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SALTATORY CONDUCTION: UNCOVERING THE MIND OF BIOLOGY STUDENTS

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ABSTRACT

Saltatory conduction of action potentials is part of the Biology curriculum which is taught since Secondary Education and it is considered an extremely important concept when teaching neuron physiology and the nervous system. However, students' understanding of this particular concept implies several difficulties, such as the conceptualization of "local" currents which allow the self-regeneration of an action potential. The purpose of this work is, therefore, to answer the following question: what do Biology students understand by "saltatory conduction"? This aims to identify students' difficulties in order to help us improve our teaching practices. So as to answer this question, a survey with open and closed questions was conducted among first year Biology students from Instituto de Profesores "Artigas". The results show that, even though students can establish an association among saltatory conduction, myelin sheath and nodes of Ranvier, they understand saltatory conduction in a vague and superficial way. Only few highlighted the importance of an inversion in the membrane potential in the active zone, and even fewer students made reference to the density of the sodium channels in the nodes of Ranvier, or to the local currents. These results cast doubts on whether some students consider the use of the term "saltatory" as literal.

KEYWORDS: action potential, myelin, local currents, teacher training, Biology teaching.

Introduction

Saltatory conduction is part of the Biology curriculum which is taught since Secondary Education. It is a central concept not only when it comes to understanding the neuron and the nervous system physiology, but it is also regarded as one of the basic concepts in animal physiology.

Nevertheless, the first difficulty in understanding saltatory conduction is to think of an action potential as an abstract entity, given that it constitutes a temporal change in a magnitude. In addition, it entails a new difficulty: the presence of local currents as responsible for an action potential self-regeneration.

The complexity of such topics has been studied by several authors in an attempt to search for better teaching strategies. Therefore, as Biology and Biophysics teachers, it is beneficial to go deeper and identify these difficulties, in order to improve our teaching practice.

The purpose of this work is to answer the following question: what do Biology students understand by "saltatory conduction"? Consequently, a survey with open and closed questions was carried out among Biology students.

Concepts which make saltatory conduction difficult to understand.

In the active zone, where the action potential takes place, the membrane potential is inverted. Consequently, local currents are generated between the neighboring zones from positive charge to negative charge. In the intracellular space, these currents allow the depolarization of the neighboring zones, even at resting membrane potential. If the neighboring zone presents high density of sodium channels -as it occurs in the nodes of Ranvier of myelinated fibres- and the depolarization is enough to reach the threshold potential, then a new action potential takes place. Therefore, an action potential occurs in discontinuous zones of membranes, which is known as "saltatory conduction".

As a way of explaining saltatory conduction, diverse sources usually illustrate arrows in the extracellular space, going from one node of Ranvier to another. However, this representation can be misleading for two reasons: it may induce to think that an action potential literally "leaps" from one node of Ranvier to another; and it does not introduce the idea of local currents as responsible for the depolarization of the neighboring zones.

Materials and Methods

A mixed methods research was carried out; it consisted of a quantitative descriptive and qualitative research based on the analysis of a survey with open and closed questions regarding saltatory conduction. This questionnaire was conducted among 47 first year Biology student from the teacher training institute in Montevideo: Instituto de Profesores "Artigas", which has the largest enrollment rate in Uruguay. Two questions were proposed in such survey. The first one directly explores what students understand by "saltatory conduction". The second question asks students to choose between two images A and B (fig. 1) in order to use it when teaching the concept of saltatory conduction in Secondary Education.

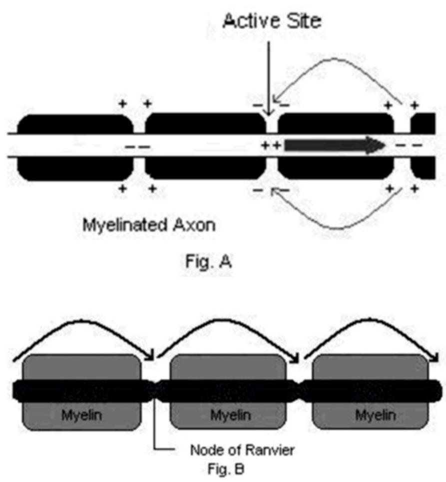

Fig.1.- Images which students had to choose in order to teach saltatory conduction in Secondary Education. Figure A represents the local currents responsible for the depolarization of the nodes of Ranvier adjacent to the active zone in which an action potential takes place. The latter is represented through an inversion in the membrane polarity with regard to the resting membrane potential. Figure B represents the usual way which is used to illustrate the "leaps" of an action potential from one node of Ranvier to the next.

In addition to selecting figures 1A or 1B, this question requested that students explained their reasons for their choice. For purposes of analysis, we consider more appropriate figure 1A, since it represents the local currents and it does not introduce any of the misconceptions already discussed.

