What is transmitted in “synaptic transmission”?

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Montagna E, Azevedo AM, Romano C, Ranvaud R. What is transmitted in “synaptic transmission”? Adv Physiol Educ 34: 115–116, 2010; doi:10.1152/advan.00006.2010.—Even students that obtain a high grade in neurophysiology often carry away a serious misconception concerning the final result of the complex set of events that follows the arrival of an action potential at the presynaptic terminal. The misconception consists in considering that “at a synapse, information is passed on from one neuron to the next” is equivalent to (and often expressed explicitly as) “the action potential passes from one neuron to the next.” More than half of four groups of students who were asked to comment on an excerpt from a recent physiology textbook that openly stated the misconception had no clear objection to the text presented. We propose that the first culprit in generating this misconception is the term “synaptic transmission,” which promotes the notion of transferring something or passing something along (implicitly unchanged). To avoid establishing this misconception, the first simple suggestion is to use words like “synaptic integration” rather than “synaptic transmission” right from the start. More generally, it would be important to focus on the function of synaptic events rather than on rote listing of all the numerous steps that are known to occur, which are so complex as to saturate the mind of the student.

misconception; action potential; neurophysiology

IN THE DISCUSSION OF SYNAPSES, with a detailed description of many cellular structures end events, many books approach synaptic function with a section titled “synaptic transmission.” Typically, the subject is approached something like this: “... synaptic transmission is the process by which nerve cells signal one another” (1). We identified a widespread misconception (2) that arises in thinking about what happens when an action potential reaches the presynaptic button. If asked whether the action potential passes on to the postsynaptic neuron, a large proportion of students answer yes, despite the fact that, under closer inspection, this would eliminate any possibility of information processing in neural circuits.

In an analogous situation, Silverthorn (3) detected that students presented misconceptions about the membrane resting potential. If misconceptions arise in this much simpler situation, which is the basis for understanding the mechanisms that cause firing and propagation of action potentials, it is not surprising that they may also arise in understanding synaptic function. In fact, it is particularly interesting to note how one misconception may lead to another, or at least remove an obstacle for the establishment of another, in some related issue.

After detecting the misconception in verbal exchanges with many students, and noticing how ambiguous some textbooks can be, especially to the eyes of a rookie, we decided to test the understanding of four groups of students in two countries.

PROCEDURES

To be as objective as possible, we used a paragraph from a recently published textbook on physiology, where the misconception is explicitly stated. It is particularly preoccupying that such an explicit formulation of the misconception should appear in a textbook, leading to the suspicion that it may be particularly pervasive.

The book excerpt reads as follows:

[The] Synapse is the place where the action potential is transmitted from one neuron to the other. Its principal function is to modulate nervous activity, that is to increase or decrease impulse frequency. Therefore in a synapse we may have excitation, inhibition, or both of these at the same time. Morphologically, the synapse is constituted of a thin space of about 20 nanometers ...

Specifically, the misconception is that in a chemical synapse, the action potential arriving in the presynaptic cell is transmitted to the postsynaptic cell.

Students enrolled in three distinct postgraduate courses, or having recently completed medical school, were asked to comment the excerpt in any way they wished. The three graduate student groups were as follows.

Group 1. Students (n = 40) had emerged from an introductory neurophysiology discipline in which the issue was widely and accurately discussed by a highly respected lecturer enrolled in a pedagogical discipline.

Group 2. Students (n = 10) were enrolled in a Human Physiology program, in which students were expected to discuss questions e-mailed by undergraduate students enrolled in life science courses and provide answers after discussion with three lecturers (students had widely differing backgrounds).

Group 3. Students (n = 34) were enrolled in an advanced cognitive science discipline on attention and memory (students had widely differing backgrounds).

RESULTS

Table 1 shows how students commented on the text, clearly revealing the widespread presence of the misconception. Although a portion of the students formulated clear objections, most students were unable to detect the fundamental misconceptions in the text. They emphasized minor questions in the excerpt, such as whether it was appropriate to consider a synapse as a region where certain mechanisms occurred, arguing that the term synapse refers to events rather than anatomic areas. Few students explicitly declared that there is no transmission of action potential at chemical synapses from cell to cell.

