Teaching Enhancement by Simulated Learning Aids: Simulated Animation of the Lifecycle of Neurotransmitter: Acetylcholine

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ABSTRACT

The neurotransmitter is one of the most important parts of the syllabus in the BISC 395 Neuroscience course taught at HKUST. Acetylcholine (ACh) is the first example used. In the past, students were only shown and taught by descriptive texts and picture storyboards. Some found it hard to grasp the whole story by reading the texts and looking at static pictures. Therefore they lost interest. To enhance student learning, an animation prototype was developed to simulate the biochemical reaction of the ACh lifecycle.

The aim behind the development of such simulated animations is to show students the molecular structure of a selected neurotransmitter and the pathways of biochemical reactions and to demonstrate therapeutic uses of neurotransmitters. Through the use of SLAs, students are expected to have a better understanding of the ACh lifecycle. The SLAs' core component is constructed by Flash. The materials, including the texts, pictures and animations, are stored in modular reusable blocks which are linked and presented in a hierarchical structure. The links are shown in the designated main page. Furthermore, narration by a native English speaker has been added to illustrate each step of the animation. In the spring semester of 2007, the SLA programme was used in class. Students' evaluation was positive.

Keywords

Lifecycle of ACh, neurotransmitters, SLAs, narration

BIOCHEMICAL OF ACETYLCHOLINE (ACH)

Acetylcholine (ACh), the first neurotransmitter ever to be identified, is a small- molecule neurotransmitter with a wide variety of known functions. ACh is the neurotransmitter at the neuromuscular junction and therefore is synthesized by all the motor neurons in the spinal cord and brain stem. Other cholinergic cells contribute to the functions of specific circuits in the PNS and CNS. A specific enzyme, choline acetyltransferase (ChAT), synthesizes ACh in the cytosol of the axon terminal. It is then stored in synaptic vesicles by actions of an ACh transporter. ACh will be released from synaptic vesicles when the signal comes. The release of ACh binds to the specific receptors and continues the signal transmission. After that, ACh is degraded into choline and acetic acid by a specific enzyme: acrtylcholinesterase (AChE). Choline is taken up by cholinergic axon terminals via a specific transporter and forms a new ACh.

In a study of the pharmacological actions of acetylcholine carried out in 1914, Dale distinguished two types of activity, which he designated as muscarinic and nicotinic. The muscarinic actions of acetylcholine are those that can be reproduced by the injection of muscarine, the active principle of the poisonous mushroom amanita muscaria, and can be abolished by a small dose of atropine (the poisonous constituent of deadly nightshade). On the whole, muscarinic actions correspond to those of parasympathetic stimulation. After the muscarinic effects have been blocked by atropine, larger doses of acrtylcholien produce another set of effects, closely similar to those of nicotine.

COURSE DESIGN

The neurotransmitter is one of the most important topics in the syllabus of the BISC 395 Neuroscience course taught at HKUST. ACh was chosen out of several important neurotransmitters to be discussed first in class. The reason for this lies in the fact that ACh is the first neurotransmitter ever to be identified and its wide variety of functions have been well studied. Therefore, ACh is a good model through which students can study the working mechanisms of a neurotransmitter. In class, ACh is taught in the order of its lifecycle: syntheses, storage, release, action and degradation. At each stage, students are required to remember the molecular structure of molecules, pathways of biochemical reactions and some therapeutic uses of its agonist or antagonist. Several drugs which can interact with ACh or the related enzyme and receptors will also be discussed at the end of this section.

STUDENTS' NEED

According to previous experience, students find it hard to remember and understand the movements and interactions of molecules. As a result, they fail to perform well in examinations, especially in the essay dealing with the detail of the reactions.

