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Stereoscopic 3D's impact on constructing spatial hands-on representations

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ABSTRACT

While learning biological topics constructing depictive representations may be the first step to a deeper understanding. The referred to as visualization type as well as interaction type are supposed to have influence on learning with multimedia applications. Comparing 3D and 2D visualizations (both in combination with written text), there is little evidence whether stereoscopic 3D visualizations better support the understanding of biological topics by constructing adequate depictive representations. Likewise, insufficient indication is given of how the interaction type impacts these results (e.g. the ability/disability to move and rotate the displayed object). Therefore, our study focused on an e-learning environment dealing with the anatomy and physiology of the nasal cavity. Here, either (1) text and 2D visualisations or (2) text and stereoscopic 3D visualisations were used – both in combination with two interaction types (interaction/no interaction). Research subjects were 144 eighth grade students at medium stratification level. During a working phase with the different multimedia applications (visualization type 2D/stereoscopic 3D and interaction type 'interaction'/'no interaction') the students were instructed to form the nasal cavity out of modeling clay. Finally, for both interaction types the 3D cohorts were by far more successful in representing anatomical details. Hence, stereoscopic 3D technology should be implemented in biological e-learning environments.

1. Introduction

For instance, the question of how it looks like behind the nostrils exemplifies the fact that several topics in science education presumably are out of students' direct viewing. Therefore, these topics require a visualization in order to gain a proper imagination. This may help to get even more familiar with concepts such like the process of breathing air's moistening or warming in the nasal cavity. These two physiological processes, for example, occur in a three-dimensional cavity. Thus, in order to imagine this phenomenon more accurately information and ideas of what a cavity exactly is and how it can be displayed are needed.

Although various kinds of representations are available, science education at undergraduate level mostly deals with two-dimensional visual representations. For example, pictures in textbooks or common multimedia software are often used to illustrate spatial structures. Learners then are obliged to abstract from these two-dimensional representations so as to generate a three-dimensional internal representation. Precisely this is the point where stereoscopic 3D displays are able to provide spatial information using stereoscopic depth perception – the way we gain spatial information in everyday life. Unfortunately, little evidence is known about the impact of stereoscopic 3D visualizations in educational contexts (McIntire, Havig, & Geiselman, 2012, 2014). Thus, applying an e-learning environment, the present study discovers students' ability to represent a human organ in dependency on the vision modus stereoscopic 3D/2D. Here, the students were given the opportunity to mold an anatomic model consisting of modeling clay.

1.1. Learning science with external representations (ER)

Learning with external representations means interacting with various descriptive and depictive types of representation (Schnotz & Bannert, 2003). This might lead to a deeper understanding (Ainsworth, 2006, 1999). Not surprisingly, information gained by computing

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ERs plays an important role in learning science. Accordingly, several inquiry (Hubber, Tytler, & Haslam, 2010; Prain & Waldripp, 2006; Tytler, Peterson, & Prain, 2006) reveal the potential of ERs to foster the acquisition of content knowledge in science subjects. Whereas some older researches interpreted already available representations (Ainsworth, 2008; Gilbert, 2005), recent studies point at the relevance of constructing their own external representations for conceptual understanding (Prain & Tytler, 2012, 2013; diSessa, 2004; Yore & Hand, 2010).

1.1.1. Learning science with realistic pictures

Some research articles particularly pay attention to utilizing realistic pictures. More precisely, utilizing realistic pictures could be described as representations with a high degree of structural accordance with its template (Schnotz & Bannert, 2003), such as pictures displaying human organs or molecular structures. In science education, it is acknowledged that realistic pictures are useful in order to visualize topics which cannot be observed originally. Hence, focusing on research in molecular learning, the alignment of recent inquiry (Bivall, Ainsworth, & Tibell, 2011; Dori & Barak, 2001; Rundgren & Tibell, 2010; Schönborn, Bivall, & Tibell, 2011; Stieff, 2005) reveals that it is not the question if but in which form or setting realistic pictures should be employed.

Referring to the drawing of a cell that beforehand was observed under a microscope – a realistic depictive representation – Ainsworth, Prain, and Tytler (2011) point out the suitability of a drawing in order to construct one's own representations. This simplifies that the process of construction enables students to develop perception, e.g. of relevant anatomical structures. As physiological processes and anatomical structures rely on each other, creating one's own realistic depictive representation offers the possibility of being a starting point for physiological conceptual learning.

