Does an Audiovisual Dissection Manual Improve Medical Students’ Learning in the Gross Anatomy Dissection Course?

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The gross anatomy dissection course is considered to be one of the most important subjects in medical school. Advancing technology facilitates the production of e-learning material that can improve the learning of topographic anatomy during the course. The purpose of this study was to examine a locally produced audiovisual dissection manual’s effects on performance in dissection, formal knowledge gained, motivation, emotions, learning behavior, and learning efficiency of the medical students. The results, combined with the total effort put into the production of the manual, should support decisions on further implementation of this kind of audiovisual e-learning resource into the university’s curriculum. First-year medical students (n = 279) were randomly divided into three groups for two weeks within the regular dissection course hours during the dissection of the anterior and posterior triangles of the neck. Two groups received an audiovisual dissection manual (n = 96) or an improved written manual (n = 94) as an intervention, the control group (n = 89) received the standard dissection manual. After dissection, each student filled out tests and surveys and their dissections were evaluated. The audiovisual dissection manual did not have any significant positive effects on the examined parameters. The effects of the audiovisual dissection manual on the medical students’ learning experience, as observed in this study, did not support further curriculum implementation of this kind of e-learning resource. This study can serve as an orientation for further evaluation and design of e-learning resources for the gross anatomy dissection course.

Key words: gross anatomy education; medical education; undergraduate education; anatomy curriculum; dissection video; learning technology

INTRODUCTION

The dissection of cadavers in gross anatomy classes has a long tradition (Albanese, 2010). Besides a deeper understanding of anatomy in its three-dimensions and of human variability, a dissection course promotes teamwork and independent learning, it leads students to understand concepts of death and dying, to respect humanistic values, and thus, promotes emotional maturity toward professional, medical behavior (Theroet et al., 2007; Larkin and McAndrew, 2013; Ali et al., 2015). Anatomy is considered by doctors to be one of the most important subjects in medical school (Pabst and Rothkötter, 1996; Jungbauer et al., 2004).

Dissection is a complex task that requires proper preparation and instruction for an optimal learning success. Different e-learning resources try to enhance the dissection course’s learning experience (Trelease, 2016; Bork et al., 2019) but there is no consensus yet on how to best design a dissection course (Chung et al., 2013; Clunie et al., 2018). Research on the optimal design becomes more important as first Northern American and European medical faculties cancel the cost intensive dissection courses (Böckers et al., 2010; Bekele et
and others, including those in Germany, start to introduce and create novel e-learning resources to supplement the dissection course and increase its efficiency (Bork et al., 2019; Grosser et al., 2019). With advances in technology and new requirements for dissection courses due to changing curricula, videos have become an important supporting learning material (Hulme and Srškralj, 2017) that can provide audiovisual instruction prior to dissection (Ahmad et al., 2016).

Generally, students accept anatomical videos very well and state as reasons that they help to understand anatomy and to create memorable images and have a high availability (Jaffar, 2012). Videos are perceived as a very important resource for review and examination preparation (McNulty et al., 2009a; Barry et al., 2016; Hulme and Srškralj, 2017). The application of audiovisual material in universities is especially useful as young residents and fellows entering hospitals can work with the same e-learning resources to educate themselves and receive training (Abdelsattar et al., 2015; Collins et al., 2015; Saberski et al., 2015). With increasing student numbers and rising costs of cadavers, videos can be an alternative for traditional anatomical education methods (Theoret et al., 2007; Chung et al., 2013; Ozer et al., 2017). Videos might not be the optimal form of conveying information for every individual student (McNulty et al., 2009a, b). Students with lesser preference for visual content experience a higher cognitive load and score worse on tests in the learned material (Homer et al., 2008). However, by definition of cognitive learning theories, audiovisual instruction is an advance organizer (AO) which should help the students link prior knowledge to new information and facilitate its application to new contexts. Students who have prepared for the material to be learned with an AO generally should be able to perform better on tests in the learned material than students in a control group (Ausubel, 1968; Chen et al., 2009). Thus, providing such an AO via video might be inferior to certain traditional anatomical education methods like prosection and certainly varies in effectiveness with the students’ learning types but it can improve the students’ learning experience during the course, improve test results, and reduce anxiety (Saxena et al., 2008; Casado et al., 2012; Chung et al., 2013; Al-Khalili and Coppoc, 2014; Collins et al., 2015; Ahmad et al., 2016). Also, a video can be created fairly easily and at a low cost by universities themselves (Rarey et al., 1995; Inwood and Ahmad, 2005; DiLullo et al., 2006; Saxena et al., 2008; Al-Khalili and Coppoc, 2014) enabling it to be specifically designed for the university’s needs (Pereira et al., 2004).

At Hannover Medical School, the gross anatomy dissection course takes place in the first academic year which is divided into three trimesters of 10 weeks each. The dissection course lasts for 20 weeks, starts in the fourth week of the first trimester and ends in the eighth week of the third trimester. It is one of the longitudinal learning constructs that connect several classical medical modules and promote interdisciplinary learning. The teaching of gross anatomy is setup around the dissection course (92 hours), with seminars (14 hours) and lectures (127 hours) in the module “anatomical foundations of medicine.” Besides anatomy, the students are also required to attend the biology, chemistry, and parts of the physics/physiology modules in the first year. Dissection starts with the dorsal body wall, shoulders, and arms in the first trimester (6 weeks), continues with the leg, the ventral body wall as well as the thoracic and abdominal situs in the second trimester (9 weeks) and ends with the neck, skull cavity, and face in the third trimester (6 weeks). One side or region of a cadaver is dissected by six students. The other is dissected by another dissection team on another day of the week so that a maximum of 12 students can dissect one cadaver. There is an oral examination on the cadavers’ topographical and systematic anatomy for ten minutes for each student at the end of each trimester conducted by the chief instructor with the students standing around the dissected cadavers. At least 60% of all asked questions have to be answered correctly in order to pass.

