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Draw Anatomy - An investigation of the learning method drawing on a tablet to learn gross anatomy

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Abstract

Medical students can learn anatomy in many ways. Traditional methods of learning anatomy are increasingly being supplemented by new technology-based methods as mobile devices are used more frequently. Therefore, this thesis aimed to investigate one learning method, namely drawing anatomical content on a tablet. The central questions were whether drawing on a tablet leads to better learning outcome than paper-based methods and whether there is a difference in the sustainability of this learning outcome. Furthermore, it was investigated whether there is a correlation between the quality of strategy implementation and the learning outcome.

To answer these questions, a study was conducted with a total of 105 medical students who learned anatomical content using three different learning methods. These three learning methods were drawing on a tablet, drawing on paper, and making summaries on paper. The learning phase consisted of all participants reading the same learning text with the corresponding pictures and making drawings and summaries in sections about the anatomical content of this learning text. The group with the tablet used a drawing app, developed by our workgroup, on the tablet with a digital pen. To measure the learning outcome, an anatomy knowledge test was administered directly after the learning phase and at intervals of 4-6 weeks, and the quality of the drawings and summaries was assessed with a scoring sheet.

The results of this study showed that there was no significant difference between the three learning methods in terms of learning outcome and its sustainability. It was also found that there was a positive relationship between the quality of strategy implementation and the learning outcome and that the quality of the drawings and summaries produced moderated the effect of the learning method on the learning outcome. At low quality, writing on paper compared to drawing on paper, as well as drawing on a tablet compared to drawing on paper, led to lower learning outcome. At high quality, writing on paper compared to drawing on paper as well as drawing on the tablet compared to drawing on paper led to higher learning outcome.

These results show that drawing on a tablet can be used as an equivalent learning method for learning gross anatomy by medical students and that it is especially beneficial when the quality of the drawings is high. It must be kept in mind that the app we developed is still in its early stages and still has room for improvement. In addition, the students in this

study have just had the opportunity to get to know the app and had to get used to the new learning method. Future research could conduct further studies on drawing on the tablet and investigate how learning outcomes change when the tablet and a drawing app are integrated into the gross anatomy course and used regularly by the students. This work contributes insights to this new learning method and thus enables further support of medical students in their learning.

Zusammenfassung

Medizinstudierende können Anatomie auf viele Arten lernen. Traditionelle Methoden zum Erlernen der Anatomie werden zunehmend durch neue technologiebasierte Methoden ergänzt, da mobile Geräte immer häufiger verwendet werden. Ziel dieser Arbeit war es daher, eine neuere Lernmethode zu untersuchen, nämlich das Zeichnen anatomischer Inhalte auf einem Tablet. Die zentralen Fragen waren, ob das Zeichnen auf einem Tablet zu besseren Lernergebnissen führt als papierbasierte Methoden und ob es einen Unterschied in der Nachhaltigkeit dieser Lernergebnisse gibt. Darüber hinaus wurde untersucht, ob es einen Zusammenhang zwischen der Qualität der Strategieumsetzung und dem Lernerfolg gibt.

Zur Beantwortung dieser Fragen wurde eine Studie mit insgesamt 105 Medizinstudierenden durchgeführt, die anatomische Inhalte mit drei verschiedenen Lernmethoden lernten. Diese drei Lernmethoden waren das Zeichnen auf einem Tablet, das Zeichnen auf Papier und das Erstellen von Zusammenfassungen auf Papier. Die Lernphase bestand darin, dass alle Teilnehmenden denselben Lerntext mit den entsprechenden Bildern lasen und in Abschnitten Zeichnungen und Zusammenfassungen zu den anatomischen Inhalten dieses Lerntextes anfertigten. Die Gruppe mit dem Tablet nutzte eine von unserer Arbeitsgruppe entwickelte Zeichen-App auf dem Tablet mit einem digitalen Zeichenstift. Zur Messung des Lernerfolgs wurde direkt nach der Lernphase und in Abstand von 4-6 Wochen ein Anatomie-Wissenstest durchgeführt und die Qualität der Zeichnungen und Zusammenfassungen mit einem Bewertungsbogen beurteilt.

Die Ergebnisse dieser Studie zeigten, dass es keinen signifikanten Unterschied zwischen den drei Lernmethoden in Bezug auf den Lernerfolg und dessen Nachhaltigkeit gab. Es wurde auch festgestellt, dass ein positiver Zusammenhang zwischen der Qualität der Strategieumsetzung und dem Lernergebnis besteht und dass die Qualität der erstellten Zeichnungen und Zusammenfassungen die Auswirkungen der Lernmethode auf das Lernergebnis beeinflusst. Bei geringer Qualität führte das Schreiben auf Papier im Vergleich zum Zeichnen auf Papier sowie das Zeichnen auf einem Tablet im Vergleich zum Zeichnen auf Papier zu einem geringeren Lernerfolg. Bei hoher Qualität führte das Schreiben auf Papier im Vergleich zum Zeichnen auf Papier sowie das Zeichnen auf dem Tablet im Vergleich zum Zeichnen auf Papier zu einem höheren Lernerfolg.

Diese Ergebnisse zeigen, dass das Zeichnen auf einem Tablet als gleichwertige Lernmethode für das Erlernen der makroskopischen Anatomie durch Medizinstudierende verwendet werden kann und dass es besonders vorteilhaft ist, wenn die Qualität der Zeichnungen hoch ist. Es ist zu bedenken, dass sich die von uns entwickelte App noch in der Anfangsphase befindet und noch verbessert werden kann. Außerdem hatten die Studierenden in dieser Studie gerade erst die Gelegenheit, die App kennenzulernen und mussten sich an die neue Lernmethode gewöhnen. Zukünftige Forschungen könnten weitere Studien zum Zeichnen auf dem Tablet durchführen und untersuchen, wie die Ergebnisse beeinflusst werden, wenn das Tablet und eine Zeichen-App in den Kurs für makroskopische Anatomie integriert und regelmäßig von den Studierenden genutzt werden. Die vorliegende Arbeit trägt Erkenntnisse über diese neue Lernmethode bei und ermöglicht somit eine weiterführende Unterstützung der Medizinstudierenden beim Lernen.

Table of contents

List of figures

List of tables

List of abbreviations

VARK	Visual, Aural, Read, Kinesthetic
ICAP	Interactive, Constructive, Active, Passive
STEM	Science, Technology, Engineering, Mathematics
AR	Augmented Reality
ICC	Intra-class-coefficient

Declaration of published contents

Parts of this thesis have already been published in the following paper:

Styn, A., Scheiter, K., Fischer, M. R., Shiozawa, T., Behrmann, F., Steffan, A., Kugelmann, D., & Berndt, M. (2023). Effects of tablet-based drawing and paper-based methods on medical students' learning of gross anatomy. *Anatomical Sciences Education, 16*(2), 266-279. https://doi.org/10.1002/ase.2237

As a consequence, several instances of this thesis relate to content also reported in the above paper, however, in paraphrased form. To uphold transparency, these instances within this thesis contain a reference to the above paper, usually as *see Styn et al., 2023* or *Styn et al., 2023*.

Parts of this dissertation have already been published in the follwing conference contribution:

Styn, A., Scheiter, K., Fischer, M. R., Shiozawa, T., Behrmann, F., Steffan, A., Kugelmann, D., & Berndt, M. (2022). Tablet oder Papier? Vergleich zwischen tablet- und papierbasierten Lernmethoden für makroskopische Anatomie. Short communication at the annual meeting of the Society for Medical Education (Gesellschaft für Medizinische Ausbildung, GMA), Halle (Saale), Germany.

1 Introduction

1.1 Learning anatomy

Learning and teaching anatomy is a central component of medical education and important to different medical specialties, like diagnostic radiology or general surgery (Cottam, 1999). Over time, various methods have been used and further developed for this purpose. As early as the Renaissance, deceased persons were used to teach people about the anatomy of the human body. This method allowed Vesalius to depict every layer of the body and enabled him to create his famous anatomical atlas (Vesalius, 1543). Dissections are also still used today as a successful learning method (Ghosh, 2017). Besides dissections, simpler methods such as making drawings on a blackboard have always been popular (Barabas, 1965). Even today these are very useful methods to learn anatomy. In France, the basic anatomical content is taught through drawings with different colors on a blackboard (Clavert et al., 2012). However, the drawings should not stand alone, but rather should be accompanied by explanations and comments.

Over time, other learning methods have been added to medical education. The focus was no longer only on teacher-bound learning such as lectures and dissections, but also on self-regulated learning. The learners should participate more actively in the acquisition of knowledge and so problem-based learning was developed. Here, students are presented with a problem to solve, such as a patient or a research problem (Barrows & Tamblyn, 1980). This reinforces their problem-solving skills, and they actively engage with the issues and information relevant to the problem. To further support the students' activity, methods that focus on generation were also used. The creation of learner-generated drawings of the main idea of a scientific text showed positive effects on the comprehension of content, especially compared to learning without strategy (Leopold & Leutner, 2012).

The combination of old and new learning methods represents an opportunity to use multiple ways of acquiring knowledge at the same time. Drawing during dissection seems to be a successful and promising learning method for students, bringing them closer to the anatomical content of the human body in multiple manners, and leading to better learning outcome (Chaudhuri, 2021). In the previously mentioned study, students were instructed to make accurate drawings of the anatomical structures of the body from memory. So, they use the advantages of both learning methods, namely the three-

dimensionality and authenticity of the cadaver and the positive effect of the learner-generated drawing.

As the technology has evolved, it has also found its place in the medical field. Personal digital assistants were small portable computers that could be used by physicians for patient management, among other things (Adatia & Bedard, 2003). Mobile devices are not only used in the clinical setting but also by students. Textbooks can be read on a tablet and provided with interactive tasks, such as labeling exercises or interactive diagrams with different levels, which increases the popularity of this learning medium among students and makes learning anatomy fun (Stewart & Choudhury, 2015).

With this move towards self-regulated active learning and the emergence and widespread use of new technologies, it is important to study these new learning methods for anatomy well to see if they are of benefit to students and can be used successfully.

1.2 Learning theories

To explain the success of learning methods, there are several learning theories that have been developed by researchers over the last centuries. In 1991, Clark and Paivio tried to explain why a combination of words and pictures is beneficial for learning and thus developed the dual coding theory. According to this theory, verbal and nonverbal content are perceived differently through two different channels (Clark & Paivio, 1991). By using both channels to perceive and process information, this information can be learned, understood, and remembered effectively. Hence, this theory states that words together with pictures provide a good basis for learning.

Another theory deals with the processing of information and the memory of humans. The assumption from the dual coding theory that information is processed via two channels is still valid. The cognitive theory of multimedia learning explains that humans have three memory storages (Mayer, 2014). The sensory memory stores the incoming information, whether verbal or nonverbal, for a short time. Afterwards, this information is passed on to the working memory. Here the relevant information is selected and organized into models. It must be noted that the working memory has only a certain capacity and can be overloaded by too much information over one channel. In the long-term memory, the third and last memory storage, these models are integrated into the existing prior knowledge and thus the knowledge is acquired. This procedure is essential for learning content.

Based on this, the cognitive model of drawing construction was developed, which deals with the making of drawings and states that the information to be learned must be selected, organized and integrated in a mental model with prior knowledge having a significant influence on this process (Van Meter & Firetto, 2013). Afterwards, this resulting mental model must then be externalized, in other words, drawn.