1.1.2. Interpreting and constructing realistic depictive representations for learning about the nasal cavity

The nasal cavity, as discussed beforehand, is a well suited topic in order to investigate stereoscopic 3D's impact on interpreting and constructing depictive representations in context with human biology. Here it has to be mentioned that physiological processes within the nasal cavity, e.g. meatus of the nose fostering breathings airs' warming and moistening by increasing airflow distance, occur within a three-dimensional area depending on spatial structures. These spatial structures need to be realized in order to generate a concept of the nasal cavity's anatomy and physiology. Therefore, accurate depictive imagination of anatomic structures is obligated.

In turn, while interpreting or constructing realistic representations concerning this topic, spatial information has to be computed. Applying multimedia technologies, stereoscopic 3D visualizations are proven to be useful to foster spatial understanding of abstract displayed structures (Aitsiselmi & Holliman, 2009; Neubauer, Bergner, & Schatz, 2010; Ware & Mitchell, 2005). This means that stereoscopic 3D might also be suitable for anatomical and physiological understanding. To enable students to pictorially represent a human organ in its spatial proportions, e.g. the nasal cavity, in order to display anatomical structure recognition (because of its three-dimensional structure) the construction of tangible hands-on representations appears to be appropriate. However, according to our knowledge there is a lack of studies in science education. At least, we could not find one single study concerning the construction of external depictive representations using computer-generated 3D visualizations as template. Hence, this study, as a first step, is an investigation of the impact of stereoscopic 3D images compared to 2D images on how students represent the nasal cavity by the aforementioned procedure. Here, the focus lies on the question if 3D enhances the representation of relevant anatomical structures and authentic proportions. Before this research aim will be specified, we review in the following literature concerning 3D applications in human biological contexts.

1.2. Stereoscopic vision in science learning

These days, the term 3D often is used in context with biological education (Huk, 2006; Keller, Gerjets, Scheiter & Gassofsky, 2004; Korakakis, Pavlatou, Palyvos, & Spyrellis, 2009). However, all these studies operationalize the term 3D as 3D appearance on the basis of monocular depth cues, such as accommodation, shading, object motion parallax or relative size lacking stereoscopic vision. By means of experience, human's brain may generate a spatial perception from out a two-dimensional visualization. 3D in context of stereoscopic vision gains spatial perception in another way: The two human eyes are separated by an interocular distance. That means, for seeing an object near around us, that each eye sees a slightly different picture of one and the same object. Two different retinal images arise at the same time. Hereby, the left and the right field of view overlap. Increased overlapping implies an increased chance of gaining spatial information. While calculating stereoscopic depth information, the human's brain fuses both retinal pictures. Thus, the degree of depth perception is impacted by the distance of corresponding points within retinal pictures. However, not every point of a retinal picture can be seen stereoscopically: Fixated points fall onto the horopter. Each point on the horopter got zero retinal disparity and thus cannot be seen stereoscopically. Points in front or behind the horopter got retinal disparity, but only in a small area around the horopter – panum's fusional area – sensoric fusion is possible (Cutting & Vishton, 1995; Patterson & Martin, 1992). If focused objects move in distance, eyes move to parallel alignment, and stereoscopic depth perception stops. Watching pictures on a flat plane like on leaves of a book or a monitor, fixated points are displayed on a horopter lacking of a panum's fusional area. Hereby, stereoscopic vision is impossible without technical aids.

1.2.1. Stereoscopic display technologies

Stereoscopic display technologies work with an imitation of stereoscopic viewing in everyday life. Therefore, each eye sees an image of the same object. To imitate disparity, the displayed objects differ within the viewing angle. To make the eyes see different images, various techniques are used (Urey, Chellepan, Erden, & Surman, 2011). In the case of passive 3D, polarizer glasses utilize two different permeable glasses for different polarized light, whereas the monitor utilizes these polarized lights in order to generate a left eye picture as well as a right eye picture. In the case of active 3D, shutter glasses alternately open and close for light, whereas the picture source alternately displays the appropriate image. In the case of autostereoscopic 3D, displays address the eyes with distinguishing pictures without glasses.

1.2.2. Interacting with stereoscopic displays in biological contexts

In general, a recent meta-analysis reveals judgment of distances and identification of objects as potential benefits of applying stereoscopic 3D images (McIntire, Havig, & Geiselman, 2012). Accordingly, van Beurden, Ijsselsteijn, and Juola (2012) and Holliman (2005) highlight an increased perception of objects and improved relative depth judgment as well as an enhanced surface interpretation, for