In 2017, the dissection manual, which was the main guide in the dissection course, consisted only of few anatomical drawings and text. Medical students taking the course thought it could be further improved to help facilitate education in one of the most relevant subjects in medical school. Therefore, an interactive, web-based audiovisual dissection manual for the anterior and posterior triangles of the neck based on the original dissection manual was created locally at Hannover Medical School. It was decided to cover only the dissection of the anterior and posterior triangles of the neck initially because of the relatively high complexity of this anatomical region (Archibald and Carlson, 2009), and thus, expected high benefits for the students independent of their previous experience with dissection.

An evaluation of the audiovisual dissection manual was needed to apply for further financial resources from the Studies Commission which decides on the distribution of grants to fund e-learning resources. For the evaluation, a comparative study with three study groups within a year performing the dissection of the anterior and posterior triangle of the neck was conducted. One group prepared with the standard manual containing text and drawings (control group) and another group with the locally created audiovisual manual (video group).

To test whether comparable effects could be achieved by another intervention that was much easier, faster and cheaper to produce, a third group prepared with an improved manual containing more thorough text and drawings (manual group).

**MATERIALS AND METHODS**

The study was approved by the Ethics Commission of Hannover Medical School on 8 January 2015, and filed under No. 2538-2015. Participation in the study was voluntary and the students’ consent for the anonymous analysis of their data was obtained before the tests. The body donors whose cadavers were used for the creation of the improved and audiovisual manuals had consented to their usage for medical education and research purposes according to ethical standards and German federal law.

**Research Objects**

The primary objective of the study was to evaluate effects of the interventions with regard to the following aspects: (1) Performance in dissection, (2) Acquired formal knowledge, (3) Epistemically related emotions, (4) Learning motivation, (5) Learning behavior, and (6) Efficiency of preparation for dissection.

**Standard Manual**

In 2017, the standard manual, which served as the main guide throughout the course, consisted only of text accompanied by a few anatomical drawings from the atlas of anatomy for the dissection course (Tillman and Schünke, 1993) which were used with permission by the publisher. The text described briefly...
which anatomical structures needed to be dissected and how (sample in Supporting Information).

**Improved Manual**

The improved manual follows the same order of dissection as the standard manual. However, it focuses more on the technical aspects of dissection and the steps and techniques that are proven to be complicated to allow for a more efficient preparation for dissection. Additionally, more drawings from the atlas of anatomy for the dissection course (Tillman and Schünke, 1993) are used to illustrate the proper way of dissection. The drawings are used with permission by the publisher (sample in Supporting Information).

**Audiovisual Manual**

The audiovisual manual is an interactive, web-based video covering the dissection of the anterior and posterior triangles of the neck in 30 minutes. It is based on a publicly available programming sample (Dudley Storey, 2017) and runs on a web browser. In the video, the dissection is shown simultaneously from two perspectives, supervision and side view. Each step of the dissection is commented by a speaker whose words are also displayed in a text box next to the video and highlighted when spoken. The assignment of the text to the video has been done using the web standard Web Video Text Tracks (WebVTT) and the open-source software Subtitle Edit, version 3.5.1 (Olsson, 2017). The text can be searched for anatomical structures and used to jump through the steps of the dissection. The anatomical structures in the videos are labeled when dissected and mentioned by the speaker (Fig. 2 in Supporting Information). The procedure of the dissection shown in the video is the same as that described in the standard manual but it provided more information on where the anatomical structures should be looked for, how they could be found and how they would look fully dissected (sample in Supporting Information).

**Dissection Course and Study Group Setup**

In 2017, a total of 279 students were enrolled in the gross anatomy dissection course. The dissection of the anterior and posterior triangles of the neck took place during two four-hour lessons in the third and fourth weeks of the third trimester parallel to the dissection of the skull, brain, and face.

As every year, in the beginning of the gross anatomy dissection course, the students were told to get together in groups of up to six to form a dissection team. A dissection team would then go through all dissections together for the rest of the year. The dissection team is usually also the students’ main learning group for other subjects in the first year of medical school. Other outside review groups are usually not formed.

Six dissection teams (or a total of 36 students) were randomly assigned to a dissection group which could be taught in one dissection room. Since two dissection rooms were available, a maximum of 72 students could dissect simultaneously on one day. Since every student had one four-hour dissection course per week, four days (Monday–Thursday) were needed for everyone to finish the week’s dissection.

All students had gone through the seminars and could attend the lectures for the anterior and posterior triangles of the neck before the dissection. In 2017, the students mainly prepared for dissection with the standard manual and the Thieme and Sobotta atlases of anatomy (Paulsen and Waschke, 2013; Schünke et al., 2016) as well as with lecture slides that were uploaded to the university’s learning management system (LMS). The students were also invited to read further anatomical literature but no specific recommendations were made. During the study, there were no professors available for students to ask questions after hours.

**Spatial Study Setup**

Each dissection group has its own individual chief instructor, represented by an experienced lecturer in anatomy, who is assisted by student assistants that have previously completed the dissection course. The student assistants are assigned to one dissection team and stay with that team for the whole year.

For the study, each dissection group was split up into the three study groups. The dissection teams themselves were not split up. A blinding of the student assistants and chief instructors with regard to the interventions of the dissection teams was not possible. The study groups were distributed in the room in such a way that the interaction between them was reduced to a minimum (Fig. 1).

In addition to that, the dissection teams were supervised by the chief instructor and the student assistants to ensure as little as possible exchange between study groups during dissection.

For each study group, a separate group area was created in the university’s LMS, in which the corresponding learning material was made available to the students.