The cognitive load theory deals with the load that occurs during learning (Chandler & Sweller, 1991). This means that the working memory has only a limited capacity and if it is overloaded, the process of learning can no longer be carried out properly. Furthermore, during learning, schemata are made in which the information is learned and stored. Cognitive load theory also deals with the characteristics of the content to be learned and the way it is presented, as it distinguishes between three different cognitive loads (Sweller et al., 1998). The intrinsic load is the load that arises from the difficulty and complexity of the information to be learned and is influenced by prior knowledge. The way the content is presented influences the extraneous load. The third and last cognitive load is the germane load. This arises from the learning-related load that is needed to learn the content. To prevent a cognitive overload the total cognitive load must not be exceeded. So, the intrinsic and extraneous load must be reduced to leave enough room to increase the germane load. This way the learner is supported in his learning process by having more capacity to concentrate on learning and not being overwhelmed by the presentation or complexity.

Not to be neglected is also the individual way how people learn information best. When students know their learning style, they can choose their appropriate learning method. For this purpose, a model of different learning styles has been designed, which distinguishes four styles. The VARK model distinguishes between visual, auditory, read/write and kinesthetic learners (Fleming & Mills, 1992). Visual learners prefer pictures, videos or diagrams, auditory learners prefer spoken content. Learners who primarily read or write learn well through texts or lists and kinesthetic learners need real-world opportunities whether through personal experiences or simulations.

It must also be considered how students pick up knowledge and how they perceive it. Constructivism holds that knowledge cannot be transferred but must instead be created by each individual using information from the objective reality (Bodner, 1986; Bodner & Orgill, 2007). As a result, each learner constructs their own subjective reality, which is also influenced by their individual prior knowledge (Bodner & Orgill, 2007). Therefore,

instead of trying to transfer the knowledge, teachers should provide guidance and thereby support the learning process (Bodner, 1986).

Fitting to this, the more active learners are with the content, the higher is the learning (Chi & Wylie, 2014). In this ICAP model, four different modes are distinguished, namely passive, active, constructive, and interactive. In the passive mode, there is no interaction other than receiving the information. In the active mode there is action or manipulation. In constructive mode the learner generates something, and interactive mode involves interactive behavior with others. Furthermore, generating information from one's own mind, such as creating a word from hints, was found to have an advantage over simply reading it (Slamecka & Graf, 1978). This positive effect is called generation effect and assumes that by generating independently a better memory is created because the cognitive effort is greater.

Based on these different theories, learning methods that are well presented and adapted to the students' prior knowledge, where they are actively involved in the acquisition of knowledge, seem to have a positive effect on learning. The generation of images is an interesting part of this.

1.3 Drawing to learn

It has been known for a long time that pictures can be recalled from memory better than words (Paivio et al., 1968). In addition, some effects are more likely to occur when the content being learned are pictures rather than words. The production effect, i.e. the better recall of produced contents, was demonstrated in a study to a greater extent for pictures than for words (Fawcett et al., 2012). Here the learned content was quietly mouthed. Even in elementary school, making drawings of the content of an informative text shows a greater effect on comprehension compared to writing about this content (Edens & Potter, 2003). But also older students benefit from drawings of content to be learned in the terms of a better learning outcome and a higher ability to accomplish transfer exercises resulting in a deeper understanding and better application of the learned knowledge (Leopold & Leutner, 2012). In addition to a better understanding, drawing also promotes memory for content. Items that are drawn are better remembered than those that are only written, which is referred to as the drawing effect (Wammes et al., 2016). Especially for complex

scientific texts in STEM domains, pictorial explanations seem to lead to a better understanding than those that are written (Bobek & Tversky, 2016).

Drawing is also used as a learning method in the medical field, among other things to teach students about musculoskeletal anatomy. It was found that drawing increased students' understanding in this area of medicine compared to those who did not draw (Joewono et al., 2018). In another study, students were able to increase their anatomical knowledge through drawing workshops, which was determined subjectively and objectively through anatomy testing (Borrelli et al., 2018). Drawing also has a positive impact in learning histological content when the microscopic images are drawn (Citation Rafi 2017). This knowledge is also retained longer by students, even for several weeks (Balemans et al., 2016).

In addition to better understanding and acquiring information, drawing has other benefits. Through drawings made by students, it is possible to determine their current level of knowledge and what assumptions they have about the questioned topic (Slominski et al., 2017). Furthermore, by actively participating in generating drawings, students are encouraged to recognize differences between their prior knowledge and the knowledge presented (Zhang & Linn, 2011). If misconceptions have occurred, for example about the size and configuration of anatomical structures, these can be well illustrated by drawings (Osório et al., 2013).

Not only drawing has advantages but also preparing for it without actually making a drawing improves remembering content more than preparing for writing (Wammes et al., 2018). So just thinking about what to draw and how to draw it has a positive impact on learning. It was also investigated how students feel when they do not draw themselves but are actively involved in the creation of a drawing on the blackboard by the teacher by labeling the structures and anticipating what will be drawn next. The students found it very useful, as it encouraged them to actively participate and made the lecture more varied (Nayak & Kodimajalu, 2010). Besides lectures, drawing is also used in dissections. When students draw the region, they are studying either before or after the dissection, it promotes the acquisition of knowledge and retention up to 7 weeks after the dissection. The time when they drew did not matter (Alsaid & Bertrand, 2016)

Other forms of implementing besides paper and blackboard were also used for drawing. Drawing the dural venous sinuses by painting them on a cap on each other's heads is shown to be an effective and well-received learning method for teaching this anatomical

content to students (Shaia & Elzie, 2019). Painting other body parts with the underlying anatomical structures or features was tested in another study. There it was shown that students found this learning method useful and enjoyable (McMenamin, 2008).

Another study examined the sketching of content from an informative text. It was compared with the performance of self-explanations, it was compared with the performance of self-explanations, where the participants of this study had to write down an explanation about the main ideas of the text, with which they should be able to reproduce the explained process. This study showed that sketching has an advantage in learning compared to self-explanation, but only if both learning methods are performed with high quality (Scheiter et al., 2017). In this case, the quality was measured by the number of major idea units mentioned or drawn. This means that the quality of the implementation of the learning methods has an influence on their effect.

Of course, in addition to the objective benefits of drawing as a learning method, students' opinions count as to whether they find it an effective learning method for them. For this purpose, dental students, among others, were surveyed who find drawing anatomical content important and very useful as a learning aid and for a deeper understanding of the subject (Alhamdani & Hatem, 2017). Furthermore, it increases the students' confidence to reproduce the drawn content, which may be important for the acceptability of this learning method by the students (Gheysens et al., 2017). When the students are supported by the teacher drawing and they are supposed to draw at the same time, the students feel that it is easy to learn the drawn anatomical contents and that this is a good and attractive learning method (Noorafshan et al., 2014).

1.4 Use of technology in education

In addition to new learning methods, technology has also become widespread among students. Many students use mobile devices inside the classroom, for example to take notes or for learning applications, but they are also used outside the classroom, for instance for social networking. (Foti & Mendez, 2014). Medical students also use digital resources, especially just before exams, with many not even reading the paper-based course textbook (Scott et al., 2018). These resources can be lecture audio recordings, tutorials, or educational videos. Mobile devices also seem to increase students' perceived

efficiency, making them feel that the hours they spent working were more efficient. (Chase et al., 2018).

One possible method to incorporate new technology into the classroom is to create animated PowerPoint presentations and work through them in an interactive way with students. For instance, drawings can be shown while they are also provided to the students as a handout and the assignment is for the students to label these drawings during the presentation. This way of teaching anatomical content is very well accepted by medical students (Carmichael & Pawlina, 2000). Anatomy drawing screencasts, so in this case, a video which shows a drawing of an anatomical feature and includes an audio description of the specific structure, are also very popular and are used very flexibly by students (Pickering, 2015). This allows students to use this learning device at a time that is appropriate for their own learning preferences. They also show an increase in learning compared to traditional paper-based learning methods like a textbook (Pickering, 2017). Interest in other digital resources such as podcasts, blogs or social networking sites is very high in the medical field but there is a need for training in the use of these technologies if they were to be adopted as learning materials (Sandars & Schroter, 2008).

Augmented reality (AR), so when the real world is supplemented by digital elements, is also a possibility to impart knowledge with technical help. One study examined the impact of AR on student learning and found that students who learned with AR had an advantage in understanding and test scores over those who learned with traditional methods (Gonzalez et al., 2020). Here, students were able to explore the human heart with various features, such as zooming in, changing perspective, and adjusting the speed of the heart's contractions. A magic mirror, also a type of AR that uses a camera to view one's own body with its anatomical structures, was tested in a study in Munich. It was found that students found this interactive learning tool useful for understanding anatomical content and perceived the three-dimensionality and interactivity in particular as positive (Kugelmann et al., 2018).

There are many ways to incorporate new technologies into education. In this thesis, however, we will focus on tablets. A tablet is a portable computer with a touch screen. Tablets are already being used in the classroom for different activities and are receiving positive feedback from students for their usefulness in learning (Miller, 2012). Applications on the tablet, such as an anatomy atlas with interactive 3D models, can support students to learn anatomical content and are even able to help students improve

their grade (Chakraborty & Cooperstein, 2018). Another way to use the tablet, which is also used by many students, is to take notes from lectures (Lazarus et al., 2017).

Combining new learning media with traditional ones opens new possibilities. When a tablet is used to support medical students during dissection with a dissection manual that includes instructions, images and videos, it seems to have a positive impact on learning behavior, as students are very active and productive during dissection (Mayfield et al., 2013). Even anatomy assessments, like naming anatomical structures which were marked on wet specimen, can be done using tablets, with students performing better than traditional assessments and finding it useful (Polak et al., 2021). The tablet can also be used as a helping tool in the clinical setting, supporting students in their self-regulatory learning and quickly accessing resources (Alegria et al., 2014).

1.5 Research objectives

The aim of this work is to compare different learning methods to learn anatomy and to find out if there is a difference in learning outcome. This will contribute to the field of educational research and teaching research in medicine.

In contrast to different drawing implementation techniques, research on drawing as a learning strategy has primarily been conducted on paper and in comparison to other non-digital learning strategies, like writing (Leopold & Leutner, 2012). Even drawing on a tablet is investigated in one study, but in contrast to typing on the tablet keyboard. (van der Meer & van der Weel, 2017). The various surfaces also have already been investigated to see if they affect performance, but only handwriting and not the drawing were looked at the time. (Gerth et al., 2016). However, there is a meta-analysis that examined the differences between technology-based drawing and traditional paper-and-pencil drawing, but it did not reveal any advantages for the former (Cromley et al., 2020). So, since there is a research gap in this area, the purpose of this thesis is to fill it by examining the merits of tablet-based learning techniques for anatomy versus those that rely on paper-based learning (see Styn et al., 2023).

To accomplish this purpose, a study was conducted with medical students comparing drawing on a tablet to drawing on paper and writing summaries on paper. Anatomy knowledge tests were used to assess student learning outcome and its sustainability. It was also investigated whether the quality of the implementation of the learning methods

had an influence on the effect of these learning methods on learning outcome. The exact research questions were (see Styn et al., 2023):

1. Does repetitive drawing with an interactive drawing app on a tablet lead to better knowledge of anatomical structures as well as better skills regarding the application of anatomical knowledge compared to paper-based learning methods (drawing on paper, writing summaries on paper)?
2. Is there a difference between the methods with regard to the sustainability of the learning outcome?
3. Does the learning outcome of learning by drawing depend on the quality of the drawings made?

