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The Effectiveness of Representations of Abstract Bio-chemical Processes in Education

Hana Pokojná[†], Barbora Kozlíková, Katarína Furmanová, and Simone Kriglstein

Faculty of Informatics, Masaryk University, Brno, Czech Republic

Abstract

Visual communication of abstract scientific concepts is a widely used technique in education. Its effectiveness is viewed differently by various target groups, and it is important to aim the correct visual representation at the desired target group for it to be most effective. We present the results of a study that contained five different representations and had two iterations. Our versions of representing the ATP synthesis process include 2D Detailed and 2D Abstract representation, Narrated Video, Video without Narration, and Hybrid Representation. These five versions were evaluated by 60 students who were randomly assigned one of the versions and nine experts who viewed and compared all five of the representations. In our iterative study, we aimed to find out what form of representations students and experts prefer; overview or continuous representations, simple or detailed representations, and whether they prefer static images or videos for representations of biochemical processes in education. The quantitative results showed that students find 2D Detailed Illustration the most useful for learning and overall find the animations (Narrated, without Narration, and Hybrid) to be more confusing than static images. In contradiction, the experts have expressed favour for the Narrated Video, followed by the Hybrid representation, while least favouring the 2D static images.

1. Introduction

Bio-medical visualisation and medical art are extensively used in education. The need to present a suitable representation of different occurrences is important as it yields higher success in learning outcomes. However, the requirements and preferences for such representations differ between experts in the field and students who are trying to grasp the context. Biochemical processes are invisible to the naked eye and need to be represented accurately due to their abstraction. Previous research has shown the benefits of both static images and animated videos in explaining concepts in biomedical fields [PS18,GDVZ21]. Medical visualisation also utilises the Theory of Multimedia Learning to create content that is effective for learning based on not over-stimulating the sensory load.

In our study, we aimed to take the benefits of the static 2D representations and combine them with animated representations to create a Hybrid overview representation of the whole process of ATP synthesis and compare it to 2D Abstract and 2D Detailed illustrations, Narrated Video, and Video Without Narration (see Figure 1) to evaluate these modes of process illustration. We carried out a series of studies to investigate what kind of representations are suitable for which target group (i.e., students/general public and experts) and why. Because target groups with different levels of knowledge need different representations, we decided to focus on the following research questions; our main focus was finding out whether abstract biochemical processes are more beneficial to view in one continuous manner or in segmented parts, creating an overview. We also focused on finding out whether there is a difference between the groups in preference for static or moving representations as well as preference for abstract representations or detailed ones. Because of the different benefits of the simplicity and overview that static images offer and the spatial and movement information that animations offer, we hypothesised that a hybrid representation consisting of sequence of short videos would be the most useful in education.

2. Methods

Our study consisted of two rounds of surveys based on online questionnaires. In the first round, an international population of students (n=60) with biochemistry, IT, and other backgrounds were asked to participate. For each of the students, we randomly generated one of the five representations; 2D Static Abstract, 2D Static Detailed, Narrated Video, Video Without Narration, and a Hybrid Representation. They then answered content questions that also tested the understanding of the order of the events in the process. They were then asked to answer open-ended questions about their impressions of the representation. The second round of surveys focused on experts in the field of biochemistry and visualisation (n=9), who were also asked to answer questions through an online questionnaire. They were asked to view all five of the representations and answer

[†] hana.pokojna@gmail.com

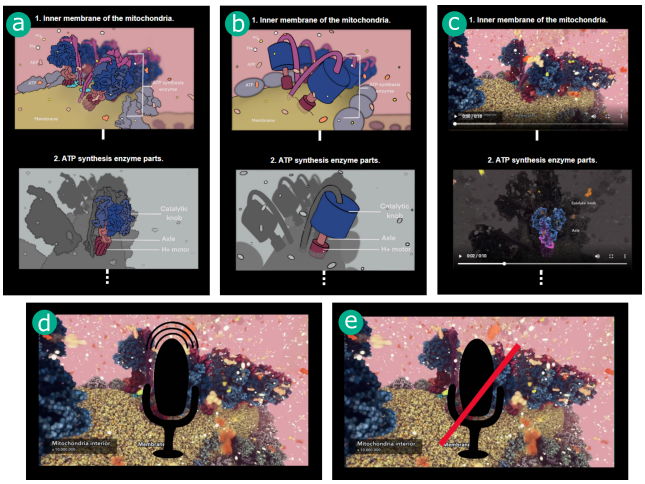

Figure 1: *Types of representations included in our study: (a) 2D Detailed, (b) 2D Abstract, (c) Hybrid, (d) Narrated Video, (d) Video without Narration.*

qualitative questions regarding each of the representations, as well as compare them and suggest improvements.

3. Results

Overall, the results have shown that students prefer an overview of static images. The least preferred method of learning about biological processes was the video format with narration, also indicated by overall scores and comments of the students. On the contrary, the experts preferred the Narrated Video representation the most, followed by the Hybrid representation. The representation deemed least useful in education was the 2D Static Abstract representation, followed by the 2D Static Detailed representation.

3.1. Students

The student population has a preference for static images compared to motion representations. This was indicated by the highest score on the content questions as well as some of the qualitative comments made by the students in open-ended questions. The highest overall success on correctly answered questions was 66.12 percent for 2D Detailed static representation. Based on the provided feedback, the students appreciated the step by step guide, arrows in the images, and the fact that representation was not visually cluttered. At the same time, some students mentioned there was too much detail and too much information. The least favoured representation, the Narrated Video, had an overall success score of 51.64 percent. It was described as too fast, dramatic, chaotic, and busy. The positive responses included appreciation for realism, motion, music, aesthetics, and the fact that it had written and narrated content.

3.2. Experts

The qualitative analyses of each representation by each expert have shown that their preference lies in the moving animated representations. The Narrated representation was voted as the best in explaining the movement and the order of events of the biochemical process. It was reported to be the most descriptive and clear when describing the process without switching between content, showing dynamic changes and dynamic movement well. One participant mentioned that it was almost overloading. The least useful representation according to experts, the 2D Abstract representation, was described mainly as too simple to facilitate deep understanding. The experts expressed concern that it was simplified to the point where it could be misleading. On the other hand, the positives included that it could be good for teaching basics.

4. Discussion

The results clearly indicate that different target groups prefer different types of representations. Our hypothesis was that the hybrid representation would be favoured across the groups. This is because it would take the advantageous points from the animations, such as movement, spatial perception, and even auditory effects, and combine them with the 2D overview and chunking approach. This approach was the second favourite of the expert group, just after the Narrated Video. This contradicted with the student group, which deemed the Narrated Video the least helpful and the video representations chaotic overall. We assume that the more knowledge people possess about a topic, the more information they can perceive without being overloaded.

5. Conclusion

From the data collected from the two different target groups, we can conclude that different types of representations are needed for different target groups. Our hypothesis that the combination of 2D and 3D elements in accordance with Multimedia Learning Theory was proven wrong in the student population. We hypothesize that a combination of different representations would be the best approach to learning about biochemical processes, such as being presented with a simple overview first and then watching a video, rather than combining those two approaches together, as we did in the Hybrid version. Based on the results from expert group we can conclude that representations containing a lot of details and information are suitable for people with background knowledge in the subject and that clustering information into sections intended for learning new content can hinder the experience. Our future work will involve conducting a Focus Group that will include experts with design, visualisation, education, and biochemistry background to discuss each of the versions, the found results, and suggest future improvements for a modality that combines the benefits of 2D and 3D representations.

6. Acknowledgements

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