The students were asked not to discuss the material with other study groups, both inside and outside of the dissection course. At the end of the study, every student was given access to the audiovisual and improved manual to prepare for future examinations so that no possible disadvantages could occur and no further motivation existed to peek at the other groups’ resources. Since students at Hannover Medical School usually live off-campus, it was rather unlikely that students from different study groups lived together, and thus, had a natural exposure to the other study groups’ material.

**Chronological Study Setup**

The study was conducted during regular course hours. Starting on Monday one week before the first week of dissection of the anterior and posterior triangles of the neck (1st May 2017), the improved and audiovisual manuals were available online in the group area on the LMS. In weeks 1 and 2 of the dissection of the anterior and posterior triangles of the neck, the improved and the audiovisual manuals were also available in the dissection rooms for the corresponding study groups. The improved manual was available as a printout, the audiovisual manual could be watched on computers next to the study groups’ dissection tables.

After finishing the dissection in week 2, each group completed the multiple-choice question (MCQ) test for acquired formal knowledge and the survey with questions on emotions related to learning, learning motivation, and learning behavior. The MCQ test and the survey were conducted with the LMS for each study group using smartphones and the process was supervised by the teaching staff. A blinded evaluation of the performance in dissection was conducted on Friday at the end of each week for each dissection team.
Data Collection

Population characteristics. Since the secondary school final grade correlates with success in college (Trapmann et al., 2007), the study participants were asked to report their grade so that potential differences between the study groups based on different average grades could be detected. The conventional final grade for German secondary school ranges from 1.0: “excellent” to 4.0: “sufficient.” The study participants were asked to report their gender since it affects various aspects of learning including the acceptance of e-learning resources (Ong and Lai, 2006; Ramírez-Correa et al., 2015; Christophel and Schnitz, 2017).

Performance in dissection. Twice, on Friday at the end of both dissection weeks, the progress on and the quality of the cadaver dissection were evaluated by two blinded experienced members of the anatomy faculty. The progress on dissection was measured by a 53-item checklist (0 = no item dissected, and 53 = all items dissected) containing all anatomical structures that were supposed to be found during the dissection of the anterior and posterior triangles of the neck. One point was given for each structure found, independent of the quality of dissection. The overall quality of dissection was measured via the standard German secondary school grading scale that ranges from 0 to 15, where 0 is a fail, 1–3 insufficient, 4–6 sufficient, 7–9 satisfactory, 10–12 good, and 13–15 very good. The progress on and the quality of dissection could only be measured for a dissection team and not for each individual student since it was assigned by evaluating the dissection of the dissection team’s cadaver.

Acquired formal knowledge. The MCQ test conducted after the completion of the dissection of the anterior and posterior triangles of the neck consisted of 20 solely text-based questions asking mainly topographical questions which a student should be able to answer better if he or she has successfully dissected a cadaver (Ramsey-Stewart et al., 2010; Chung et al., 2013; Collins et al., 2015). The MCQs that were used were similar to the ones that were regularly utilized at Hannover Medical School to test topographical knowledge in anatomical examinations. The questions were created by an author of the study who had participated in the dissection course previously and checked by an anatomy professor who regularly designs MCQ for the final written examination of the anatomy module. The minimum number of participants was based on the university’s final anatomy examination for 2013 which consisted only of MCQ but which had a higher number of potentially easier, non-topographical questions. Assuming a power of 90% and a type I error of 5%, the minimum number of participants was determined to be n = 33.

Epistemically related emotion scales. Emotions play an important role in the process of learning (Edelmann, 2000; Albrecht et al., 2013). The Epistemically Related Emotion Scales (Pekrun et al., 2017) is a questionnaire consisting of 21 adjectives where groups of three adjectives describe seven emotions (surprise, curiosity, enjoyment, confusion, anxiety, frustration, and boredom) which are relevant for learning. The adjectives can each be given a value (1 = not at all, 5 = very strong) depending on the degree to which that adjective describes the participant’s current emotional state. The scores for an emotion are determined by the mean values of the three adjectives that describe them. The means of the scores for each of the seven emotions were formed for each study group. For the study, the German version of the questionnaire was used (Vogl et al., 2018). The questionnaire’s reliability and validity were tested in a study by Pekrun et al. (Pekrun et al., 2017).
Learning motivation. The Situational Motivation Scale (SIMS) (Guay et al., 2000) is a well-established instrument to measure motivation which in return is an indicator for the students’ willingness to invest time and effort in a learning process. The SIMS measures constructs of intrinsic motivation, identified regulation, external regulation, and amotivation (Guay et al., 2000). The SIMS was translated into German for this study and adapted to use vocabulary of the dissection course. The scores for the four types of motivation are the means of the scores of the four statements attributed to each aspect of motivation. Each statement could be given a score on a seven-item Likert scale (1 = corresponds not at all, 7 = corresponds exactly). The means of the scores were formed for each study group and compared. The questionnaire’s reliability and validity were tested in five studies by Guay et al. (Guay et al., 2000).

Learning behavior. Regarding learning behavior, the students were asked about used learning time, easiness of dissection, technical support, and type of learning resource used. To determine the time, they spent preparing for the dissection and learning anatomy, a scale from 0 to 8 or more hours (in hourly steps) was used. Easiness of preparation and dissection and appreciation of technical support were measured by agreeing with three statements on a Likert scale from 1 to 6 (1 = completely disagree and 6 = completely agree). The used learning resources were indicated by choosing several options from a preselection. In addition, it was possible to provide information as a free text response. For analysis, the free text answers were split up into statements and the frequency of similar statements was counted.

In addition to that, the video and manual groups were interviewed on various aspects on the use of the interventions (see Supporting Information).