The purpose of this research is to investigate the usefulness of the new learning method, so that students can be supported in their learning process by new possibilities (see Styn et al., 2023).

2 Material and methods

2.1 Ethical approval

Ethical approval for the conduct of the study was obtained from the ethics committee at Ludwig-Maximilians-Universität München (no. 20-145).

All participants gave written consent to the collection of their data in pseudonymized form and publication of these data in anonymized form prior to the study. They were informed about the study procedure, risks, their rights, and obligations. The participants could withdraw their consent at any time without any disadvantage to them. All participants took part in the study voluntarily and received an expense allowance of 50 euros.

2.2 Design and participants

The prospective experimental study was controlled randomized with a parallel distribution. An a priori power analysis was conducted with alpha = .05, beta = .95 and an expected effect size of Cohen's f = .25. It suggested that a total of 66 participants was required. For safety, 105 participants were recruited (see Styn et al., 2023).

A total of 105 medical students from the Ludwig-Maximilians-Universität München and Technical University in Munich participated in the study. The prerequisite to participate in the study was that medical students must have already successfully completed the gross anatomy course. In Munich, this course is usually held in the first and second semesters. To reach the students, attention was drawn to the study on social media. E-mails were sent to the various semesters by university staff and the project was presented in an anatomy lecture. An informational flyer for the study could be found in various university buildings (see Styn et al., 2023).

2.3 Knowledge tests and questionnaires

During the study, the participants were asked to answer various knowledge tests and a questionnaire. These were a questionnaire on demographic data and tablet and drawing

behavior and three different anatomy knowledge tests. All tests were created independently in the working group. All data were collected in pseudonymized form.

2.3.1 Demographic data

The demographic data questionnaire included five questions about the participants, namely age, gender, the semester they are in, the semester in which they took the gross anatomy course, and whether they own or have regular access to a tablet. Furthermore, there were four more questions about the participants tablet and drawing behavior. Here, the term "tablet" was defined as a tablet or tablet PC with a touchscreen and drawing on any surface was accepted. However, mind maps, flowcharts and the like were excluded from the term "drawing". They were asked how often they use a tablet in everyday life and during learning and how often they draw in their free time and during learning. The answer options ranged from "daily" to "two to three times a week", "two to three times a month" and "less than once a month" to "never" (Appendix A) (see Styn et al., 2023).

2.3.2 Anatomy

The anatomy knowledge tests were three different tests with different questions which were all based on the learning text. The first test (pre-test) consisted of 20 questions with one point per question. This test determined the prior anatomical knowledge of the study topic. The internal consistency as a measure of the reliability of the test was determined by Cronbach's alpha (α = .71). The second test (post-test) contained 24 questions and the students could get a total of 30 points, as there were questions that needed more answers than one and therefore, they could get more points. This test measured the learning outcome, i.e., the anatomical knowledge and took place immediately after the learning phase. Again, the internal consistency of the tests was determined by Cronbach's alpha (α = .77). The third test (delayed post-test) consisted of 28 questions and 30 points. This test took place after 4-6- weeks during the second term. It also measured the learning outcome. Again, the internal consistency of the tests was determined by Cronbach's alpha (α = .72). To make the tests results of the knowledge tests more comparable they were z-standardized (see Styn et al., 2023).

The tests distinguished between several types of questions. In addition to multiple-choice questions, there were open-ended questions. In the case of the multiple-choice questions,

only one answer was correct. A distinction was made between easy and difficult questions and between questions that asked for factual knowledge and those that asked for transfer knowledge. Furthermore, the questions were also divided thematically, depending on which nerve of the upper extremity they dealt with. Besides purely written questions, there were questions with pictures from an anatomy atlas or self-made pictures (Appendix B-D) (see Styn et al., 2023).

2.3.3 Quality of strategy implementation

The quality of strategy implementation was measured by assessing the quality of the drawings and summaries produced. This was done using a scoring sheet that evaluated the drawings and summaries based on completeness and correctness. Table 1 shows an example of this scoring sheets (see Styn et al., 2023).

Table 1

Scoring sheet for drawings and summaries

Drawings	**Completeness**	**Correctness**	**Score (total)**
N. radialis 4 skeleton	- R. profundus **2 P** - Rr. musculares **2 P** - M. supinator **2 P** - Supinator tunnel **2 P**	- all structures correctly labeled (R. profundus, Rr. musculares, M. supinator, Supinator tunnel) **4 P** - R. profundus **through** M. supinator in the **supinator tunnel**, then releases **Rr. musculares 3 P** - M. supinator from **epicondylus lateralis humeri** (and olecranon) to **radius 2 P**	**17 P**
Summaries	**Completeness (mentioned)**	**Correctness**	**Score (total)**

N. radialis 4 skeleton	- R. profundus **1 P** - Rr. musculares **1 P** - M. supinator **1 P** - Supinator tunnel **1 P**	- all structures correctly mentioned (R. profundus, Rr. musculares, M. supinator, Supinator tunnel) **4 P** - R. profundus **through** M. supinator in the **supinator tunnel**, then releases **Rr. musculares 3 P** - M. supinator from **epicondylus lateralis humeri** (and olecranon) to **radius 2 P**	**13 P**

Source: *Styn et al. (2023)*

The course and the sensitive supplying areas were divided into criteria and one point was awarded per criterion. In total, a maximum score of 299 was achieved for the drawings and 248 for the summaries. The difference between the scores is due to the fact that the drawings had to be labeled, which was not the case for the summaries. The quality was recorded before the participants looked at the solution and had the opportunity to make corrections and afterwards. Again, the reliability was determined with the help of Cronbach's alpha (α = .89 for drawings and α = .95 for summaries). Similar to the results of the knowledge tests, the strategy quality scores were z-standardized to make them more comparable. To verify the evaluation of the quality of the drawings and summaries for objectivity, two different examiners evaluated them. The interrater-reliability was determined by intra-class-coefficient (ICC) and was very good with ICCs > .80 for each individual criterion (see Styn et al., 2023).

2.4 Materials

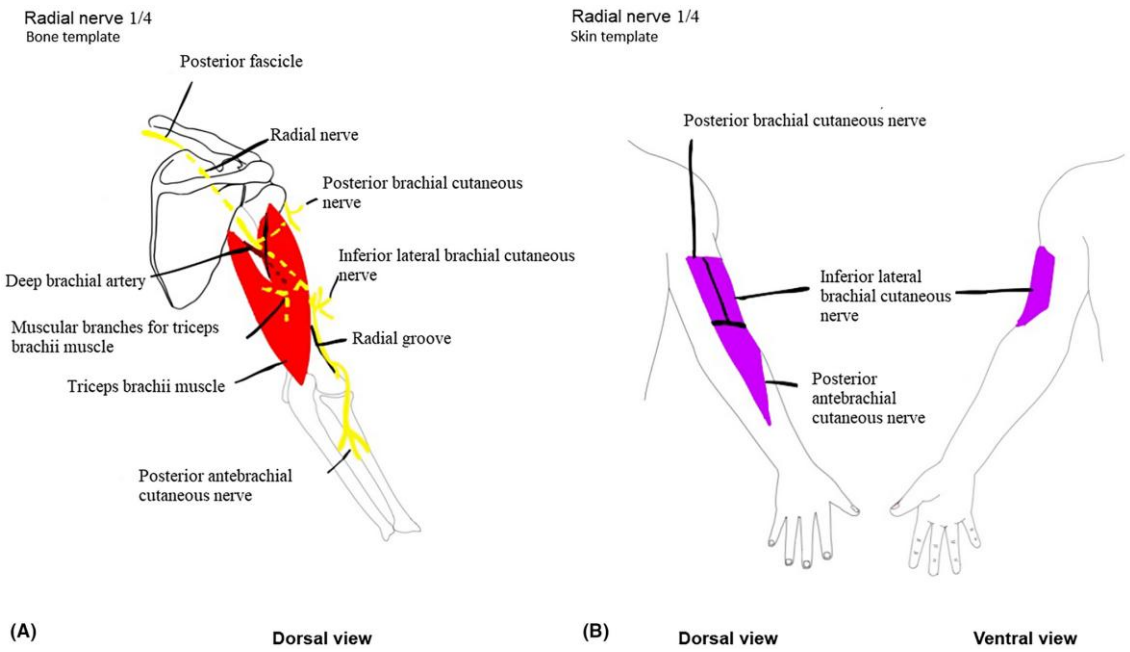
2.4.1 Learning script

To compare the learning methods a learning phase was developed. The main component of this learning phase was a learning script developed by the working group. Each learning method had its own script. These scripts contained a learning text from an

anatomy textbook (Waschke et al., 2015), which was divided into sections. The learning text covered the two nerves of the upper extremity, radial nerve, and median nerve, in their function, topography, and their sensitive supply areas. There were four sections per nerve. The learning text described the course of these nerves with important structures, like muscles and arteries. The important structures were highlighted in bold type. For each of these sections, matching pictures from an anatomy atlas (Schünke et al., 2018) and a muscle table for the respective muscles mentioned in the section were provided. After each section, participants were asked to draw or summarize the information from the previously read section using their assigned learning method. To do this, the next page provided a brief explanation of how they should construct a drawing or summary and a list of the number of structures to draw or mention. So, the structures were not mentioned by name, but only the number was specified. The different structures had different colors for the groups that drew them. Nerves were to be shown in yellow, arteries in dark red, muscles in light red, bone structures in black, and sensitive supply areas in purple. In addition, the groups that were to draw were given a bone template to draw the course of the nerve with its important structures and a skin template to draw the sensitive supply area (Figure 1) (see Styn et al., 2023).

Figure 1

Solution drawings from drawing/tablet group, bone, and skin templet.



Source: Styn et al. (2023)

The group that was to summarize was given only a white sheet of paper and was to mark the two different subjects with different colors i.e., the course of the nerve with its important structures was to be black and the information about the sensitive supply area was to be marked in red. To be able to reuse the scripts, white sheets were inserted into the script for drawing or summarizing on which the participants could work. Drawing and summarizing were to take place without a view of the learning text or pictures, in other words, from memory. The group that drew on the tablet had to switch from the script to the tablet for this. After the participants had finished drawing or summarizing, the groups that had worked in the script could simply unfold the solution and compare their own work with it. The group with the tablet could look at the solution by clicking a button on the tablet. The solutions were drawings or summaries made by the work group. After the students had compared sufficiently, the page was closed again, or the solution was not displayed again by a click on the button and the participants could improve their own work if they had forgotten something or made mistakes. Like the first attempt, the correcting was again done from memory. The solution could also only be viewed once. The participants were asked to make the corrections with a different color, i.e., green, so that it was clear what was changed or added afterwards after viewing the solution. After that, participants could turn one page, or the group with the tablet could return to the script and turn one page to the next section. The participants repeated this process with each section until all had been processed (see Styn et al., 2023).

