Using stereoscopic visualizations as templates to construct a spatial hands-on representation—Is there a novelty effect?

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presented as static templates (32, 33) and, as well, interactively moveable visualizations as templates (32).

Such advantages of stereoscopic imagery compared with nonstereoscopic imagery might be explainable by the genesis of stereoscopic depth impression: In everyday life, stereoscopic spatial perception is primarily based on a human’s interocular distance, which inevitably leads to overlapping different retinal pictures of an observed object. These retinal pictures are automatically fused by the brain, which perceives spatial information by focusing on both retinal pictures and then calculating the distance between corresponding points (5, 29). In addition, nonstereoscopic depth cues (“monocular depth cues”), such as texture, relative size, or shading, support this impression of spatial depth. Watching nonstereoscopic visualizations, such as “common” images on the computer, depth impression arises due to monocular depth cues alone (13, 34).

Stereoscopic display technologies imitate stereoscopic vision in everyday life by using various output devices, such as three-dimensional glasses to provide the eyes with two slightly differing pictures representing the same object observed from nearly the same angle and thus provide a comparable degree of depth impression as watching an object near or around us in everyday life.

The quintessence of the research cited above is that stereoscopic imagery fosters enhanced structure recognition and, as well, the construction of template-close clay models. However, research shows that the application of new digital media formats can lead to a novelty effect, such as the short-term increase of motivational factors (15, 19, 23). In general, emotions aroused positively in the context of any learning settings, such as situational intrinsic motivation, appear suitable to increase task performance (22). Situational intrinsic motivation is characterized by the dualism of interest and enjoyment (6, 12). Due to the novelty of stereoscopic imagery in human biological education (13, 32), the question arises as to whether task performance in the context of the application of stereoscopic imagery as a new visualization technology is the direct result of enhanced structure recognition, or whether it is additionally impacted by situational sensations, such as situational intrinsic motivation, in the context of working with stereoscopic imagery for the first time during a school science lesson. A special area of interest is perceived competence. Perceived competence is said to be linked with situational intrinsic motivation (6) and also to co-occur with it. Due to enhanced structure recognition, participants might feel more competent while molding hands-on representations, which might also impact perceived situational intrinsic motivation. In turn, increased situational intrinsic motivation due to the novel application of stereoscopic imagery should also affect perceived competence.

The sculpted representations made of clay are constructed not as an end in itself, but to be used for the learning of anatomical facts directly (9, 20) or to additionally be applied in some ongoing learning settings on anatomy (28, 37). Because emotions aroused positively in context with any learning settings, such as situational intrinsic motivation (22), might also function as a trigger for persisting interest to engage with a distinct topic (16), the question is relevant whether the employment of stereoscopic imagery as a template for molding a representation is judged to be more positive compared with nonstereoscopic imagery. However, to what extent these immediate positive emotions can be transformed into a continued interest to engage with the distinct topic is dependent on the arrangement of further learning steps (24) and thus is not in the purview of the present research, which focuses on a short-time intervention only.

Research aims. Outgoing from the assumptions made above, the aim of the present study was to assess the students’ perceived feelings of situational intrinsic motivation in the context of using stereoscopic imagery in contrast to nonstereoscopic imagery as a template to form a human organ out of modeling clay. Furthermore, it was of interest to investigate whether there are relations between the self-reported situational intrinsic motivation and the performance during the clay modeling task. Because it was argued that stereoscopic imagery facilitates structure recognition, it should also be asked if the students working with stereoscopic imagery felt more competent while doing the modeling task, compared with students using nonstereoscopic imagery. This perceived competence should also be in relation to the performance in clay modeling and to self-reported situational intrinsic motivation.

METHODS

E-learning environment. To carry out the study, a virtual reality system called CyberClassroom (Imsanity, St. Georgen im Schwarzwald, Germany) was utilized. Hardware components were a Tarox Computer (TAROX, Luenen, Germany) equipped with an Intel Core i5 processor (3.20 GHz, 4 GB RAM, NVIDIA Quatro 600 graphics card) and a 47-in. LCD monitor, type 47LD950. The system was prepared to utilize passive stereoscopic visualization by providing polarizer glasses. For navigation, a remote was used. The software could be presented in a version with stereoscopic imagery and as well in a version utilizing nonstereoscopic imagery. The e-learning module dealt with the nasal cavity’s anatomy and physiology. Physiological processes, such as the warming and moistening of breath, are linked with concrete anatomical structures, like the meatus of the nose and their mucosa. Spatial understanding appeared to be an important factor to recognize and estimate relevant structures, such as the meatus of the nose, and to bring them into context with the physiological concept of breathing air’s warming and moistening. To highlight those phenomena, five different screen pages depicted parts of the nasal cavity, and written text explained structures and the related physiological concepts of breath’s warming and moistening (Fig. 1). To provide the best descriptive information for all students working with either stereoscopic or nonstereoscopic imagery, each visualization included strong monocular depth cues, e.g., perspective imaging or shading. The students could observe the nasal cavity with dorsoventral positioning turned 20° toward the learner. Three screen pages show the left cavity in front, and two pages show the right cavity in front. The remote could be used by the research subjects to switch between the screen pages. For the stereoscopic imagery version, the screen disparity between the right-eye picture and the left-eye picture was smaller than 1° to enable comfortable viewing. This was important because screen disparities >1° are found to hinder comfortable viewing (21).

