Is virtual reality a useful tool in the teaching of physiology?

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Richardson D. Is virtual reality a useful tool in the teaching of physiology? Adv Physiol Educ 35: 117–119, 2011; doi:10.1152/advan.00002.2011.—This opinion statement points out some of the considerations and pitfalls in using virtual reality computer programs in the teaching of life sciences. Emphasis is placed on the possibility of such programs leading to reductionist thinking including how reductionist thinking could foster the formation of misconceptions. Negative feedback is used as the classic example of reductionist thinking in physiological regulation, including how classic negative feedback is inconsistent with evidence of complexity in living systems. This statement concludes that virtual reality can be a useful tool in the teaching of physiology so long as the complexity of living systems is taken into account.

negative feedback; complexity

VIRTUAL REALITY, a concept of the computer era, is defined as “an artificial environment experienced through sensory stimuli, such as sights and sounds . . .” (4). In the context of computer programs, this implies the use of visual and auditory cues provided by the program to assist the user in building a mental model of the system being studied. However, the choice of the term “virtual reality” to describe these programs is unfortunate because the words virtual and reality, when combined into a phrase, become an oxymoron, i.e., the juxtapositioning of contradictory or incongruous words.

Virtual has its origins in the Latin “virtus” (virtue), but its modern definition boils down to “objects whose existence is inferred from indirect evidence . . .” (4). For example, the existence of a tree can be inferred from a painting of a tree, but the picture is canvas and paint, not a real, living tree.

Reality refers to objects that are not artificial or illusionary but occur or exist in actuality. In other words, virtual objects are inferred from the senses, whereas real objects are experienced by the senses.

The bottom line is that something can’t be both inferred and experienced at the same time. That is, it cannot exist as a virtual reality. It is either virtual or real, but it can’t simultaneously be both.

Admittedly, this line of reasoning is philosophical and somewhat abstract, so let’s discuss what virtual reality programs have to do with physiological education. First, there is the issue of selection, which falls mainly on the instructor’s shoulders. An initial internet scan by just about any search engine reveals that there are thousands virtual reality programs. Within this rubric, several hundred relate to health science education, and, among these, there is a wide range of levels from basic programs, such as MolecularStudio for learning the structures of biomolecules, to more advanced clinical training programs, such as SimMan. Accordingly, an instructor intending to use a virtual reality program initially faces the daunting task of selecting those that are appropriate for their course.

Once having selected an appropriate program, the instructor must build in safeguards against the use of the program in a manner that might violate two fundamental principles of biology: 1) that living organisms are not machines and should not be thought of, or treated, as such and 2) that the behavior of living organisms and systems within organisms are inherently unpredictable. A helpful aspect of building in these safeguards is to know the bioeducation history of the students. Have they been taught and do they understand that living organisms are not machines, and, as such, that the computer programs they study from can only simulate hypothetical situations that may or may not exist in reality? Without such an understanding, students, in particular novice students in the biosciences, are likely to garner the misconception from virtual reality programs that living organisms do behave like machines.

The perception of living organisms as machines leads to the misconception that their behaviors, both internally and externally, can be accurately predicted. Just one day spent in either the clinic or laboratory will show that this is simply not true. To illustrate, as an example, all the physiology textbooks and computer simulation programs say that when a person stands up, their heart rate (HR) will increase (as a compensation for reduced cardiac filling and stroke volume). I have tested this by having students measure their HRs in sitting and standing positions in just about every bioscience class I have taught from middle school to graduate school. On average, only ~85% of the students experience an increase in HR upon standing. The remaining ~15% of students experience either no change or a decrease in HR. Furthermore, among those who do experience the “predicted” increase in HR, the magnitude of change is all over the map, from ~2 or 3 beats/min to ~10–20 beats/min. These results are consistent with evidence indicating that HR regulation is a complex interaction of multiple physiological signals (6). So, clearly something as simple as the HR response to orthostasis can only be predicted within a certain range of probability (in this case, 85% for the direction of the response).

The lack of absolute predictability of the HR response to orthostasis is not unique but rather exemplary of the general phenomenon of biological heterogeneity. Accordingly, an instructor must determine if the programs they have selected have biological heterogeneity built in. If not, then this phenomenon should be discussed with the class, preferably before they use the programs.

Another problem with simulations, including virtual reality, is that they foster reductionist thinking: “to fold the laws and principles of each level of organization into those at more general, hence more fundamental, levels” (10). The folding of principles at one level into those at a higher level results in the loss of detail. For example, although the laws of physics underpin several biological phenomena, such as the elasticity...
of tissues, the complexity of living systems becomes lost when the principles of biology are folded into those of physics. Since the phrase “the devil is in the details” applies quite well to living organisms, failure to consider details can lead bioscience thinking astray.