For the participants to become better acquainted with the learning phase and the script before focusing on learning, this process was practiced beforehand using a practice example. This example was also in the script but was not included in the evaluation because it dealt with the lower extremity femoral nerve. In addition, the example was accompanied by videos that described and showed the exact procedure of the learning phase. These videos were also made by the working group. Each learning method had its own videos (see Styn et al., 2023).

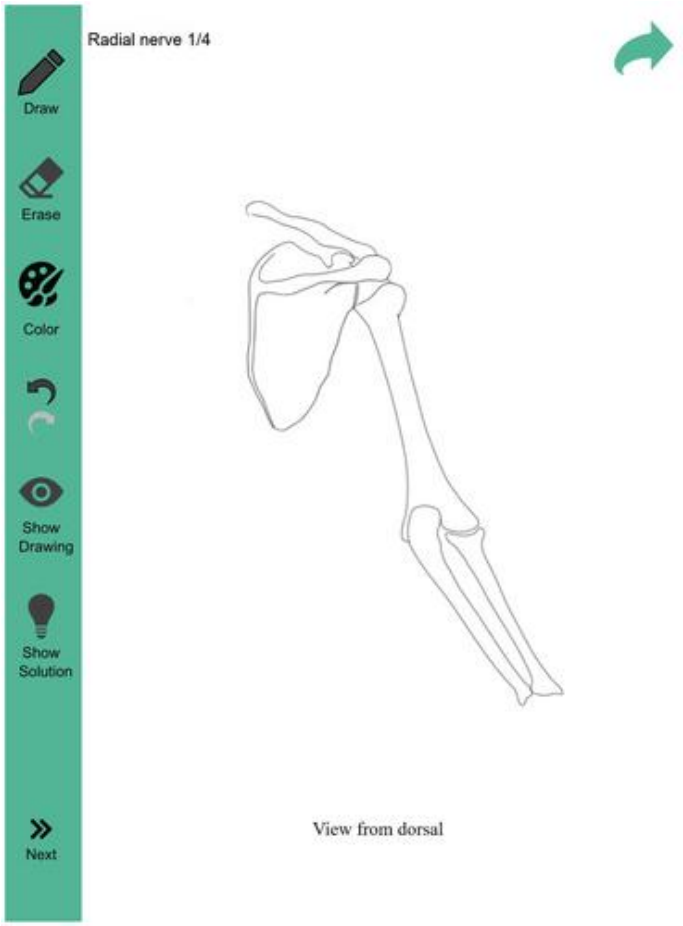
2.4.2 Anatomy app

For the group that drew on tablets, the workgroup developed a webapp, which the participants could use via the browser of a tablet. In this study iPads (6th Generation, 32GB model) from Apple© with iPadOS 13.6 were used. The app was structured as

follows: First there was a start page where the participants had to enter their pseudo code and decide if they were left or right-handed, as the app would adapt to that. In addition, they could choose whether to draw on the tablet with their finger or with a pen. In this study, additional to the tablet, students were given a digital pen, a Logitech© crayon (914-000034), that could be used to draw on the tablet via Bluetooth. Clicking on "next" took them to the next page. There the participants saw an instruction that they should not scroll any further yet. This page was repeated before each drawing template, since the test participants were supposed to read the learning text in the script during this time without already seeing the template. On the next page the first template was shown (Figure 2) (see Styn et al., 2023).

Figure 2

Screenshot from the app, bone templet and buttons



Source: Styn et al. (2023)

By clicking on an arrow at the top of the screen, the apps switched to the skin template. On the opposite side of the drawing hand, there were different symbols for settings for drawing. The participants could set the pen thickness and color, use the eraser, and jump back and forth in their steps. Also, they could have their own drawing fade out and fade back in. A light bulb icon marked the display of the solution drawing. This symbol could be clicked only once. The participants could choose between two variants of the solution display. Once the solution drawing was displayed next to the own drawing and the other variant was that solution drawing is superimposed onto the students drawing. To switch between these two variants, they simply had to turn the tablet horizontally or vertically (see Styn et al., 2023).

2.5 Study implementation

2.5.1 First appointment

The study was divided into two dates with four to six weeks between them. Participants were randomly assigned to one of the three groups (drawing on tablet, drawing on paper, summarize on paper; $n = 35$ students per group). During the first appointment, the study was presented to the participants. It was explained how the study is conducted and further information regarding the conditions of participation and the rights of the participants were given. All information was available in written form. They signed the consent form, one copy of which they could take with them.

Next, the demographic questionnaire and the anatomy pre-test were completed. For the pre-test, participants had 30 minutes. Next, the learning phase was explained using the exercise example and the explanatory videos via a projector. The participants were able to use the script and pens or the tablet with pen. When all participants had finished the example and understood the process, a short break of five minutes was taken. During this time, the participants were not allowed to talk to each other about the study topic. After the break, the learning phase began, in which the complete script with the eight sections was worked through with the help of the assigned learning method. The participants had a total of 105 minutes for this. They were able to decide for themselves how much time they wanted to spend on each section. In between, the remaining time was communicated by the study leader. After the learning phase, there was another break of five to ten minutes. After that, the students had ten minutes to look at their own drawings or summaries again by removing all templates from the script or displaying them on the

tablet. They were not allowed to look at the learning text or images again. After the review phase, the participants completed the anatomy post-test. They had 36 minutes for the test.

2.5.2 Second appointment

After four to six weeks, the second appointment took place. They completed the anatomy delayed post-test. They had 42 minutes for the test. The participants used their own pseudo code, which they had created during the first appointment, so that the knowledge test could be assigned to the remaining documents from the first appointment.

2.6 Statistical data analysis

2.6.1 Statistical tests

First, analyses were performed for the descriptive statistics of the knowledge tests, the demographic questionnaire, and the quality of strategy implementation. These included the mean, median, minimum, and maximum, and standard deviation. In addition, the normal distribution was examined by skewness and kurtosis and the Kolmogorov-Smirnov normality test and Shapiro-Wilk test. To examine whether the items collected from the demographic questionnaire were also equally distributed between the groups with no significant difference, ANOVAs were performed (see Styn et al., 2023).

Next, analyses were then performed for the inferential statistics. This was guided by the research questions. To detect a difference between the different learning methods in terms of learning outcome, an ANCOVA was conducted. The learning method was used as a between-subjects factor, the test results of the anatomy post-test as the dependent variable, and the result of the anatomy pre-test, i.e., the prior knowledge of the participants, as the covariate. The same analysis was also performed to test the sustainability of this learning outcome. Here, only the result of the anatomy delayed post-test was the dependent variable (see Styn et al., 2023).

To investigate the relationship between the quality of strategy implementation and the learning outcome, immediate and delayed, an ANOVA was first performed to check if the quality differed between the groups. Then, a Pearson correlation was used to examine whether there was a relationship between quality of strategy implementation and learning outcome. In addition, a partial correlation was used to rule out the effect of prior

knowledge (participants with higher pre-test scores produce drawings or summaries with higher quality). The last step was to investigate whether quality of strategy implementation moderates the effect of the learning method on learning outcome. For this purpose, regression analysis was used (see Styn et al., 2023).

The significance level for the performed analyses was set at $\alpha < .05$. The analyses were performed using IBM SPSS Statistics for Windows, version 26 (IBM Corp., Armonk, NY) (Styn et al., 2023).

3 Results

Naturally, the result section contains several identical results reported in Styn et al., 2023. However, this dissertation provides more in detail results, substantially surpassing the reporting in the published paper.

3.1 Descriptive statistics

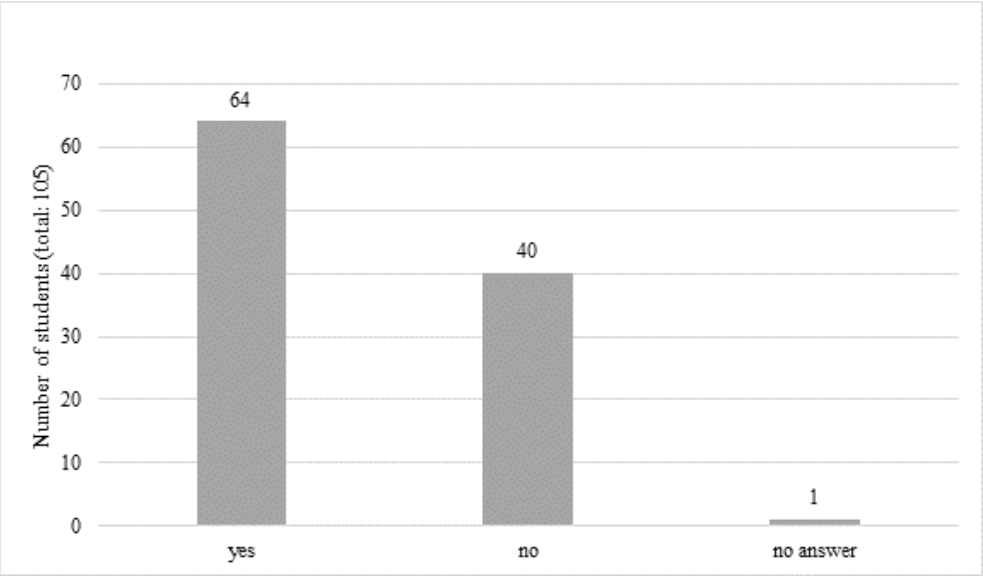
3.1.1 Demographic data

A total of 105 students participated in the study, with no one dropping out in between. The mean age of participants was 23.18 years (*SD* ± 3.22) with an age range of 19 to 35 years. 78 participants (74.3%) were female and 26 (24.8%) were male. One participant did not indicate his gender. On average, participants were in their sixth semester (5.94, *SD* ± 2.55) with participants from the 2nd to 14th semester and all but two had taken the anatomy course during the first and second semesters. These two also took the course in part during the third semester (see Styn et al., 2023).

The demographic questionnaire was also used to collect information about participants' tablet and drawing behavior. This showed that the majority (*n* = 64, 61%) owns a tablet or has regular access to it (Figure 3) (see Styn et al., 2023).

Figure 3

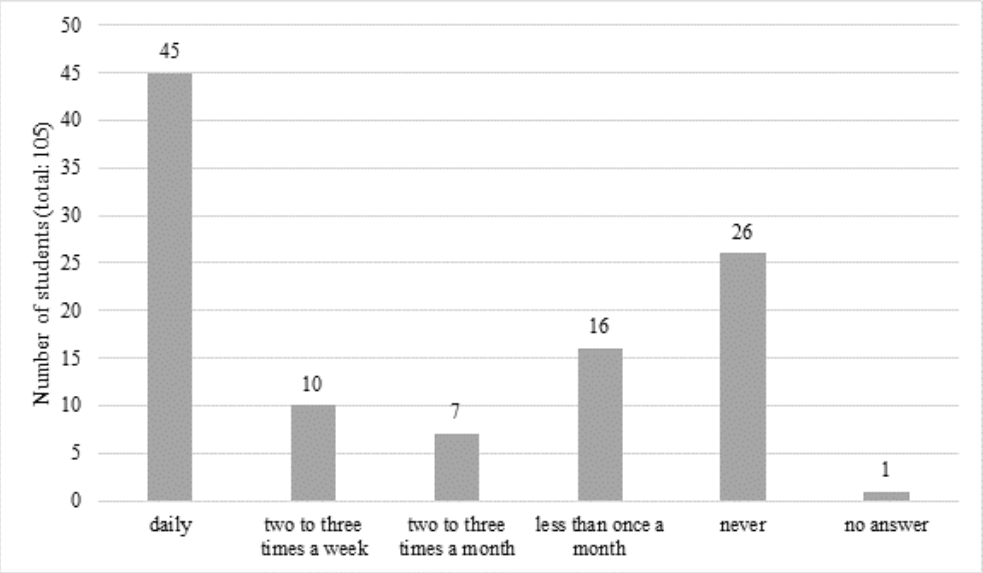
Demographic questionnaire, ownership of or access to a tablet



When asked how often they use this tablet in their daily lives, most students (*n* = 45, 42.9%) responded that they use it daily (Figure 4) (see Styn et al., 2023).

