Overcoming misconceptions in neurophysiology learning: an approach using color-coded animations

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ANYONE WHO HAS TAUGHT NEUROPHYSIOLOGY would be aware of recurring concepts that students find difficult to understand. However, a greater problem is the development of misconceptions that may be difficult to change (7). For example, one common misconception is that action potentials pass directly across chemical synapses (8). Difficulties may be compounded by explanations using voltage-time graphs, since students are not necessarily familiar with oscilloscope or computer-based representations of neural signals. Several different approaches have been used to overcome such misconceptions and provide simple explanations of complex physiological processes. These range from using groups of students acting out concepts (14) to the use of a “traveling flame” analogy for nerve conduction (11). E-learning using animations provides an additional method for overcoming physiology misconceptions (4, 6). Internet-based instruction in the health professions may be similar to traditional instruction in effectiveness (3), but it is important to clarify when to use e-learning and how to use it effectively (2). Thus, an online self-directed e-learning module was developed, using best-practice approaches (1), to engage students and help them overcome some common neurophysiology misconceptions. The essential features of the module were: the use of well-designed (9) and simple (low cognitive load) (12, 13) animations intended to promote good learning outcomes (5) and the use of multiple-choice questions linked with the animations to provide immediate feedback.

METHODS

Students in a second-year undergraduate physiology class (n = 146) were able to freely access the module during the neurophysiology component as a supplement to other instructional modes. All students had received basic neurophysiology lectures during first-year classes. Students taking part in the study gave informed consent, and the study was conducted according to institutional human ethics guidelines.

A trial version of a locally developed application “Enact Education” (EnactEd) was used to develop the e-learning module. The animations were developed using Adobe Flash software. The module was designed in serial fashion with an introductory page (including a menu) followed by the animation template (demonstrating “resting potential”). This was followed by seven animations based on the same template. After observing an animation, the student then attempted a related multiple-choice question. A correct answer took the student to the next animation, whereas an incorrect answer gave the student a choice of revisiting the animation or moving to the next animation.

Synaptic and action potentials were shown as graded color changes instead of voltage-time displays. A color bar was provided that matched the color against the potential. Action potentials were represented as red dots (peak potentials), excitatory synaptic potentials were represented as graded blue-green colors, and inhibitory synaptic potentials were represented graded deep blue colors. A neuronal interaction produced the appropriate color. Observation of color changes was facilitated by the slow animation speed (each animation lasted ~20 s). Each animation used the same template: three neurons, one motor neuron, and three muscle fibers (two of which were innervated by the motor neuron; Fig. 1). The animations covered “effective excitatory input,” “ineffective excitatory input,” “inhibitory input,” “spatial summation of excitatory inputs,” “spatial summation of excitatory and inhibitory inputs,” “temporal summation,” and “spatial summation of several inputs.”

To assess relevant prior knowledge, a pretest, which consisted of eight multiple-choice questions, was administered without warning in semester week 7. The questions consisted of one correct answer and two distractors based on experience gained by the author over previous years. Students were then informed about the online module and were encouraged to freely access it. A small group of students (from the pretest group, n = 15) who used the module completed a posttest in week 13 without warning (same questions as for the pretest) and provided detailed feedback in terms of module usability and learning support using a 5-point Likert scale (where 1 = strongly disagree and 5 = strongly agree). Ten of these students provided written comments, and the following framework was provided for this feedback: “Use three adjectives to describe your overall reaction on usability.” “Describe the aspect of the module activity that you like the most.” “Describe the aspect of the module activity that you like the least.” “What will be the most important factors influencing your use of the module activity?” “Suggestions for improvement.” and “Describe overall reaction to the module activity.” In addition, an end-of-semester course evaluation included questions relating to the number of times that the module had been accessed and whether the module was a useful learning aid (5-point Likert scale, where 1 = not very useful and 5 = very useful).

RESULTS

The pretest was taken by 51% of the class (n = 74). Only distractors attracting 30% or more of student answers were included in the analysis. The misconceptions derived from the latter analysis (followed by the percentages of students choosing them) were as follows: “synaptic potentials do not reduce in amplitude as they spread” (57%), “the action potential passes directly from one neuron to the next” (40%), “action potentials are similar in amplitude to synaptic potentials” (39%), “excitatory synaptic potentials generally exceed 0 mV” (35%), and “some parts of the neuron (compared with the whole of the neuron) have a resting membrane potential of about −70 mV” (33%).