Efficiency of preparation for dissection. To measure the efficiency of preparation for the dissection of the anterior and posterior triangles of the neck, three ratios were created:

- by dividing the dissection teams’ scores in progress on dissection at the end of dissection week 2 by the mean time the dissection teams spent preparing for the dissection of the anterior and posterior triangles of the neck;
- by dividing the dissection teams’ scores in quality of the dissection at the end of dissection week 2 by the mean time the dissection teams spent preparing for the dissection of the anterior and posterior triangles of the neck;
- by dividing the students’ results on the MCQ test by the mean time the students spent preparing for the dissection.

The scores of the progress on and quality of dissection were only given to the 48 dissection teams and not to the 246 individual students. Therefore, the mean of the time spent preparing for the dissection of the anterior and posterior triangles of the neck by each of the 48 teams was taken into consideration. The mean of each ratio was created for each study group and compared to each other.

Statistical Methods

The IBM SPSS statistical package, version 24 for Windows (IBM Corp., Armonk NY), was used in this study. One-way ANOVA and $t$ test for independent samples were used to compare all three study groups and the two intervention groups, respectively. The level of significance was set at 95% ($P < 0.05$) and a Bonferroni alpha adjustment was performed wherever indicated. Tukey HSD test was used as a post hoc test if necessary (Kim, 2015). The chi-square test was used for binary data.

Normal distribution was tested via visual inspection of histogram and the Shapiro–Wilk test. If the Shapiro–Wilk test did not indicate a normal distribution, the visual inspection of histogram was used to determine the statistical test for analysis of the data. Since the size of the sample ($n = 48, n = 246$) is considered large, if justifiable by visual inspection, a normal distribution was assumed (Ghasemi and Zahediasl, 2012). In all cases except one, even if visual inspection of the histogram did not indicate a normal distribution beyond any doubt, ANOVA was used due to its robustness with regard to non-normally distributed data (Ghasemi and Zahediasl, 2012; Blanca et al., 2017). The same applies for data obtained from Likert scales, especially due to the large sample size (Norman, 2010). The Kruskal–Wallis test was used only for the analysis of the secondary school final grades, which by design (applicant quotas at German universities) is non-normally distributed.

Homogeneity of variances was checked via the Levene’s test and if not confirmed, Brown–Forsythe and Welch test as well as the Games-Howell test as a post hoc test were used. Cronbach’s alpha was calculated for the MCQ test. Item difficulty was calculated by dividing the number of correct answers for a question by the total number of participants who answered the question. Missing values were not replaced by a series mean but considered missing.

RESULTS

Study Participants

The 279 students who were enrolled for the dissection course in May 2017 were divided up into the control ($n = 96$), manual ($n = 94$) or video group ($n = 89$). Valid responses from 246 students were collected, of which $n = 84$ were in the control, $n = 81$ in the manual, and $n = 81$ in the video group.

Among the 246 remaining students, 159 (64.6%) were female and 69 (28%) male students, whereas 18 (7.3%) did not report their gender. A chi-square test was performed to examine the relation in gender distribution between the three study groups. No significant difference was found ($\chi^2(2, N = 228) = 0.245, P = 0.885$).

The secondary school final grade was reported by 228 students (1.0 = the best and 4.0 = the worst). Due to a non-normally distributed sample, a Kruskal–Wallis test was performed to analyze the relation of distribution among the study groups. No significant difference between the groups was detected ($H(2) = 3.903, P = 0.142$).

Performance in Dissection

The results of the performance in dissection are summarized in Table 1. While a tendency toward a better quality in dissection from the control over the manual to the video study groups could be observed in the first week, there was no significant difference ($F(2, 45) = 2.862, P = 0.068$), nor was there one in the second week ($F(2, 45) = 0.135, P = 0.874$).

There was no significant difference in the progress on dissection between the study groups in the first ($F(2, 45) = 0.485, P = 0.619$) and in the second week of dissection ($F(2, 45) = 0.024, P = 0.977$).
Acquired Formal Knowledge

The results of the MCQ test are summarized in Table 1. While the intervention groups scored slightly higher than the control group, the acquired formal knowledge measured by a 20-item MCQ test showed no significant differences between the three study groups ($F(2, 240) = 0.445$, $P = 0.641$). The Cronbach’s alpha value of this MCQ test was 0.52.

Table 1.

Quality and Progress on Dissection in Weeks 1 and 2 and Multiple-Choice Question Test Results in Percentages

| Evaluation method | Control ($N^2 = 16$) Mean (±SD) | Manual ($N = 16$) Mean (±SD) | Video ($N = 16$) Mean (±SD) | $P$-value |
|-------------------|---------------------------------|-------------------------------|-----------------------------|-----------|
| Quality$^a$       |                                 |                               |                             |           |
| Week 1            | 37.50 (±16.84)                  | 43.33 (±10.89)                | 48.75 (±11.34)              | 0.068     |
| Week 2            | 46.25 (±16.41)                  | 48.75 (±16.10)                | 46.25 (±14.50)              | 0.874     |
| Progress$^b$      |                                 |                               |                             |           |
| Week 1            | 29.13 (±9.86)                   | 29.95 (±6.99)                 | 31.72 (±5.26)               | 0.619     |
| Week 2            | 51.77 (±13.02)                  | 52.59 (±13.62)                | 51.77 (±10.29)              | 0.977     |
| Knowledge test$^c$|                                 |                               |                             |           |
| MCQ (N)           | 38.80 (±14.99) (83)             | 40.94 (±13.94) (80)           | 40.19 (±15.23) (80)         | 0.641     |

$^a$The quality in percentage is derived from the German secondary school grading system (0 = failed, 15 = very good) that was originally used to grade the quality. Here, for simplification, the percentage was calculated based on how many points out of a total of 15 were achieved;$^b$Progress is displayed in percentage of dissected structures from a total of 53;$^c$MCQ test result is displayed in percentage of correctly answered MCQ of a total of 20;$^d$N shows the number of dissections teams in each study group, does not apply for MCQ test results.