Figure 4

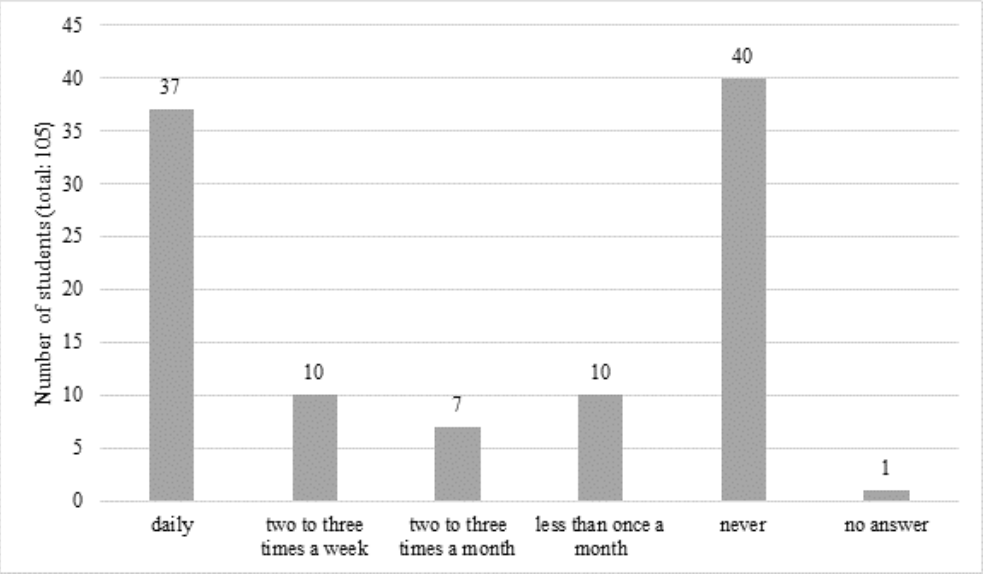
Demographic questionnaire, use of a tablet in everyday life



The situation was different for learning with the tablet, as most of the respondents (n = 40, 38.1%) never learn with a tablet (Figure 5). On the other hand, some students (n = 37, 35.2%) also reported learning with a tablet on a daily basis (see Styn et al., 2023).

Figure 5

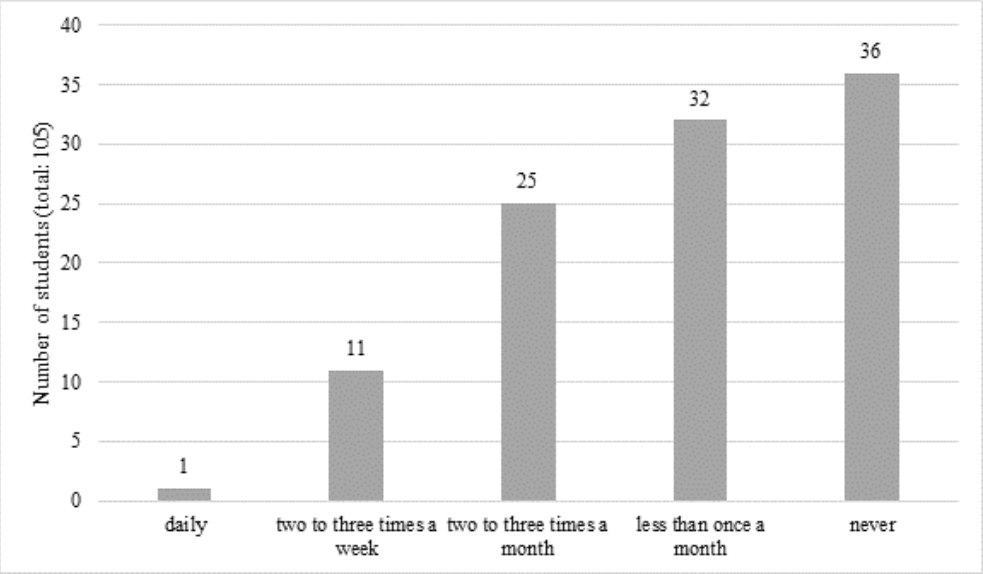
Demographic questionnaire, learning with a tablet



Drawing was less common among the participants. The majority (n = 36, 34.3%) never made drawings in their free time with only one person doing so daily (Figure 6) (see Styn et al., 2023).

Figure 6

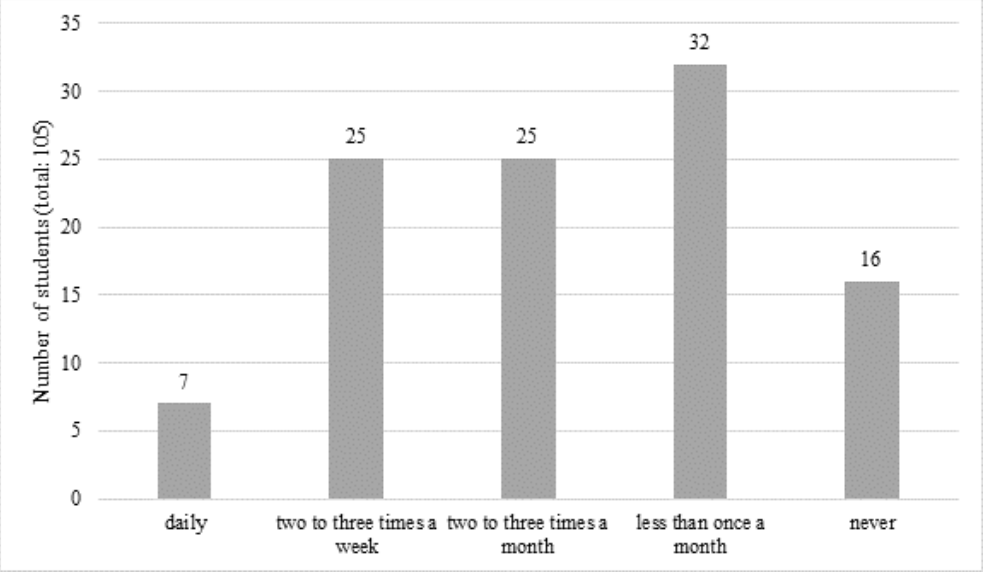
Demographic questionnaire, drawing in free time



Less than once a month, most participants (n = 32, 30.5%) drew to learn (Figure 7), although it was more common than drawing in their free time (see Styn et al., 2023).

Figure 7

Demographic questionnaire, learning by drawing



Multiple ANOVAs were used to check whether the above items were equally distributed in the three different groups. It was found that there was no significant difference between the groups (Table 2).

Table 2

ANOVAs, Differences in the distribution of the demographic items between the groups

	df	***F***	***p***
Age	2	1.605	.206
Gender	2	2.441	.092
Semester	2	1.247	.292
Ownership of or access to a tablet	2	1.449	.240
Use of tablet in everyday life	2	1.219	.300
Learning with a tablet	2	1.546	.218
Drawing in free time	2	.724	.667
Learning by drawing	2	1.453	.239

3.1.2 Anatomy knowledge tests

This section discusses the results of all participants in the anatomy knowledge tests. As can be seen in Figure 8 the participants performed best on average in the post-test, which took place immediately after the learning phase. They performed worst in the pre-test, which they could only answer with the prior knowledge they had acquired through the anatomy course and independent learning. Mean values and standard deviations of the knowledge tests are shown in Table 3 (see Styn et al., 2023).

Figure 8

Mean values of the results of the anatomy knowledge tests

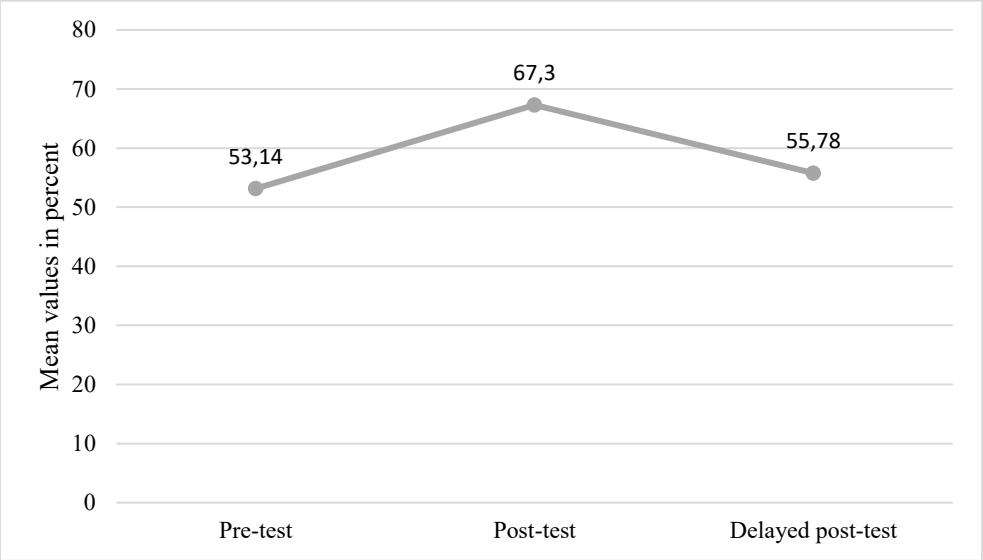


Table 3

Mean values (percentages) and standard deviation of the anatomical knowledge tests

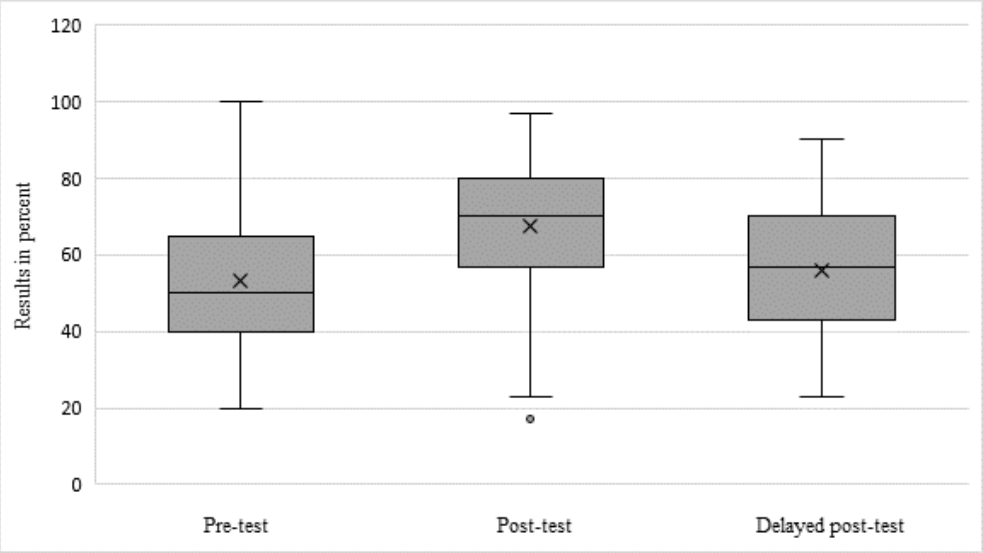
	Drawing on tablet Mean % (±SD)	**Drawing on paper Mean % (±SD)**	**Writing summaries Mean % (±SD)**
Pre-test	51.86 (± 17.45)	56.57 (± 18.70)	51.00 (± 18.94)
Post-test	65.62 (± 16.74)	68.48 (± 13.63)	67.81 (± 18.92)
Delayed post-test	54.95 (± 14.78)	56.00 (± 14.28)	56.38 (± 17.83)

Source: Styn et al. (2023)

Figure 9 also illustrates this result. Furthermore, it can be seen here that the distribution of the data in the pre-test was greater than in the other two. In addition, the interquartile range of the delayed post-test is the largest, indicating a wide dispersion of the data.