Results and Discussion

Analysis of question 1

The first question consisted in asking directly what students understood by saltatory conduction. The results are the following:

From a total of 47 students, only 2 (4,3%) answered in an acceptable way, explaining adequately what saltatory conduction consists of. It is important to make clear that from these two students, only one mentioned the local currents. The other student's answer was considered acceptable because he regarded the change in the membrane polarity as important, even though his explanation was incomplete. From the remaining students: 5 (10,6%) did not answer; 22 (46,8%) students gave an elusive answer; and 18 students (38,3%) answered incorrectly. Among those 40 students (85% overall) that either answered incorrectly or gave an off-topic answer, 14 (29,8% overall) explained that the nerve impulse “leaps from one node of Ranvier to the next”; nevertheless, 9 (19% overall) students used the word “leap” between inverted commas. These last students seemed to understand that the word “leap” is not used literally, therefore some doubts remain regarding the other 5 students (10,6% overall). Moreover, among the 40 students (85%) who answered incorrectly or in an elusive way, 4 of them (8,6% overall) expressed that the conduction is not continuous; however, it is not clearly stated that the action potential generation is discontinuous because it occurs only in the nodes of Ranvier.

To put it briefly, only some students managed to explain the concept of saltatory conduction satisfactorily. Even though some students link this property with a discontinuous form of propagation, they are not able to explain it clearly. In general terms, saltatory conduction seems to be familiar to most students but its understanding is, on the whole, very vague.

Analysis of question 2:

Regarding the second question, these are the results:

Table 1.- Students´ choices to the second question (n = 47), according to whether they chose figure 1A, 1B, both figures, none, or did not answer.

	Chose A	Chose B	Chose Both	None	No Answer	Total
Relative Frequency (%)	27,7	38,3	12,8	6,4	14,8	100

According to this quantitative data, 27,7% of the students chose the option that we consider best represents the concept of saltatory conduction. Of the remaining 72,3%, more than half of them chose figure 1B and the rest selected either both options, none or did not answer. In order to understand more deeply students' ideas concerning this concept, we address the qualitative analysis of the open answers.

Firstly, we analyze students' reasons for choosing the different figures, starting by those who chose the “correct” option, that is to say, option 1A. From a total of 13 students (27,7% overall) that selected it, only one student (2% overall) made reference to the representation of the intracellular current responsible for the depolarization of the neighboring zones. The remaining 12 reasons are based on the figure showing the charges as a representation of a change in the membrane potential, but they do not refer to the local currents. Even though the representation of charges is a fundamental element when explaining saltatory conduction, it should be used to explain the generation of the local currents. That is to say, the simple representation of these charges does not necessarily imply an adequate explanation of the so called “saltatory conduction”.

From the remaining 34 students that either chose 1B, both, none or did not answer, only one student made reference to the intracellular current responsible for the depolarization of the neighboring zones. This student was one of the two who did not choose an image, explaining that he considered the arrow located in the extracellular region in figure 1A was incorrect, although he recognized other good characteristics in it. Even though it is not exactly a mistake, since there are other local currents in the extracellular region, this misconception is not major. Therefore, we consider that his explanation is acceptable and that he understands, in general terms, the concept of saltatory conduction.

Some of the students who chose figure 1B (38,3%) explained that this one was much clearer, others stated that it indicates the names “myelin” and “node of Ranvier”, and the rest that the arrows clearly show that the nerve impulse “leaps from node of Ranvier to node of Ranvier”. In each case it is evident that students have not integrated the key concept that the local currents are responsible for the action potential self-generation.

There are 12,8% of students who would use either figure. They explained that both show the myelin sheaths and the nodes of Ranvier which, according to them, is what explains the concept of saltatory conduction.

The remaining 14,8% who did not answer could be those students who do not understand clearly this concept, deciding not to choose an option.

From the previous analysis, we would like to highlight the fact that only one student made reference to the intracellular current that allows the depolarization of the neighboring zones, while another student considered important the change in the membrane polarity as crucial for saltatory conduction. Consequently, we regard that only 4,3% of all students have a satisfactory idea of what saltatory conduction means.

Taking into account these results, we establish these conclusions and new questions:

- A high percentage of students coursing the Biology teacher training make an association between saltatory conduction and the presence of myelin sheaths and nodes of Ranvier. In fact, a lot of them believe that the mere presence of these structures explains saltatory conduction.

- Few students understand that the representation of charges on either side of the cell membrane can help explain the concept of saltatory conduction, although they do not mention its function in the local currents generation.

- A low percentage understand that intracellular currents are responsible for the depolarization of the neighboring zones to the active zone, allowing the generation of a new action potential in those zones.

- The arguments of those students who either chose figure 1B or both make us wonder if they actually believe that the action potential literally “leaps” from one node of Ranvier to the next. Moreover, we ask ourselves if Biology students are able to truly understand the concept of an action potential as an abstract entity and not as something that has mass and can “leap”.

- When asked to explain the concept of saltatory conduction, only few students achieved it satisfactorily. Some of them connected the concept with discontinuous conduction, without explaining clearly how such conduction is produced.

- A vast majority of students show that they vaguely understand what saltatory conduction means.

- To conclude, we consider that both the term “saltatory conduction” and the images frequently used, where arrows in the extracellular region are represented from node to node, may be fostering students' misconceptions.

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