Epistemically Related Emotion Scales

Figure 2 shows the distribution of the scores for the seven items of the Epistemically Related Emotion Scales among the study groups. For the items anxiety and frustration, all three study groups achieved scores between 1 (“not at all”) and 2 (“very little”). For the items confusion and surprise, only the manual group achieved a score between 2 and 3 (“moderate”) and the control and video groups between 1 and 2. For the item boredom, all three study groups achieved scores between 2 and 3. For the item enjoyment a significant difference between the study groups was found ($F(2, 219) = 9.343$, $P < 0.001$). The manual group achieved a score between 3 and 4 (“strong”) (M = 3.25, SD ± 0.778) which was higher than in the video (M = 2.85, SD ± 0.811) and control group (M = 2.67, SD ± 0.938). For the item curiosity, all study groups achieved scores between 3 and 4. For the detailed data, please refer to Table 1 in the Supporting Information.

Brown–Forsythe, Welch, and Games-Howell as a post hoc test were performed for anxiety and frustration due to the inhomogeneity of variances. No significant differences were found: ($F(2, 198.64) = 2.834$, $P = 0.061$ and $F(2, 209.53) = 2.813$, $P = 0.062$, respectively).

Figure 2.

The epistemically related emotion scales display the study groups’ mean scores for an emotion. The score for an emotion is based on the mean score of agreement with three adjectives on a five-item Likert scale (1 = not at all, 5 = very strong). The number of participants with valid replies (N) is displayed on the left of the bars. $^aP = 0.013; ^bP < 0.001$.
Learning Motivation

Figure 3 shows the distribution of the scores of the four aspects of motivation among the study groups. For intrinsic motivation, identified regulation, and external regulation, all three study groups achieved in almost all cases scores between 4 (“corresponds moderately”) and 5 (“corresponds enough”). For intrinsic motivation, the manual group achieved a score between 5 and 6 (“corresponds a lot”). For amotivation, the video and manual groups achieved scores between 1 (“corresponds not at all”) and 2 (“corresponds a very little”), while the control group achieved a score between 2 and 3 (“corresponds a little”).

No significant differences were found for identified regulation ($F (2, 214) = 2.068, P = 0.129$) or external regulation ($F (2, 211) = 1.678, P = 0.189$). For the detailed data, please refer to Table 2 in the Supporting Information.

Brown–Forsythe and Welch were performed for intrinsic motivation and amotivation due to the inhomogeneity of variances. No significant difference between the study groups was found.

General Learning Behavior of All Study Groups

The results do not indicate significant differences between the mean time spent preparing for the dissection in general and for the three dissection areas that had to be dissected at the same time during the study (Table 2).

The usage of other learning aids by the three study groups was largely identical but differed significantly with regard to the usage of online courses. At least 65% of each group used textbooks and books of drawings which were the most popular learning aids. Artificial anatomical models and extra time studying anatomy on the cadavers was used by over 30% of each study group. Books of pictures, other videos, virtual three-dimensional (3D) models, and online encyclopedias had a usage rate below 20%, and thus, were the least popular learning aids. A chi-square test of independence was performed to examine the relation between study group and online course usage. The relation between these variables was highly significant $\chi^2 (2, N = 225) = 25.024, P < 0.001$. Control and manual groups had usage rates of online courses below 5%, the video group above 25% (Fig. 3 in Supporting Information).

![Figure 3.](image)

The situational motivation scale displays the study groups’ mean scores for an aspect of motivation. The score for an aspect of motivation is based on the mean score of agreement with four statements on a seven-item Likert scale (1 = corresponds not at all, 7 = corresponds exactly). The number of participants with valid replies (N) is displayed on the left of the bars.
The level of agreement with the statement, “The preparation for the dissection of the anterior and posterior triangle of the neck was easy,” did not differ significantly between the study groups (F (2, 219) = 2.888, P = 0.058). A significant difference between the three study groups was found when asked if the dissection of the anterior and posterior triangles of the neck was easy (F (2,220) = 7.454, P = 0.001). The video group indicated a significantly higher agreement (M = 3.74, SD ± 1.035) than the control group (M = 3.01, SD ± 1.274). However, the manual group (M = 3.47, SD ± 1.156) also showed a significantly higher agreement with the statement than the control group and did not differ significantly from the video group (Fig. 4). The three study groups differed significantly in agreeing on whether a greater use of technology in the dissection course is appropriate (F (2, 221) = 5.176, P = 0.006). The video group’s agreement (M = 4.00, SD ± 1.473) was significantly lower than that in the control group (M = 4.73, SD ± 1.286), while the mean score in the manual group (M = 4.39, SD ± 1.412) did not differ significantly from the control or video group (Fig. 4).

In the video group, 39 students provided free text answers. The most frequent statement, given by 19 students (48.72%), related to differences of the video from the standard dissection manual and that the first 12 minutes were a repetition of dissection that had already happened. Accordingly, 10 students (25.64%) remarked that the video would have fit much better in the beginning of the course. The second most frequent statement, given by 14 students (35.90%), suggested that the image was too small which is accompanied by the fourth most frequent statement that the image was too dark which was given by eight students (20.51%). The fifth most frequent statement given by six students (15.38%) noted that the student assistants were the best support during the dissection.

In the manual group, 24 students out of 81 (29.62%) provided free text answers. The most frequent statement asked for even more pictures in the improved manual, given by five students (20.83%). Two statements were given by four students each (16.67%). One said that the improved manual was a good supplement for the dissection. The other noted that the video would have been a good support.

In the control group, 18 students out of 84 (21.43%) provided free text answers. Most statements given by five students (27.78%) mentioned that the study was a good and interesting idea. The second most statement given by four students (22.22%) made clear that student assistants were the best support during dissection and could not be replaced.