Figure 9

Boxplots of the results of the anatomy knowledge tests



3.1.3 Quality of strategy implementation

The quality of the drawings and summaries made by the participants was evaluated twice. Once the quality was measured after the test persons had looked at the learning text and the corresponding pictures once and then again after they could look at the solution and make corrections to their own work. As can be seen in Figure 10, the quality of the drawings and summaries made after they had the opportunity to make corrections was higher than before. Mean values and standard deviations of the quality are shown in Table 4 (see Styn et al., 2023).

Figure 10

Mean values of quality of drawings and summaries before and after correction

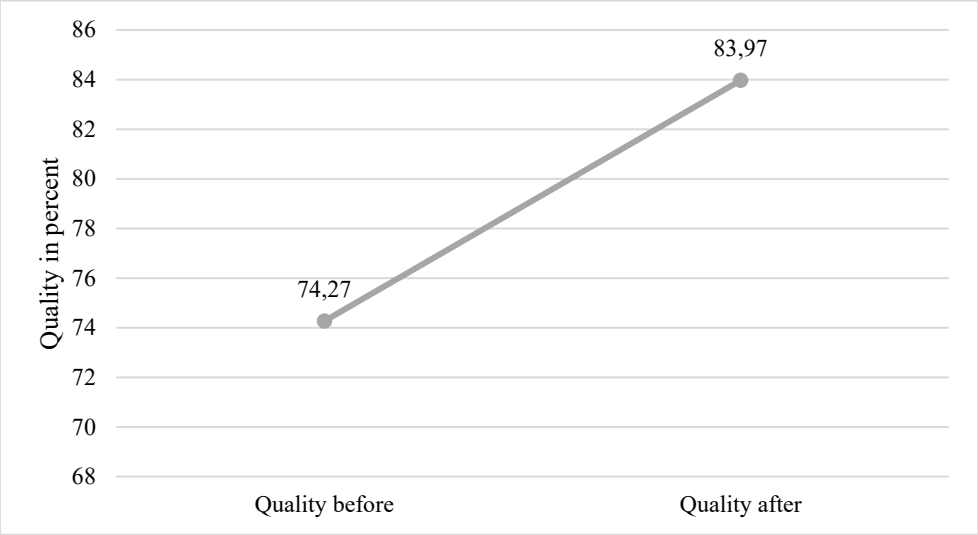


Table 4

Means values (percentages) and standard deviation of quality of drawings and summaries before and after correction

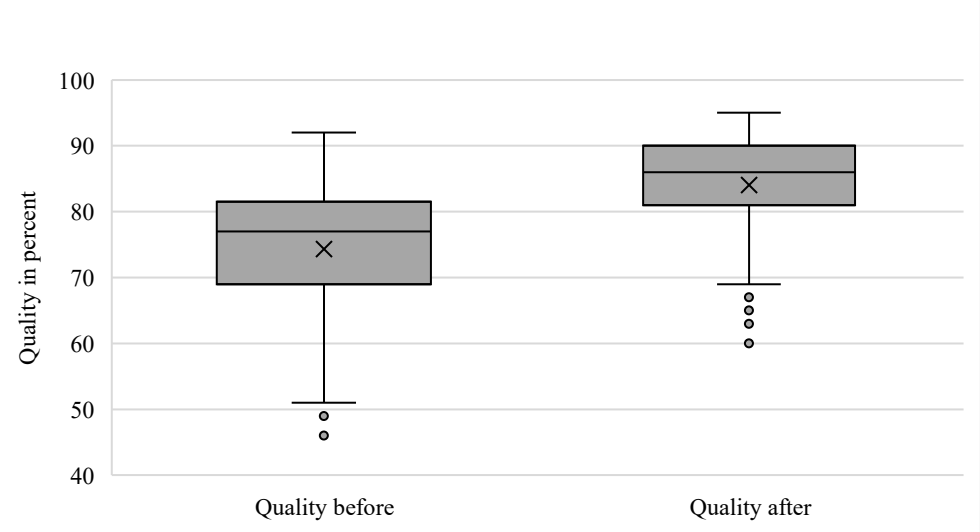
	Drawing on tablet Mean % (±SD)	**Drawing on paper Mean % (±SD)**	**Writing summaries Mean % (±SD)**
Quality of strategy implementation (before correction)	72.19 (± 9.48)	73.53 (± 9.29)	77.07 (± 12.19)
Quality of strategy implementation (after correction)	82.63 (± 6.54)	84.54 (± 6.48)	84.76 (± 9.60)

Source: Styn et al. (2023)

The distribution of the data and the interquartile range was larger for the quality before the corrections than for the quality after, as can be seen in Figure 11. There were a few outliers for both.

Figure 11

Boxplots of quality of drawings and summaries before and after correction



3.2 Learning outcome

The first research question addressed whether using a tablet to make drawings achieves better learning outcome than paper-based learning methods. A distinction was made between a better knowledge of anatomical structures, which was tested by factual questions, and a better skill in applying anatomical knowledge, which was tested by transfer questions. To answer the question, an ANCOVA was performed using the learning method as a between-subjects factor. The results of the anatomy post-test were the dependent variable, and the results of the anatomy pre-test were the covariate, as they represent the prior knowledge of the participants. There were no significant differences between the groups for either the total scores in the post-test or for the split between factual and transfer questions (Table 5) (see Styn et al., 2023).

Table 5

ANCOVA, difference of learning outcome between groups

	df	*F*	*p*	η^2
All questions	2	.356	.701	.007
Factual questions	2	.711	.494	.014
Transfer questions	2	.357	.701	.007

Source: modified Styn et al. (2023)

3.3 Sustainability of learning outcome

The second research question was to examine the difference between learning methods in terms of sustainability of learning outcome. For this purpose, an ANCOVA was also performed as explained above, but this time the results of the anatomy delayed post-test were the dependent variable. Again, there was no significant difference between the three groups regarding the sustainability of the learning outcome (Table 3) (see Styn et al., 2023).

Table 6

ANCOVA, difference of sustainability of learning outcome between groups

	df	*F*	*p*	η^2
All questions	2	0.271	.763	.005

Source: modified Styn et al. (2023)

3.4 Moderation of learning outcome through quality of strategy implementation

The third research question was whether learning outcome in learning by drawing depends on the quality of the drawings made. To answer this question, a three-stage analysis was conducted. First, an ANOVA was used to examine if quality of strategy implementation differed between groups. As can be seen in Table 7, there was no significant difference between the groups for either quality before corrections or quality after (see Styn et al., 2023).

Table 7

ANOVA, difference of quality of strategy implementation between groups

	df	*F*	*p*	*η²*
Quality before	2	2.056	.133	.039
Quality after	2	0.815	.445	.016

Source: modified Styn et al. (2023)

The second step was to examine whether quality before correction was related to learning outcome. For this, first a Pearson correlation was used and then a partial correlation to factor out the effect of prior knowledge, i.e. the results from the anatomy pre-test. Table 8 shows the results of these analyses for the group that drew on paper. It can be seen that there was a positive significant correlation of medium strength for the anatomy post-test and the quality before correction and this remained even when the effect of prior knowledge was excluded. For the group that had written summaries on paper, there was a significant positive correlation of strong strength also for the anatomy post-test but also for the delayed post-test (Table 9). Likewise for the group that made drawings on the tablet (Table 10). So, students who created high quality drawings or summaries also performed better on the post-tests, although prior knowledge was not relevant (see Styn et al., 2023).

Table 8

Pearson correlation and partial correlation between quality of strategy implementation and learning outcome in the drawing group

		r	*p*
	Post-test	.445	.007
	Delayed post-test	-.193	.268
With control variable	**Post-test**	.408	.017
	Delayed post-test	-.322	.063

Note: Anatomy pre-test as control variable
Source: modified Styn et al. (2023)

Table 9

Pearson correlation and partial correlation between quality of strategy implementation and learning outcome in the summary group

		r	*p*
	Post-test	.777	<.001
	Delayed post-test	.554	<.001
With control variable	**Post-test**	.736	<.001
	Delayed post-test	.448	.008

Note: Anatomy pre-test as control variable
Source: modified Styn et al. (2023)

Table 10

Pearson correlation and partial correlation between quality of strategy implementation and learning outcome in the tablet group

		r	*p*
	Post-test	.613	<.001
	Delayed post-test	.471	.004
With control variable	**Post-test**	.541	<.001
	Delayed post-test	.431	.011

Note: Anatomy pre-test as control variable
Source: modified Styn et al. (2023)

As a final step, we tested whether quality of strategy implementation moderates the effect of the learning method on learning outcome. For this purpose, regression analyses and simple slope analyses were performed when comparing two learning methods. Two dummy variables were created which each compared two learning methods. Dummy variable 1 represented the comparison between the drawing group (coded -1) and the summary group (coded + 1). Dummy variable 2 represented the comparison between the drawing group (coded – 1) and the tablet group (coded + 1). In the regression analysis, the dummy code, the quality of strategy implementation, and the interaction between the dummy code and quality were entered ad predictors and regressed onto one of the two post-test scores. When significant interactions were observed and thus quality could be assumed to moderate differences between groups, simple slope analyses were performed.

These were performed at - 1 standard deviation (SD) and + 1 SD relative to the mean of the continuous variable (Aiken et al., 1991), so the effect of the learning methods could be assessed at different levels of quality whereby low quality of strategy implementation is measured at - 1 SD relative to the mean of the continuous variable and high quality at + 1 SD (see Styn et al., 2023).