Study design and outcome measures. Two alternative conditions were provided. One consisted of the multimedia application utilizing stereoscopic imagery, and the other the same application utilizing nonstereoscopic imagery. Consequently, the visualization type was the independent variable. Dependent variables were 1) the self-reported perception of positive emotions, 2) the self-estimated competence during the working session, 3) the elaboration of anatomical details within the students’ molded representations, and 4) correlations between variables 1, 2, and 3.
related physiological concepts of breathing air’s warming and moistening (32).

Fig. 1. Screen pages of the e-learning module included depictive and descriptive information concerning the nasal cavity’s anatomical structures and the related physiological concepts of breathing air’s warming and moistening (32).

Participants. Participants were 73 eighth grade students from three schools in southwest Germany. Before beginning the study, parents and students gave their approval that they would participate. Such an approach is in line with the ethical guidelines in Germany. All attendees belonged to a larger sample of a study aiming to investigate stereoscopic imagery’s impact on sculpting representations of a human organ (32). All students had the innate ability of stereoscopic vision, which was pretested by accepting a stereoscopic vision test (11), which assessed their stereoscopic vision ability. It was confirmed that they all had not had any lessons on this topic beforehand and did not have any previous experience with stereoscopic imagery in the science classroom. The participants’ mean age was 14.21 yr (SD 0.71), and the sex distribution was approximately equal.

Materials. First, a worksheet was designed to guide the students through the software application. To measure their self-reported perceptions of situational intrinsic motivation and their self-estimated competence, a paper-and-pencil test was adopted. This test consisted of two subscales, one for each latent construct. The subscale for situational intrinsic motivation consisted of three items, which were constructed close to Guay and colleagues’ (12) scale, “intrinsic motivation,” and Deci and Ryan’s (6) scale, “interest/enjoyment,” in its German time-economic short version, “Interesse/Vergnügen” (38). To assess the amount of self-estimated competence, a three-item subscale, “Kompetenzerleben” (“perceived competence”), according to Wilde et al. (38), was also adopted. To prepare a spatial hands-on representation (Fig. 2) as an outcome measure, each research subject was provided with a 60-g kneading mass of Pluffy modeling clay (Eberhard Faber Vertrieb).

Procedure. To assign the research subjects to a stereoscopic imagery cohort and a nonstereoscopic imagery cohort, a randomized allocation procedure was utilized. Then, one after another, all attendees worked with the multimedia application at a single workstation. The students had 20 min to read the given descriptive information and to view the associated visualizations to learn about the anatomy of the nasal cavity. They were all asked to construct a representation of the nasal cavity as a solid body consisting of a kneading clay mass during the working phase using the software visualization as a template (32, 33). Afterwards, the students filled in the questionnaire concerning self-reported situational intrinsic motivation and perceived competence.

Data analysis. To analyze the students’ responses on the questionnaire, the points on the scale were numbered 1–5, where the pole representing maximum approval was scored at 5. Then means and SDs for both subscales were calculated. Additionally, for both of the subscales, Cronbach’s α was calculated to prove the reliability. A factor analysis was calculated to prove the two-dimensionality of the questionnaire. The presence of anatomical details was assessed by focusing on the elaboration of the meatus of the nose as they are the most obvious structure and the major cause for impacting physiological processes described in the learning module, such as warming and moistening of breathing air. Therefore, a 6-point rating scale ranging from 0 to 5 was developed. Eight raters were asked to judge the elaboration of the meatus of the nose using this scale (32, 33). To prove the reliability of this measuring instrument, the average deviation of the mean between the raters’ judgments was determined in accordance with Burke and Dunlap (3) and Burke et al. (4). Burke and Dunlap (3) indicate that the cutoff limit for a 6-point scale is 1.01. For all measurements, SDs were determined and compared by working out ANOVAs. To prove relations between the elaboration of the meatus of the nose, situational intrinsic motivation, and perceived competence, Pearson correlation analyses were processed. All statistical calculations were proceeded by using an SPSS statistical package, version 22 for Windows (IBM, Armonk, NY).

RESULTS

Both of the questionnaire’s subscales revealed sufficient reliability. For situational intrinsic motivation, α = 0.75, and for perceived competence, α = 0.77. A factor analyses with varimax rotation confirmed the existence of both subscales. The students in the stereoscopic imagery cohort reported a similar degree of situational intrinsic motivation (Table 1). Concerning perceived competence, there was also no difference between both groups (P = 0.318). As for elaborating the meatus of the nose, the students in the stereoscopic imagery cohort succeeded significantly better compared with the students working with nonstereoscopic imagery (P < 0.01). An average deviation < 0.65 showed the consistency of the raters’ judgments. A significant relation between situational intrinsic motivation and task performance represented by the elaboration of the meatus of the nose was found in the nonstereoscopic imagery cohort (r = 0.376; P = 0.020; Fig. 3A), but not in the stereoscopic imagery cohort (r = −0.022; P = 0.899; Fig. 3B).

