an important step in the encoding process, the process whereby your brain gradually converts new information into a lasting memory (20). Next, imagine linking this memory to an older framework of memory that is always there: a familiar location, a familiar route, the steps of which you can retrace with your eyes closed. Now all that must be done is to access that memory and follow the link.

**DISCUSSION**

To solve a problem, it is necessary to recall, transfer, and apply knowledge using mental processes such as identification, comparison, proposition, and argumentation (16). Thus, any intervention that facilitates in students the skills for better recall and transfer of knowledge to the resolution of problems related to the discipline should be explored. This prompted our present study. We hypothesized that the use of the mnemonic MOL technique would lead to better student performance on assessments. The results indicated that when didactic lectures are followed up by an interactive learning session involving MOL compared with supervised self-learning sessions with worksheets, student performance improved, as observed by the increased percentages of correct answers given by the students using MOL.

We begin by listing three ways in which MOL facilitates student learning: 1) by helping students retain new concepts, 2) by helping students develop self-learning skills, and 3) as a tool for integrative study. Integrative study allows students to begin to appreciate and use their immense store of knowledge, it helps them recruit facts and ideas from their memory stores and reorganize them, and, finally, it provides a welcome, even if only brief, departure from the lecture format. So, clearly, integrative study complements but does not replace other educational approaches (13).

The reason for not allowing each student to generate their own MPs were multiple. Insulin and DM are fairly difficult topics to begin with, which is one of the reasons that the MPs generated using MOL were developed in advance, by the students, under supervision of the teacher. Second, one of the many purposes of the study was to introduce students to the technique and then, depending on their feedback and their enthusiasm, take them to the next step of each and every student developing his/her own MP individually or in groups and discussing them. We considered this as a pilot project.

Student participation in the development of these MPs and the interactive sessions of teaching them to the other students served several purposes. First, these undergraduate students are being introduced, maybe for the first time, to a meaningful and highly personal hands-on experience. They appreciate that through relating to parts of the brain that are always accessible, observation and memory can actually be reinforced (21). Second, it demonstrated to them that their year of schooling has provided a great fund of immediately usable knowledge. Third, it revealed to them that the individual steps in any complex chain of cause and effect are usually conceptually simple (13).

**Table 4. Words or phrases that the participants used to explain whether they would change anything about the way MOL was taught**

<table>
<thead>
<tr>
<th>Number</th>
<th>Phrase</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>I don’t think that this method needs to be changed. It was taught in the best way possible.</td>
</tr>
<tr>
<td>2.</td>
<td>No, I wouldn’t change anything. It’s a good technique.</td>
</tr>
<tr>
<td>3.</td>
<td>I wouldn’t change anything at all; the only thing I would wish for were more palaces (e.g. glucagon)!</td>
</tr>
<tr>
<td>4.</td>
<td>It should be taught by the teachers and it must be to the point.</td>
</tr>
<tr>
<td>5.</td>
<td>I want to make my own Memory Palace now.</td>
</tr>
<tr>
<td>6.</td>
<td>In some topics there were extra things to imagine that took a lot of time. There should be fewer things to cover more detail in a topic.</td>
</tr>
<tr>
<td>7.</td>
<td>Everything should be linked; imagination should be linked to something that makes sense.</td>
</tr>
</tbody>
</table>

**Table 5. Some of the multiple-choice questions used in the assessment exam**

<table>
<thead>
<tr>
<th>Number</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Patients with non-insulin-dependent diabetes mellitus:</td>
</tr>
<tr>
<td></td>
<td>A. Do not need to exercise</td>
</tr>
<tr>
<td></td>
<td>B. Develop insulin resistance*</td>
</tr>
<tr>
<td></td>
<td>C. Only require insulin injections</td>
</tr>
<tr>
<td></td>
<td>D. Are very rarely obese</td>
</tr>
<tr>
<td></td>
<td>E. Usually belong to the younger age group</td>
</tr>
<tr>
<td>2.</td>
<td>Insulin increases:</td>
</tr>
<tr>
<td></td>
<td>A. The breakdown of proteins</td>
</tr>
<tr>
<td></td>
<td>B. The breakdown of fats</td>
</tr>
<tr>
<td></td>
<td>C. Glycogen breakdown in the liver</td>
</tr>
<tr>
<td></td>
<td>D. The uptake of glucose by its target tissues*</td>
</tr>
<tr>
<td></td>
<td>E. Plasma glucose levels</td>
</tr>
<tr>
<td>3.</td>
<td>In diabetes mellitus type I:</td>
</tr>
<tr>
<td></td>
<td>A. There is increased production of insulin</td>
</tr>
<tr>
<td></td>
<td>B. The only treatment is insulin injections*</td>
</tr>
<tr>
<td></td>
<td>C. Oral hypoglycemic drugs should be immediately started</td>
</tr>
<tr>
<td></td>
<td>D. Desensitization of the insulin receptor occurs</td>
</tr>
<tr>
<td></td>
<td>E. Usually the older age group is involved</td>
</tr>
</tbody>
</table>

*Correct answer.
It must be clarified that we are not encouraging rote learning here. Quite the contrary, it is the availability of the vital basic information that must be recalled by each and every student while solving any problem. As D. U. Silverthorn, an advocate of the interactive classroom, declares: “I do expect them to have read and learned the basics before they come to class” (23). It is knowledge that is stored in a way that allows it to be accessed from many different starting points. That is, it is knowledge that is well integrated with everything that you know (17). Thus, not only do long-lasting memories form “pegs” on which new memories may be “hung,” but, as their retrieval requires less time and energy, all attention may be focused on problem solving and the application of the retrieved facts.

Limitations. An important limitation of research into MOL is that the effective use of MOL traditionally requires extensive training [e.g., two 1-h training sessions (4), three 2-h training sessions (19), one session of training and the request to practice overnight and the next day before testing (22)]. As this was the first of its kind study exploring MOL in medical students, further research, with various parameters, can be conducted to find the most optimum exposure time to the technique.

Questions may also be raised regarding the difficulty level of the MCQs used in the class quiz, as this kind of test does not challenge students in the same way as the problem-solving exam. A few MCQs are being attached as a sample. Although multiple-choice exams have been the most common tool used to evaluate medical students, in fact, they are generally designed to recall rote memory more than to assess transference of meaningful learning (8).

A caveat of this research is that it does not allow us to draw conclusions on the impact of the intervention on the permanence of meaningful learning and in the ability to transfer knowledge to other and more complex contexts. This could be studied by tracking the student participants through subsequent semesters and taking regular feedback.

Conclusions. In summary, the results suggest that mediation through MOL is an effective technique in learning physiology that can also be used in other disciplines related to medicine. Qualitative analysis suggests that the intervention increases students’ motivation and stimulates a better attitude to actively participate in the construction of personal knowledge, a finding that should encourage further research into the topic. Also of interest is the effective use of a single MP across various participants, a theory that has not been extensively previously researched.

DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the author(s).

AUTHOR CONTRIBUTIONS

Author contributions: A.Q., A. Syed, and A. Shahid conception and design of research; A.Q., F.R., A. Shahid, and H.M. interpreted results of experiments; A.Q., A. Syed, and H.M. edited and revised manuscript; A.Q. and A. Syed approved final version of manuscript; F.R. performed experiments; F.R. analyzed data.

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