In each study group, there were additional statements with general remarks on the study and the interventions. In each study group students remarked that the understanding of anatomy would come only with time and time spent on dissection. It was stated that other dissection areas and subjects required attention at the same time as the dissection of the neck and understanding of anatomy would be highest only right before the according examinations.

Specific Learning Behavior of Intervention Groups

The intervention groups were asked questions about their learning with the interventions (Fig. 5). An expansion of the intervention to other dissection areas was significantly more favored by the video (M = 4.28, SD ± 1.452) than by the manual group (M = 3.77, SD ± 1.457); t (139) = −2.109, P = 0.037. The video group (M = 3.20, SD ± 1.480) also disagreed significantly less that the intervention improved the dissection technique compared to the manual group (M = 2.47, SD ± 1.338) (t (139) = −3.054, P = 0.003).

No significant differences between manual and video group were found regarding time efficiency due to the intervention (t (140) = 0.191, P = 0.849) and time invested in preparing for the dissection due to the intervention (“more time”: t (139) = −1.967, P = 0.051 and “less time”: t (139) = −0.214, P = 0.831).

No significant differences were found regarding the grading of the interventions according to the German secondary school grading system (t (140) = 0.458, P = 0.648).

The students were on average willing to pay 28.06 Euros for an improved manual and 50.14 Euros for an audiovisual dissection manual that covered all dissection areas.

Efficiency of Preparation for Dissection

For each study group, the means of the three ratios, selected to determine efficiency of preparation for dissection, were calculated and compared. The results are summarized in Table 3. No significant differences could be detected.

DISCUSSION

Since the gross anatomy dissection course is an essential part of medical education, there have been several studies on how new media can be used to improve teaching. Often the focus was on single aspects and no analysis with regard to more
affordable alternatives was conducted. With this study, however, an attempt was made to gain a broad insight into different effects the use of an audiovisual manual has on student learning and to critically reflect on whether the same effect can be also achieved with a cheaper and much more affordable alternative. The response rate of 88% can be considered high when compared to similar studies that reported: 43% in Saxena et al. (2008), 47.5% in Inwood and Ahmad (2005), 64% in DiLullo et al. (2006), and 69% in Mahmud et al. (2011) studies and provides a valid basis for the interpretation of the results.

Performance in Dissection and Efficiency of Preparation for Dissection

The evaluation of students’ performance in dissection has been neglected in previous research. This is especially problematic amid concerns about an effective use of time intended for...
learning anatomy (Nwachukwu et al., 2015). Likewise, little is known about the effect of audiovisual instruction on the performance in dissection. The only study on this topic was conducted on frogs in a high school dissection course (Akpan and Andre, 1999). While audiovisual instruction has various positive effects on different aspects of learning in the dissection course (Saxena et al., 2008; Casado et al., 2012; Chung et al., 2013; Al-Khalili and Coppoc, 2014; Collins et al., 2015; Ahmad et al., 2016), its positive effect on the students' performance remains yet to be proven. The results of this study demonstrate the variety of factors that need to be considered when evaluating the performance.

After the video group achieved better but nonsignificant results in the quality of dissection in the first week, this lead was lost in the second week. It is possible that the student assistants who were supposed to assist in dissection whenever a group lagged behind might have had an equalizing effect on the quality of dissection by intensifying their support for the slower dissection teams in the second week. This hypothesis is partly supported by two studies that examined the role of student assistants during dissection more closely. A Purdue University study with veterinary students recorded the dissection course with a camera to analyze the number of contacts of the study groups with student assistants. The study groups had prepared for dissection either with 3D or two-dimensional (2D) videos or the laboratory manual. No significant differences were found but a tendency toward less contact with student assistants by the study group using 3D videos was detected (Al-Khalili and Coppoc, 2014). In a UCSF study, investigators in the dissection course rotated between dissection tables for two-minute observation intervals to record the presence of certain activities including consulting instructors. A significant difference between the two study groups (audiovisual instruction on iPad and not) was not observed. However, judging from effect size, the study group working with the iPad was less likely to call and look for an instructor (Mayfield et al., 2013). It is important to note that both studies only briefly exposed the student assistants to the intervention groups (Mayfield et al., 2013: 2 hours; Al-Khalili and Coppoc, 2014: 45 minutes), while in the present study two course days lasting about four hours in two different weeks were available. Thus, the student assistants in the present study had more time to intervene and to intensify their support for the groups that were lagging behind in the second week.

As described by Winkelmann, medical students tend to perform well in academic settings and are thus likely to compensate educational interventions by investing more time on their own (Winkelmann, 2007). If higher results in quality of dissection in the first week would have been paired with a lower time spent preparing for dissection, this effect could be attributed to an audiovisual manual that allows for a more efficient preparation for dissection. Unfortunately, the time spent preparing for dissection leading up to the first week was not reported. It should be noted, however, that the video group reported the least amount of time spent preparing for the dissection of the anterior and posterior triangles of the neck in total at the end of the second week (Table 2). Even when comparing the efficiency of preparation for dissection at the end of the second week, the video group scored higher than the other two groups, although not significantly.

The students' subjective opinions provide ambivalent support for a more efficient preparation for dissection with the audiovisual manual. The video group, however, reported significantly higher usage of online videos and less usage of the four most preferred learning aids of the manual and control group. This could be a hint that students feel that learning with videos is more efficient than with other learning resources (Green et al., 2018).

To sum up, there are indications that the audiovisual manual might have either improved the quality of dissection or the efficiency for preparation for dissection. There are plausible hypotheses supported by literature and subjective student responses as to why this effect is not translated into significant results: The student assistants' influence combined with the long duration of the study might have counteracted a positive effect of the audiovisual manual. However, these indications remain accompanied by nonsignificant different results.

Further studies in a comparable setup should take into consideration the role of the student assistants. Limiting the time frame of the study to just one dissection course seems an adequate measure as well.