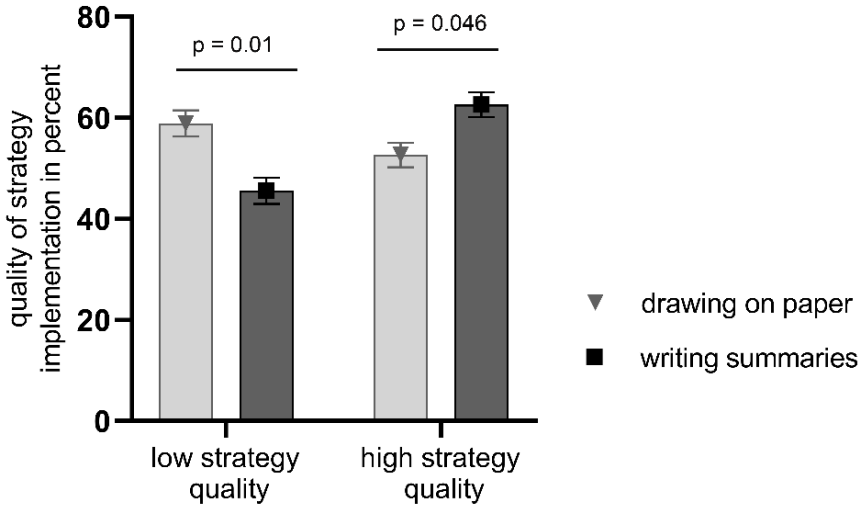
In relation to dummy variable 1, the comparison between the drawing group vs. the summary group, both the immediate post-test, $R^2 = .47$, $F(3,69) = 19.14$, $p < .001$, and the delayed post-test, $R^2 = .20$, $F(3,69) = 5.56$, $p = .002$ showed significant results for the overall regression model (see Styn et al., 2023).

Regarding the post-test, there was no effect of learning method, *Beta* = -2.27, β = -.14, $p = .13$, and no reliable interaction with the quality of strategy implementation was found, *Beta* = 2.90, β = .18, $p = .056$. As the correlational analyses had already shown, the better students had implemented one of the learning methods, the better their learning outcome was in the first post-test, *Beta* = 9.77, β = .62, $p < .001$ (see Styn et al., 2023).

In relation to the delayed post-test, a rather different picture was revealed: There was no impact of either the learning method, *Beta* = -0.84, β = -.05, $p = .64$, or the quality of strategy implementation, *Beta* = 2.71, $\beta = .18$, $p = .14$. However, there was significant interaction, *Beta* = 5.81, $\beta = .37$, $p = .002$. This interaction was resolved by simple slope analyses conducted at - 1 SD and + 1 SD of the continuous moderator strategy quality: For students that had implemented their specific strategy with low quality, drawing on paper ($M = 58.89$) was more effective than writing summaries ($M = 45.59$), *Beta* = -6.65, $\beta = -.42$, $p = .01$. On the other hand, for those who implemented the strategy with high quality, writing summaries ($M = 62.62$) resulted in better test performance than drawing on paper ($M = 52.67$), *Beta* = 4.98, $\beta = .31$, $p = .046$ (Figure 12) (see Styn et al., 2023).

Figure 12

Quality of drawings and summaries as a measurement for quality of strategy implementation



Note: Error bars represent standard errors.
Source: Styn et al. (2023)

Drawing on paper, was effective regardless of how well a strategy was implemented, whereas writing summaries required students to use the method effectively and produce summaries of higher quality in order to achieve high learning outcomes (see Styn et al., 2023).

In relation to dummy variable 2 so, the comparison between drawing on paper vs. on tablet, both the immediate post-test, $R^2 = .31$, $F(3,69) = 9.96$, $p < .001$, and the delayed post-test, $R^2 = .13$, $F(3,69) = 3.40$, $p = .02$, showed significant results for the overall regression models (see Styn et al., 2023).

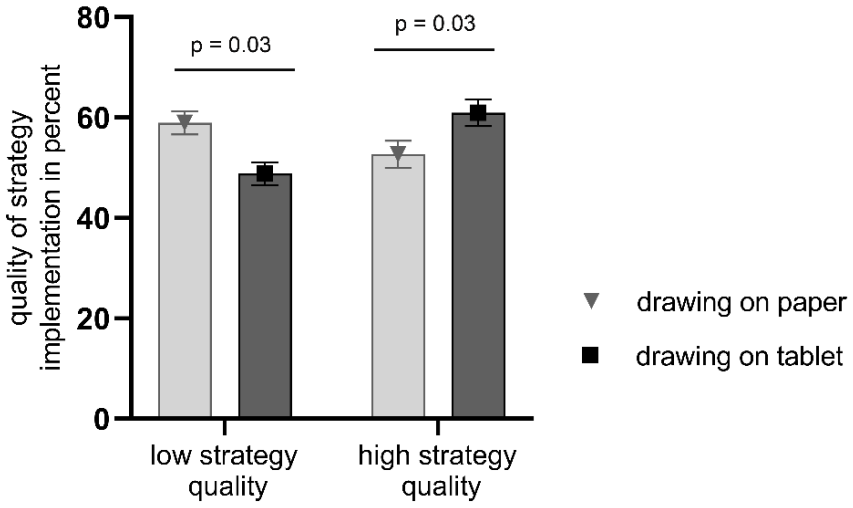
Regarding the immediate post-test, there was no effect of learning method, *Beta* = -0.55, $\beta = -.04$, $p = .73$, and no reliable interaction with the quality of strategy implementation was found, *Beta* = 2.26, $\beta = .13$, $p = .20$. As the correlational analyses had already shown, the better students had implemented one of the learning methods, the better their learning outcome was in the first post-test, *Beta* = 9.13, $\beta = .53$, $p < .001$ (see Styn et al., 2023).

In relation to the delayed post-test, again a rather different picture was revealed: There were no impact of either the learning method, *Beta* = 0.35, $\beta = .02$, $p = .84$, or the quality

of strategy implementation, *Beta* = 2.31, β = .14, p = .22. However, there was significant interaction, *Beta* = 5.42, β = .34, p = .005. This interaction was resolved by simple slope analyses conducted at - 1 SD and + 1 SD of the continuous moderator strategy quality: For students that had implemented their specific strategy with low quality, drawing on paper (M = 58.95) was more effective than drawing on tablet (M = 48.81), *Beta* = -5.07, β = -.35, p = .03. On the other hand, for those who implemented the strategy with high quality, drawing on tablet (M = 60.98) was more effective than drawing on paper (M = 52.67), *Beta* = 5.76, β = .40, p = .03 (Figure 13) (see Styn et al., 2023).

Figure 13

Quality of drawings and summaries as a measurement for quality of strategy implementation. Error bars represent standard errors



Note: Error bars represent standard errors.
Source: Styn et al. (2023)

Similar to writing summaries, drawing on tablet required students to use the method effectively and produce drawings of higher quality in order to achieve high learning outcomes (see Styn et al., 2023).

4 Discussion

To learn anatomy, there are many other learning methods besides memorizing anatomical structures from textbooks, some of which have not yet been sufficiently studied. Therefore, the aim of this study was to investigate drawing on a tablet as a learning method for gross anatomy and to compare it with paper-based methods. The results show that drawing on a tablet is an alternative learning method and shows no difference in learning outcome and its sustainability from the other learning methods studied. Furthermore, it was shown that the learning outcome depends on the quality of the drawings or summaries made, namely that the higher the quality of the drawings or summaries, the higher the learning outcome. In this context, making a summary on paper, compared to making a drawing on paper, and drawing on the tablet, compared to drawing on paper, leads to a higher sustainability of the learning outcome in each case if the quality of strategy implementation is high (see Styn et al., 2023).

4.1 Learning outcome and its sustainability

Our results are consistent with previous findings that drawing has a positive effect on learning outcome (Rafi et al., 2017). Also, sustainability of the acquired knowledge for thereby positively influenced and the knowledge lasts for several weeks (Alsaid & Bertrand, 2016). What we cannot confirm is the better recall of pictures than words (Paivio et al., 1968), because there was no significant difference between the groups that drew and the group that wrote summaries. Thus, we could not find any advantage of drawing over writing summaries as it is the case in other studies (Leopold & Leutner, 2012). Therefore we cannot confirm the drawing effect shown in Wammes et al. (2016) with our study. By the equivalent results for the group that drew on the tablet and the paper-based learning methods it is shown that tablet as the surface on which drawing is done has no limiting factor on the learning outcome. This finding is already shown by Gerth et al. (2016), but there handwriting and not drawing is compared and the adults in this study mentioned even show better results on the tablet than on paper (see Styn et al., 2023)

4.2 Moderation of learning outcome through quality of strategy implementation

The results regarding the quality of the drawings and summaries and their relationship with the learning outcome also show similarities with previous studies. As already shown by Schmidgall et al. (2020), there is a prognostic drawing effect. That is, the higher the quality of the drawing, the better the learning outcome. We could also confirm this positive correlation with our results. This correlation was also shown in the study by Scheiter et al. (2017). In the mentioned study, it was also found that drawing only had an advantage over other learning methods if it was done with a good quality. These findings are not reflected in our study, as drawing on paper compared to writing summaries on paper only leads to better learning outcome if the drawings and the summaries are of low quality (see Styn et al., 2023).

Other studies showed that students discovered errors in their understanding that became visible through drawing (Van Meter, 2001) and misconceptions of the material being learned can also be revealed (Osório et al., 2013). This effect of identifying errors in one's knowledge through generating is also evident in our study, through the increase in the average quality of the drawings and summaries produced after students had opportunities to view the solution and make corrections to their work (see Styn et al., 2023).

4.3 Classification of the results

The comparison with the existing literature shows again that specifically drawing on a tablet has not yet been extensively studied. In order to be able to classify the results, we consider possible explanatory approaches. For this purpose, results of other studies are compared with ours and possible correlations are discussed.

According to dual coding theory, the combination of pictures and words should actually promote learning in particular (Clark & Paivio, 1991). Unfortunately, in our study it showed no advantage over learning with words alone. However, the cognitive load theory could show an explanation (Chandler & Sweller, 1991). It states that there are three different types of cognitive load, and that cognitive overload must not occur (Sweller et al., 1998). It is especially advantageous if the intrinsic and extraneous cognitive load is reduced so that the germane cognitive load has enough capacities available, since this is relevant for learning. Now there are studies which show that the mental presentation of

text contents lowers the cognitive load, but the real drawing of these contents makes it rise again (Leutner et al., 2009). It could be that the task of drawing led to a cognitive overload in the participants and thus there was no advantage of drawing compared to writing. Furthermore, it is possible that the extraneous cognitive load was too high due to the presentation of the learning material and that the participants did not have enough capacity left for the germane cognitive load (see Styn et al., 2023).

Of course, it must also be kept in mind that not every learning method suits every type of learner. According to the VARK model (Fleming & Mills, 1992), there are four different types of learners who all learn best with different learning methods. The visual learners probably prefer drawing more than the other learning types. Depending on which learning types were in which groups, this of course influences the results. Kharb et al. (2013) also shows that many medical students are a multimodal learner type, meaning they learn through multiple modes. In our study, however, only the visual and read-write learning types were addressed.

Another possible explanation for the results is shown in the study by Lin et al. (2017). Here it was found that learner-generated drawing only shows a large positive effect when the prior knowledge of the students is low. It could be that in our study the students simply had too much prior knowledge due to the gross anatomy course they had already completed, and therefore there was no significant difference between the groups (see Styn et al., 2023).

Another issue to consider is the degree of exposure. Our students did not really have any time to get used to the tablet and, like the other groups, started working directly with the tablet and the app. However, according to Raney (2016), students benefit most when they have longer time to familiarize themselves with the tablet. The other two groups only used pen and paper, which are materials they already know. However, the students in the group with the tablet had to relearn how to use the app. Students also find the more frequent use of tablets helpful for their grades and understanding of the content they are learning (Chakraborty & Cooperstein, 2018) (see Styn et al., 2023).