Fig. 2. A hands-on representation consisting of a kneading clay mass was formed by a student to display the anatomy of the nasal cavity (32).
Both cohorts showed perceived competence in connection with aroused situational intrinsic motivation (stereoscopic imagery: $r = 0.422; P = 0.012$; nonstereoscopic imagery: $r = 0.580; P < 0.001$), but not with task performance (stereoscopic imagery: $r = 0.049; P = 0.780$; nonstereoscopic imagery: $r = 0.055; P = 0.741$).

### DISCUSSION

There was no relevant difference in subjects' self-reported situational intrinsic motivation between stereoscopic imagery and nonstereoscopic imagery. In summary, with means $> 3$ on a 5-point scale, both perceived a moderate degree of situational intrinsic motivation while working with the e-learning environment. Nevertheless, one can suggest that the supply of high-quality nonstereoscopic imagery provoked a nearly equal level of situational intrinsic motivation, compared with the application of stereoscopic imagery, and thus that there was no novelty effect (15, 19, 23). However, the large SDs show that this kind of perception was not true for every student: there were as well students who felt unmotivated or, in contrast, enjoyed the intervention very much. Similar to situational intrinsic motivation, even though the participants in the stereoscopic imagery cohort succeeded better in portraying anatomical structures, in line with the studies of Remmele et al. (32) and Remmele and Martens (33), this did not lead to a higher level of perceived competence compared with nonstereoscopic imagery. Both cohorts reached means $> 3$. Comparable to the sensation of situational intrinsic motivation, this shows that, in summary, the participants were moderately satisfied with their performance during the working process. Hence, for the present study, the assumption that enhanced task performance is in line with increased perceived competence due to enhanced structure recognition can no longer be supported. Given that the students working with stereoscopic imagery had enhanced perception of anatomical structures, this perception can be expected to be the level they reached with their own representations. On the other hand, participants working with nonstereoscopic imagery had decreased perception of anatomical structures and maybe had a lower level to reach with their molded representations. Both, consequently, resulted in a comparable perception of competence. Thus, without a comparison of the student's own representation with the original, there cannot be a difference in the perception of competence between the cohorts. Interestingly, a correlation between task performance and perceived competence was not found. This might be explainable as follows. For the participants in the present study, sculpting was a rather new task in their biology lessons. Thus all students were unexperienced, and, because of that, they failed to estimate their competence realistically. However, for both cohorts, the relation between situational intrinsic motivation and perceived competence was rather high. This circumstance does not appear surprising, as the connection between both factors was suggested and empirically documented (6, 38).
Relations between situational intrinsic motivation and task performance reveal quite different results within both visualization types. Interestingly, within the cohort working with nonstereoscopic imagery, there was a significant relation between the arousal of situational intrinsic motivation and the success of representing anatomical details within the hands-on representations. In contrast, even though the research participants in the stereoscopic imagery cohort succeeded significantly better in representing the meatus of the nose, within the stereoscopic imagery cohort there was no relation between situational intrinsic motivation and task performance. However, there was a relation between perceived competence and situational intrinsic motivation, but no relation between task performance and perceived competence. Because of this missing connection, it can be assumed that the success of the stereoscopic imagery cohort could not function as an engine of increased situational intrinsic motivation during the working phase. On the other hand, situational intrinsic motivation could not function as an engine of task performance. That means the positive impact of stereoscopic imagery for representing anatomical details appears to be independent from humans’ situational feelings of motivation, whereas the performance of constructing hands-on representations while working with nonstereoscopic visualizations is actually in connection with humans’ situational intrinsic motivation. For science education, these findings provide strong arguments for the application of stereoscopic imagery instead of nonstereoscopic visualizations.

First, the task performance in the case of representing anatomical structure within spatial hands-on representations is better compared with nonstereoscopic imagery. Because of the relevance of students constructing their own external representations in learning science, it can be assumed that a more elaborate representation would provide enhanced opportunities for learning concepts related to this, such as physiological concepts that are related to distinct anatomical structures. Concerning this concept, further research should be carried out. Second, science lessons, as with all other lessons, have to deal with heterogeneous degrees of students’ motivation and thus must also deal with students with low situational intrinsic motivation. Thus it appears reasonable to apply an instructional setting that works regardless of situational sensitivities and allows enhanced task performance. For the application of stereoscopic imagery in human biological learning contexts and the construction of anatomical hands-on representations, this appears to be the case.

ACKNOWLEDGMENTS

This study was part of M. Remmel’s dissertation project and was included in his dissertation thesis. We are grateful to the University of Education Karlsruhe for supporting this publication.

DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the authors.

AUTHOR CONTRIBUTIONS

M.R. performed experiments; M.R. analyzed data; M.R. interpreted results of experiments; M.R. prepared figures; M.R. drafted manuscript; M.R. edited and revised manuscript; M.R. and A.M. approved final version of manuscript.

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