### Acquired Formal Knowledge

The MCQ test scores of the two intervention groups were slightly higher than those of the control group but no significant differences were found. A reason for this might be that possible effects of dissection on the understanding of anatomy will only become apparent over time and closer to examinations, as other studies have shown (Yeager, 1996; Nwachukwu et al, 2015) and as students' free text answers suggest. Accordingly, the MCQ test was very difficult for the students. The mean result was 7.99 correct answers, whereas 12 out of 20 were necessary to pass the MCQ test. Literature recommends questions with an item difficulty between 0.4 and 0.8 (Möltner et al., 2006), while this test had 11 questions with a difficulty below 0.4. There are, however, slight differences in the present study and they are noteworthy since several other studies show how difficult it is to demonstrate differences in knowledge assessed by MCQ tests. Studies from Saxena et al. and Mahmud et al. with a similar study setup in a medical school's gross anatomy dissection course did not find any significant differences when the formal knowledge was tested via a MCQ test (Saxena et al., 2008; Mahmud et al., 2011). A study by Al-Khalili and Coppoc was able to show significantly higher examination scores due to audiovisual preconditioning but it applied other assessment methods of testing formal knowledge than MCQ (Al-Khalili and Coppoc, 2014). Only Collins and colleagues were able to show significantly higher examination scores when the formal knowledge was assessed with MCQ tests but the study was conducted with postgraduate health professionals (Collins et al., 2015).

To sum up, the interventions might have had a positive effect on the students’ acquired formal knowledge. This effect could have become more apparent if the MCQ test had been moved to a later point or closer to regular university examinations.

### Epistemically Related Emotion Scales

Only the emotion enjoyment showed a difference between the study groups and was felt significantly stronger in the manual group compared to the other study groups. One possible explanation for the significant difference is the novelty effect. Independent of its actual usefulness, receiving an intervention might have contributed to a higher level of enjoyment. This
is also indicated by the study of Liu et al. which showed that the concentration when using the new e-learning resource decreased as its novelty faded over time (Liu et al., 2009). However, the video group must have experienced the novelty effect, too, but scored significantly lower compared to the manual group with regard to enjoyment. This difference might be explained by a potential different contentment of the video and manual group with their interventions. The free text analysis reported more complaints and advice for improvement of the video than for the improved manual. This suggests that the design of an e-learning resource has a direct impact on an epistemically related emotion which in return might have decreased its effect on learning.

The results from the Epistemically Related Emotion Scales generally suggest that the dissection course is a positive emotional experience overall. The positively valenced emotions curiosity and enjoyment scored highest among all study groups, while the negatively valenced emotions confusion, anxiety, frustration, and boredom scored lowest. These results are comparable with findings from O’Carroll and colleagues who tested the Appraisal of Life Events (ALE) scale on 114 medical students four weeks into the dissection course and considers the dissection course a positive emotional experience as well (Ferguson et al., 1999; O’Carroll et al., 2002). Activating emotions (all emotions mentioned except boredom) promote the use of learning strategies and thereby a systematic effort of learning (Pekrun et al., 2017). In the dissection course, only enjoyment and curiosity received scores for a “moderate” strength of emotion.

A reduction in anxiety through the use of audiovisual material is known to literature (Casado et al., 2012). Anxiety was the emotion that was reported least by all study groups and did not differ significantly between the groups. The reason for this might be that the study was conducted after two-thirds of the dissection course when the students’ emotional status had supposedly largely been stabilized. While the dissection course is described as a “significant emotional life event,” other studies have shown that students adapt quickly to the situation and consider the dissection course as a positive experience (O’Carroll et al., 2002; Theoret et al., 2007). This quick adaptation to the dissection course might also explain the generally similar emotional status in all study groups.

Another reason why the present study could not detect many differences between the study groups might be the strong impact of the dissection course itself. This experiential activity engaging multiple senses and involving engagement and active learning enhances multiple positive pedagogical learning outcomes including motivation (Larkin and McAndrew, 2013). To design and implement an e-learning resource that further enhances this already highly engaging learning activity thus seems challenging per se. While in the very beginning of the dissection course, an intervention is proven to have a significant effect on emotions (Casado et al., 2012) this effect seems to be harder to achieve as the course proceeds and the students adapt quickly to the new situation (O’Carroll et al., 2002).

**Learning Motivation**

No significant differences between the three study groups could be detected with regard to learning motivation. The reason for this might be that the dissection course itself serves as the primary motivator for the students (Larkin and McAndrew, 2013; Abdel Meguid and Khalil, 2017) and consequently dwarfed the effect of the interventions.

Another explanation, similar as with regard to emotions, might be the timing of the study. Conducting interventions like audiovisual instruction prior to or in the beginning of the dissection course are recommended and proven measures to reduce stress and anxiety (Cahill and Ettarh, 2009; Casado et al., 2012), and thus, might benefit the motivation (Abdel Meguid and Khalil, 2017). However, later in the course the emotional setup of the students seems to be largely established and so the interventions appear to have little effect as argued above.

Nevertheless, general statements about the motivational setup of the study groups can be made. Self-determination theory associates high intrinsic motivation and identified regulation during an activity with positive outcomes. External regulation and amotivation are associated with negative outcomes (Guay et al., 2000). The two positively connotated items “intrinsic motivation” and “identified regulation” received scores above 4 in all study groups which correlates with an agreement of “corresponds moderately.” These results for intrinsic motivation and identified regulation can be confirmed with findings from Abdel Meguid and Khalil who conducted a study with 270 medical students assessing their motivation to involvement in the dissection course (Abdel Meguid and Khalil, 2017). Since the study by Abdel Meguid and Khalil applied the Attention, Relevance, Confidence, and Satisfaction (ARCS) model, the negatively connotated amotivation or external regulation were not assessed directly. The SIMS applied in the present study reported a mean score for amotivation below 2 in all study groups which correlates with an agreement of “corresponds a very little” but a mean score for external regulation above 4 in all study groups.