For example, in the stage of degradation, ACh interacts with acetylcholinesterase (AChE), which is an enzyme which catalyzes the degradation reaction of ACh, after release from the receptor. AChE can interact with ACh because of its unique molecular structure. ACh is attracted and binds to the anionic site of AChE as an enzyme-substrate complex by ionic bond and Van de Waal's force. Then the enzymatic reactions undergone in the esteractic site of AChE and ACh will be depredated to choline and acetic acid. The dominant step of the degradation is that ACh can be docked in the AChE. In another words, AChE can catalyze the reaction because its shape can match ACh perfectly.

In the past, lecturers only used notes and pictures from textbooks as teaching materials in class. Some students found it hard to grasp the whole story by only studying these. Past experience and examination results show students were weak in remembering the detail of interactions occurring between molecules in biochemical reaction. ACh will only interact with a specific functional site of molecules or organisms to perform the specific function. For example, after release from the pre-synaptic neuron, ACh will bind to the specific receptor to trigger reactions downstream.

Students said they had difficulty understanding and remembering how the ACh is attracted by AChE with the help of its unique molecular structures. Lecturers have only been able to present the details in recent years through the use of texts, transparencies and PowerPoint. Such teaching media cannot simulate the actual situation of the molecular reaction. To help students understand the lifecycle of ACh in its entirety, an animation which simulates the biochemical reaction of ACh was developed.

VISUALIZATION AND SIMULATIONS OF THE LIFE CYCLE OF ACH

With help from CELT, a series of Simulated Learning Aids (SLAs) containing mainly visualization and simulations of biochemical interactions of the lifecycle of ACh was developed last year. The SLAs show students the biochemical pathways of synthesis, release, actions and degradation of ACh. In addition, the reactions of three drugs, which have an important interaction with ACh, were selected for demonstration as supplementary contents. In the initial phase of the animation, a macro view of the lifecycle of ACh in neuron was chosen as a whole framework with which to impress students. Each part of the lifecycle is designed to be shown in detail: a brief overview, a 2D animated simulation of biochemical pathway, labels of important components and reference. The 2D animations mainly demonstrate the details step by step. Biochemical reactions of pathways, such as the signal transduction of nerves, movement of molecules, locations of reactions, interactions between functional groups of particles and the conformational changes of cellular organisms were animated. Brief instructions also were added to describe the key stages of the pathways.

The SLAs' core component is constructed by Flash. The materials, including the texts, pictures and animations, are stored in the modular reusable blocks. And these blocks are linked and presented in a hierarchical structure. The links are shown in the designated main page. Narration of the instructions was added, matching each step of the animation, to draw students' attention. An exchange student from U.S. was invited to deliver the instructions.

STUDENTS' RESPONDS

Over 85% of the students agreed, or strongly agreed, that the 3D animation prototype increased their interest in learning the lifecycle of ACh and its therapeutic application. All students agreed, or strongly agreed, that the 3D animation prototype improved their understanding of the ACh lifecycle. 76.7% understood all, or most, of the pathways of the 3D animation prototype. 86.7% agreed that the keyword explanation helped very much, or quite helped them, understand the contents. Only 20% of the students considered that most of the references helped them learn more about the topics. 43.3% considered that the English-Chinese glossary helped very much, or quite helped them, to understand the keywords. 66.7% thought that their understanding would be very much, or quite, enhanced if narration was added for the pathways. 90% agreed, or strongly agreed, that the overall navigation of the 3D animation prototype was easy and the appearance was clear and good.

In sum, the prototype increased students' interest and improved their understanding. Keyword explanations helped their understanding. References were not very helpful for learning. The English-Chinese glossary was fairly helpful for understanding keywords. Layout, navigation and design was clear and good.

CONCLUSION

Neuroscience is complicated; it contains many pathways, organisms and particles, which students are required to remember and understand. As a teaching staff, it is difficult to only illustrate such complicated subjects on paper or by PowerPoint. The actual situation can be simulated in class through the use of SLAs. Students are expected to be given a clear impression of the framework and have a better understanding of neuroscience. The SLAs programme was used in class in the spring semester of 2007. Students' evaluation was positive.

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