Due to time constraints and the voluntary nature of the activity, only 15 students who had used the module completed both the posttest and survey questions. These students averaged seven correct responses of eight total responses for the posttest. However, 4 of 15 students (27%) gave an incorrect answer for question 4 (misconception: “synaptic potentials do not reduce in amplitude as they spread”). The survey results from these students indicated that “the activity was interesting”...
(mean ± SD: 4.2 ± 0.9), “the screen display was easy to understand” (4.2 ± 0.7), “interactive feedback helped me learn” (4.1 ± 0.7), “the use of animations was appropriate” (4.1 ± 0.9), “the activity supports my learning” (4.0 ± 0.8), “the activity helped me to understand course content” (3.9 ± 0.8), and “navigation was clear and simple” (3.7 ± 0.8).

Ten of the fifteen students provided written comments regarding the module. The “usability” comments fell into two main positive groups: ease of use (15 comments) and engagement (12 comments). Students liked the animations and visual nature of the module (11 comments), e.g., “Animations for concepts that are confusing–helpful in physiology.” The activity was rated as “very good” (8 comments). Use of the module was linked to how well it covered the concepts (7 comments). There were no negative comments; however, suggestions were made for content increase (10 comments), improvements in the stability of the module (e.g., eliminating error messages, 8 comments), increasing the speed of the animations (2 comments), and improving the visibility of the action potentials (1 comment).

The end-of-semester survey was completed by 62% of the class (n = 90). Within the class, 29% had not accessed the module, 31% used it once or twice (average: 1.5 times), and 40% used it more than twice (average: 4 times). In answer to the question “The online module was a useful learning aid,” those students who accessed it once or twice had an average satisfaction level of 3 (±1.2), whereas those who accessed it more than twice had a satisfaction level of 4 (±0.8).

**DISCUSSION**

The pretest data demonstrated the existence of neurophysiology misconceptions among undergraduate physiology students with the highest level of misconception related to uniformity of the resting membrane potential, the amplitude and decrement of synaptic potentials, synaptic transmission, and action potential amplitude. The results were concerning since the students had exposure to neurophysiology basics in previous studies. Misconceptions have been identified in previous studies of neurophysiology learning, e.g., Silverthorn (10) found that student understanding of membrane potential was superficial even after neurophysiology training and Montagna et al. (8) found that students had serious misconceptions about synaptic transmission. Importantly, once such misconceptions are formed, it can be difficult for students to correct them (7); hence, it is important to test different methods to deal with this problem.

The module was successful in engaging a significant proportion of the students, even though it was a voluntary activity with no associated formative assessment. The positive responses to presentation and learning support indicate the effectiveness of the methods used. Detailed survey and written responses supported module effectiveness in terms of the animations, learning support, feedback, and interactivity. Additional support was provided by the large group survey, where students who had used the module more than twice (40% of those responding) had a degree of satisfaction similar to that determined from the more detailed...
small-group analysis. Although the student responses were positive, the major misconception determined from the pretest ("synaptic potentials do not reduce in amplitude as they spread") was still evident to some extent in the small group of students who provided detailed feedback on the module. This may be related to difficulty in graphically demonstrating “fading” of color with distance when representing the graded responses in the animations. Although there is evidence that engagement relates to learning, the data in this study alone are not sufficient to establish that the module was an effective learning tool. An earlier study by the author (6) found evidence that spinal reflex animations contributed to student learning, but further work is required to establish the learning efficacy of the current online module.

The module provided an adjunct to more traditional methods of instruction; however, it should be emphasized that the module only engaged a proportion of the students, with 60% not accessing it or only accessing it once or twice (with an average neutral response). For these students, it is not clear whether lack of access or engagement was related to the voluntary nature of the activity (with no associated formative assessment) or whether this type of online support is only appropriate for students with particular learning approaches.

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DISCLOSURES

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

AUTHOR CONTRIBUTIONS

Author contributions: R.G.G. conception and design of research; R.G.G. performed experiments; R.G.G. analyzed data; R.G.G. interpreted results of experiments; R.G.G. prepared figures; R.G.G. drafted manuscript; R.G.G. edited and revised manuscript; R.G.G. approved final version of manuscript.

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