In further studies, reasons for that discrepancy should be identified. This would enable teachers to lower external regulation in favor of more intrinsic motivation and identified regulation, and thus, possibly promote better outcomes in the dissection course.

To sum up, both the strong influence of the dissection course itself on learning and the students’ quick adaptation to the dissection course are plausible explanations for the little differences. The audiovisual and improved manual are thus not likely to be the kinds of interventions to have an effect on motivation later in the course. If, for example, the high external regulation should be decreased, other measures such as organizational changes would have to be undertaken.

**General Discussion of Interventions**

An interactive e-learning resource alone contributes little to the overall learning effect of a module. Proper implementation into the curriculum is at least as important as the quality of the e-learning resource itself (Chumley-Jones et al., 2002; Clunie et al., 2018). However, anatomy classes are subject to constant transformation due to changes in staff and learning time available for students or curricular requirements (Granger and Calleson, 2007). E-learning resources that had previously been well implemented in the curriculum might turn out to be unsustainable if adaptations cannot be made (Stepanyan et al., 2013). In 2014, the dissection course at Hannover Medical School underwent a change in order to fit well alongside the neuroanatomy classes. In this process,
the dissection of the anterior and posterior triangles of the neck was moved from the beginning to the second third of the course. The audiovisual manual, however, was produced before this change. Though it still covered the same area, the audiovisual manual partly deviated in content and organization from the actual dissection as confirmed by the student answers to the free text.

The present study was conducted as a field study in a realistic and fast-changing learning environment that is experienced by medical faculties around the world (Granger and Callesen, 2007; Larkin and McAndrew, 2013; Topping, 2014; Barry et al., 2016; Hulme and Štrkalj, 2017). Thus, the late implementation into the curriculum was difficult to avoid. Hulme and Štrkalj argue that results of studies examining the use of anatomy videos can differ because of the way the interventions are integrated into the curriculum and recommend further research to identify the components that make a video successful (Hulme and Štrkalj, 2017). Based on the quantitative and qualitative results of this study, flexibility can be identified as such a crucial component. Shorter videos, for example, covering only specific anatomical areas could have been flexibly rearranged to meet the necessary requirements of the fast-changing curriculum, increasing their longevity and cost-efficiency and ultimately improving the learning experience. This is supported by the analysis of free text answers which showed that a lot of issues were caused by the nature of the inflexibly long audiovisual manual.

At Hannover Medical School, the Studies Commission decides on study-related affairs including the distribution of grants to fund learning resources. Funding is preferably granted to e-learning resources that have the most effect compared to the investment needed. In the vast majority of cases, the improved manual produced results that did not differ significantly from that of the audiovisual manual and the audiovisual manual could not produce significant differences from the standard manual. Since the production effort of an audiovisual manual that covered all dissection areas is much higher than the equivalent of the standard and improved manual, such a production cannot be recommended.

Partly due to the experiences with the audiovisual manual described in this study, Hannover Medical School is now experimenting with interactive high-resolution images of prosections that guide dissection. These are not only flexibly implementable alongside newer technology that will emerge (e.g., 3D objects), but they are also cheaper and easier to produce and rearrange based on curricular needs.

Limitation of the Study

The aim of this study was to investigate as comprehensively as possible the effects of an e-learning resource in the form of an audiovisual manual. Lacking a best practice way of evaluating e-learning resources, the study assembled a number of tests, most of them either well established and/or well evaluated. The great number of tests, however, diminished the value of a single significant result.

The aspects of the learning behavior were in many cases based on a personal opinion (e.g., self-reported time spent learning for dissection) and might have been a source of distortion.

Setting up the study during regular course hours provided a realistic implementation scenario for the evaluation of the audiovisual dissection manual but caused some restrictions concerning randomization. There were only stationary computers available in the dissection rooms that could not be moved easily so the two dissection teams in each dissection room belonging to the video group were always in the front at the right and the dissection teams belonging to the control group always in the back. In the beginning of their studies, the dissection teams were distributed randomly across the room. The chief instructors usually do not interfere in dissection and try to distribute their time equally to all dissection teams. But if placement of the table for example led to increased attention by the chief instructor who was in the front of the room, this might have biased the results.

A dissection team contained a maximum of six members who dissected on one half of a cadaver together. All members of a dissection team were always in the same study group. Assigning individual members of a dissection team to different study groups for the sake of randomization would have allowed for too much interaction between the study groups and interfered with the regular setup of the dissection course.

The dissection teams’ tables were not completely separated from each other. Despite the controlling by the staff and reasonable spacing between the tables, it is possible that interaction among dissection groups belonging to different study groups might still have occurred.

Not all factors such as the influence of the student assistants could be fully controlled and might have been a reason for few significant differences with regard to performance in dissection between the study groups. Some of the interventions’ effects might further have been lost due to a late implementation in the dissection course that was caused by a change in the curriculum.

CONCLUSION

With this study, a field test was realized in a regular learning situation of a university course. With the study settings, it was possible to accurately compare different learning factors by comparing equivalent study groups.

The results showed several nonsignificant tendencies that speak for the audiovisual manual. The improved manual was, however, not significantly inferior to the audiovisual manual. Considering the great effort of creating the audiovisual manual and its inflexibility with regard to common changes in the curriculum, the improved manual seemed to be the far better alternative for an improvement of the dissection course.

This study cannot recommend the use of an audiovisual dissection manual at the moment. It can potentially save the medical students precious learning time but is initially expensive to produce and has to be carefully implemented into the curriculum for a maximum effect. If the know-how for a sustainable production and implementation of an audiovisual dissection manual is not available, text- and image-based instruction seems to be the more cost-effective alternative.

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