The prime example of reductionist thinking that has led physiologists astray for over 60 yr is the negative feedback loop as “the” control mechanism that keeps physiological variables at homeostatic levels. To give a brief historical background, the first practical use of the concept of negative feedback is attributed to Harold Black, who developed the negative feedback amplifier while working at Bell Labs in the 1930s (2). As an aside, his device became known as “Black’s box;” no doubt the origin of the term “black box” as used in society today. During the Second World War, Norbert Wiener, an engineer at Massachusetts Institute of Technology, developed servo control systems for military use that used negative feedback (e.g., controlling the trajectory of aircraft fire). After World War II, Wiener’s work became declassified and was published (9). During the World War II time period, Wiener began collaborating with Walter Cannon to address feedback issues in physiology (5). Their collaboration sprang from Cannon’s notions of homeostasis (3), and this formed the framework for the principles of negative feedback control as presently used in physiology. The basic idea of negative feedback as a physiological controller is that when a variable is driven from its steady state “set point,” the change in the variable is somehow detected, and that information is relayed to an integrator, such as the central nervous system, which elicits corrective measures to restore the variable to its steady state, or set point, value.

The simplicity of negative feedback has made it quite popular as a framework for explaining the mechanisms of physiological control and as a lynch pin for coupling the concept of homeostasis to physiological regulation. Accordingly, you can find it mentioned in just about every general physiology textbook that has been published over the past 50–60 yr. However, very few, if any, physiological variables are controlled in the engineering model of negative feedback. The classic model that comes to mind is the baroreflex regulation of blood pressure. But even with this relatively simple model, the notions of set point (6) and steady state (7), key elements in feedback control, are problematic.

The enormous complexity of living systems has been underscored over the past few decades through the exploration of biological phenomena such as brain function (11). In keeping with the understanding of such complexity, life scientists have been moving away from reductionist thinking, and, within this rubric, physiologists are exploring models more complex than negative feedback as frameworks of physiological regulation and homeostatic balance. Jim Bassingthwaighte and colleagues (1) suggested that physiological regulatory systems may be temporal manifestations of fractal organizations. Richardson et al. (8) viewed complex regulatory systems, such as that for blood pressure, as a hierarchical organization of the factors that determine the magnitude of a given variable. Nested within these hierarchical “trees” are numerous mass balance relationships between factors that increase and factors that decrease a particular variable, such as HR. What these various new looks at physiological regulation have in common is their relative high degree of complexity compared with straightforward models, such as negative feedback interactions around a set point.

The consideration of complexity does not mean that only those programs that define all of the factors and interactions that result in the behavior of a system can be used (in fact, there are no such programs). It only means that such consideration should be taken into account when operating a program and/or discussing the results obtained therein. Here, a computer program could be helpful in exploring the origins of heterogeneity within a particular physiological response. For example, in considering the response of HR to orthostasis mentioned above, students could use a cardiovascular program to test possible interactions that would lead to a decrease in HR upon standing—what was observed in some of the students that I tested.

Another problem that I see with virtual reality as a teaching tool is with the operation of the programs themselves. Granted, every technical tool has a learning curve, even a hand-held calculator. But computer programs, which tend not to be user friendly, often require a sizable amount of instructional and operational time, which cuts into the time spent learning the subject matter of the program. Accordingly, user friendliness should be taken into account in the program selection process. Here, again, knowing something about the students’ educational history may be helpful. If the students are computer savvy, then operation time will not be as important a consideration as it will with students who are computer novices. However, the latter group is rapidly disappearing with the increasing use of computers in K-12 education coupled with the popularity of devices such as iPhones and iPads among today’s youth. Accordingly, in the not too distant future, operational expertise may be no more of a consideration in selecting a computer program than the ability of students to read is presently a consideration in selecting a textbook. But we’re not there yet.

Finally, a hard and fast rule in education is that a particular teaching method should be used only if it enhances the ability of the student to learn in a correct manner (i.e., without forming misconceptions). Virtual reality programs have the potential to meet this criterion so long as both instructors and students consider such programs in light of the complexity of “real” living systems. This means that there is not an absolute yes or no answer to the question posed in the title of this essay; rather, it depends on how well virtual reality programs are selected and how cautiously they are used.

DISCLOSURES

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

REFERENCES