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Table 1. Results of the evaluation of student answers to the book excerpt

<table>
<thead>
<tr>
<th>Course</th>
<th>No Clear Objections</th>
<th>Clear Objection</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introductory</td>
<td>20 (50)</td>
<td>20 (50)</td>
<td>40 (100)</td>
</tr>
<tr>
<td>Pedagogical</td>
<td>10 (80)</td>
<td>2 (20)</td>
<td>12 (100)</td>
</tr>
<tr>
<td>Advanced</td>
<td>29 (85)</td>
<td>5 (15)</td>
<td>34 (100)</td>
</tr>
<tr>
<td>Medical students</td>
<td>8 (80)</td>
<td>2 (20)</td>
<td>10 (100)</td>
</tr>
</tbody>
</table>

Values are numbers of students, with percentages of the total group in parentheses.

DISCUSSION

The replies often indicated explicit and unconditional approval of the text, with no trace of doubt or mention of graduated postsynaptic potentials. At no point was there any questioning of how information might be processed in neural circuits or if at chemical synapses the action potential just continues to propagate. Nor was there any questioning of why should there be a synapse in the first place, with the metabolic requirements and with the evolutionary investment implied. Thus, the main conclusion of the present work is that many students:

1. admit that in synapses there is transmission of the action potential itself, sometimes identified with the vague notion of “nervous impulse,”

2. do not question the consequence of such a notion.

It is not surprising that the group of students with the least incidence of the misconception was a homogeneous, large class that had just finished earning credit in a very popular review course offered by a highly respected lecturer, well known not only as an authority in the field but also with a well-deserved reputation as an excellent teacher. Although the subject matter was presented very clearly and correctly, the word “transmission” was not avoided, and the consequence of events was discussed in great detail. Some of the students in the other three groups commented that it had been a long time since they had studied the subject matter and that they therefore did not feel confident about the details. However, many students felt quite sure about the fact that at synapses action potentials were passed on to the next neuron in the chain.

The origin of this misconception in our view begins with the use of the term “synaptic transmission” most often used in textbooks. In our opinion, a better term would be “synaptic integration,” which emphasizes the essential function of summation of excitatory and inhibitory postsynaptic potentials rather than focus a single synapse. This would help prevent the idea of a mere, albeit complex, transmission process, in which what arrives on one side is simply transmitted, faithfully, to the other side. These students have probably not fully mastered the mechanisms that are responsible for the existence of membrane potentials (chemical potential and selective membrane permeability) (3) and have mostly followed a routine of learning long descriptive sequences of events by heart with little concern for integrating them into a complete physical mechanism, including its evolutionary function.

Historically, the origin of this misconception might go back to the fact that much of what is known about synaptic events comes from the study of the motor plate (1). This is a readily accessible structure but a very special kind of synapse. First, the postsynaptic cell is not a neuron but a muscle cell. Second, atypically, the arrival of a presynaptic action potential at the motor plate indeed always results in an action potential in the postsynaptic cell. The detailed individual phenomena occurring in motor plates were later confirmed in most synapses in the central nervous system, for example, the synaptic vesicle fusing with the presynaptic membrane and liberating a neurotransmitter. This situation might well have favored generalizing the overall features of motor plates to neuron-neuron synapses, including the transmission of the action potential.

We believe that in teaching synaptic function, there should not be an emphasis on the long series of individual steps and the time sequence of these complicated phenomena. This approach starts by discussing a complex sequence of events in the presynaptic neuron and seamlessly goes on to consider the events in the postsynaptic neuron. Better would be to first discuss the overall result, which is normally a small and local change in the membrane potential of the postsynaptic cell, and only then investigate how this overall result comes about.

We understand that well-established terms are hard to change, but, having identified such a widespread misconception, which is at least in part a probable consequence of the adoption of a misleading word, we would recommend that teachers adopt other terms, such as synaptic integration rather than synaptic transmission. The alternative is to carry this load of fuzzy thinking and conceptual error into the future.

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DISCLOSURES

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

REFERENCES