4.4 Limitations

It is plausible that several limitations might have influenced the results obtained. First of all, there was no control group in our study that did not contain any form of

externalization, for example, a group that had only read the text. Thus, it is not possible to determine how much influence externalizing had on the learning outcome, since all groups did it. Also, a comparison between reading on paper and reading on the tablet is interesting. This would allow a more specific investigation of the effect of the mobile device (see Styn et al., 2023).

Furthermore, the students increasingly stated that the learning phase was too long. It could be that the length and also the absence of breaks within the learning phase had an influence on the concentration, especially if one is not familiar with the learning method and is just learning to deal with it. Breaks or shortened texts could maintain the students' concentration (see Styn et al., 2023).

As already mentioned, the students from the group with the tablet were not used to this learning method, because we also developed the app ourselves and it has not yet been published. In addition, the majority of the students stated that they did not learn with the tablet. This shows that the students had to get to know this particular learning method first and had to learn how to use it. In comparison, the other groups only had materials they were already familiar with (pens and paper). So, the group with the tablet had to spend extra effort to get to know the learning medium while the other groups could only concentrate on learning (see Styn et al., 2023).

Another disadvantage of the group with the tablet was that they had to switch between two learning tools during the learning phase. The learning texts with the corresponding pictures were all in the script, i.e. on paper. The drawing itself, however, took place on the tablet and with a digital pen. This switching could have had an influence on the concentration and the learning process and thus also on the learning outcome. The knowledge tests were also all on paper, which meant that the other two groups stayed with their learning medium and the group with the tablet had to get used to paper again (see Styn et al., 2023).

Another limitation to keep in mind is that drawing and summarizing were tested from memory. The students could not see the structures that were to be drawn or named and had to generate a drawing or summary from their memory. This put more stress on the students than simply copying a picture or text. Whether there would be a difference could be found out in future research (see Styn et al., 2023).

The last thing to consider is the time between the two dates. In this time, we could not check if the students repeated the topic of the study on their own. In the gross anatomy

course, the topic was already covered and since everyone had already taken the gross anatomy course, the students could only repeat it privately. If some students repeated the topic in the 4 to 6 weeks between the appointments, this could have influenced the results of the delayed post-test (see Styn et al., 2023).

Future research should continue to focus on drawing on a tablet as a learning method and consider new viewpoints. With our study, it was shown that drawing on a tablet is an equivalent learning method to more traditional learning methods such as drawing on paper and writing on paper. New approaches such as integrating this learning method into the gross anatomy course or further developing the app so that switching between learning media is no longer necessary could put drawing on the tablet as a learning method for learning gross anatomy in a new light (see Styn et al., 2023).

4.5 Conclusion

The purpose of this thesis was to find out if drawing on the tablet can be used as a learning method for medical students to learn gross anatomy. It was shown that drawing on the tablet is an equivalent learning method to more traditional paper-based learning methods and that there is no difference in learning outcome and its sustainability. It was also shown that the quality of the strategy implementation moderates the effect of the learning method on learning outcome. From these findings, drawing on a tablet can be used as a learning method to learn gross anatomy and thus can help medical students in their learning process. Therefore, mobile devices offer a new way to bring learning content to students. However, it is also important to keep in mind that the app we developed is brand new and still has a lot of potential for further improvement. Future research should conduct more studies on drawing on the tablet, considering different aspects such as further development of the drawing software on the tablet and the degree of exposure to the tablet, by integrating the tablet in the gross anatomy course (see Styn et al., 2023).

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Appendix

A: Demographic questionnaire

- Alter: _____ Jahre

- Geschlecht: [ ] m [ ] w [ ] d

- Fachsemester (Anzahl der Semester in spezifischem Studienfach, ohne Urlaubs-, Freisemester oder Ähnliches): _____

- Kurs der makroskopischen Anatomie besucht: im _____ Semester (z.B. im 1.-2. Semester)

Bitte markieren Sie Ihre Antwort in folgender Tabelle mit einem Kreuz in dem zutreffenden Kästchen.

	Täglich	2-3 Mal pro Woche	2-3 Mal pro Monat	Weniger als 1 Mal pro Monat	Nie
1. Wie häufig verwenden Sie ein Tablet* in Ihrem Alltag?					
2. Wie häufig lernen Sie mit einem Tablet*? (wenn Sie lernen müssen)					
3. Wie häufig zeichnen** Sie in Ihrer Freizeit?					
4. Wie häufig lernen Sie, indem Sie Zeichnungen** anfertigen (Zeichnungen von Strukturen, keine Mindmaps, Flow Chart oder Ähnliches)? (wenn Sie lernen müssen)					

* Tablets oder Tablet-PCs (mit Touchscreen), wenn sie wie ein Tablet benutzt werden

** Zeichnen auf jeglichem Untergrund (Tablet, Papier,…)

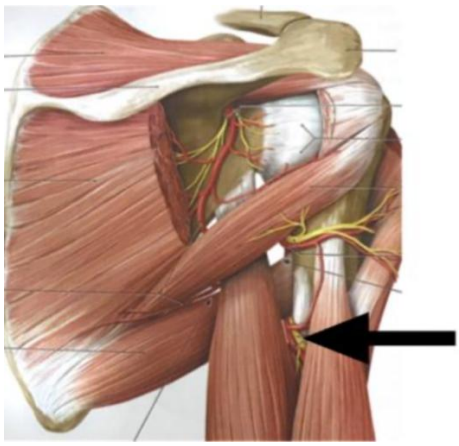
B: Anatomy pre-test

MC-Fragen: jeweils nur eine Antwort korrekt

Korrektur der Antwort: Kreuz für falsch ausgewählte Antwortmöglichkeit durchstreichen und Kreuz links neben Buchstaben der gewünschten Antwortmöglichkeit (z. B.: X (A))

1. Anatomie-Fragebogen (20 Punkte)

1) Auf welchen Nerv zeigt der Pfeil? (Es ist nach dem **Hauptnerven** gefragt) (**Ansicht von dorsal**) (1P)



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_____ (1 Antwort)

2) Wo entspringt der M. pronator teres unter anderem? (1P)

(A) Os capitatum
(B) Epicondylus medialis humeri
(C) Scapula
(D) Proximale Humerus
(E) Distaler dorsaler Radius

3) Auf welcher Seite der A. axillaris müsste man einstechen, um die Medianusgabel zu verletzen? (1P)

(A) Ventralseite
(B) Dorsalseite
(C) Lateralseite

(D) Kranial Richtung A. subclavia
(E) Kaudal Richtung A. brachialis

4) Welcher der folgenden Muskeln wird vom N. radialis innerviert? (1P)

(A) M. brachioradialis
(B) M. palmaris longus
(C) M. brachialis
(D) M. flexor carpi radialis
(E) M. pronator quadratus

5) Wo tritt eine Sensibilitätsstörung bei einer Schädigung des N. radialis am ehesten auf? (1P)

(A) Am ventralen Unterarm
(B) An der Fingerspitze des Mittelfingers
(C) Am dorsalen Oberarm
(D) Am Hypothenar
(E) Am medialen Handrücken

6) Der N. radialis wird verletzt, was ist wahrscheinlich eine Folge der Verletzung? (1P)

(A) Innenrotation der Schulter gestört
(B) Flexion im Ellenbogengelenk gestört
(C) Opposition des Daumens gestört
(D) Supination des Unterarms gestört (bei gestrecktem Arm)
(E) Flexion im Handgelenk gestört

7) Welcher Nerv versorgt das markierte Gebiet sensibel? (Es ist nach dem **Hauptnerven** gefragt) (1P)

_____ (1 Antwort)

8) Auf welcher Struktur verläuft der N. interosseus antebrachii anterior? (1P)

(A) Septum intermusculare brachii mediale
(B) M. brachialis
(C) M. supinator
(D) Membrana interossea
(E) Retinaculum musculorum flexorum

9) Ein Nerv wird in der Fossa cubitalis nach Abgabe verschiedener Äste und vor seiner Aufspaltung in R. superficialis und R. profundus verletzt. Welche motorische Funktion des Nervens bleibt dem Patienten trotz der Läsion am ehesten Erhalten? (1P)

(A) Extension des Daumens
(B) Supination im Radioulnargelenk
(C) Extension des Kleinfingers
(D) Radialabduktion im Handgelenk
(E) Extension des Zeigefingers

10) Welcher Nerv versorgt das markierte Areal sensibel? (Es ist nach dem **Hauptnerven** gefragt) (1P)

dorsal

_____ (1 Antwort)

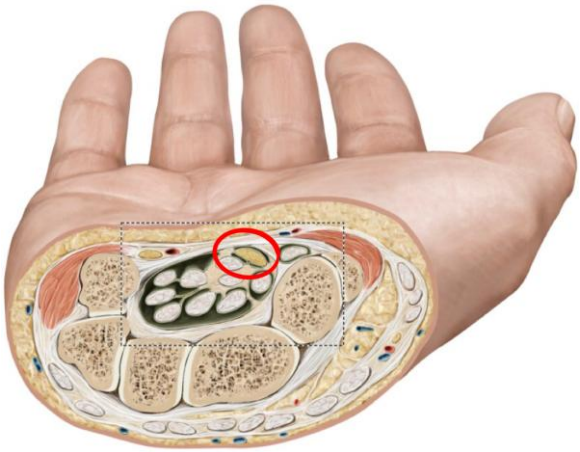
11) Von welchem Nerven wird der M. abductor pollicis brevis innerviert? (Es ist nach dem **Hauptnerven** gefragt) (1P)

_____ (1 Antwort)

12) Durch elektrische Reize können periphere Nerven stimuliert werden. Welche Bewegung wird durch Elektrostimulation des N. radialis am ehesten hervorgerufen? (1P)

(A) Dorsalextension im Handgelenk
(B) Pronation im Radioulnargelenk
(C) Abduktion im Daumensattelgelenk
(D) Flexion im Handgelenk
(E) Flexion in Fingergrundgelenken

13) Welche Struktur ist hier markiert? (**Ansicht von distal**) (1P)



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_____ (1 Antwort)

14) Welcher Nerv zieht zwischen den Köpfen des M. pronator teres durch? (Es ist nach dem **Hauptnerven** gefragt) (1P)

_____ (1 Antwort)

15) Wo tritt eine Sensibilitätsstörung bei einer Läsion des N. medianus wahrscheinlich auf? An… (1P)

(A) Endglied vom Mittelfinger
(B) Dorsalseite zwischen Daumen und Zeigefinger
(C) Radiale 2 ½ Finger dorsal

(D) Endglied des kleinen Fingers
(E) Ulnare 1 ½ Finger

16) Ein Patient kann nach einem Sturz auf den rechten Arm einen Becher nicht mehr fest umschließen (positives Flaschenzeichen), welcher Nerv ist am ehesten verletzt? (Es ist nach dem **Hauptnerven** gefragt) (1P)

_____ (1 Antwort)

17) Wo entspringt der M. supinator unter anderem? (1P)

(A) Scapula
(B) Epicondylus lateralis
(C) Distaler Radius
(D) Proximale Humerus
(E) Os metacarpale I

18) Aus welchem/welchen Faszikel/n des Plexus brachialis entspringt der N. radialis? (1P)

_____ (1 Antwort)

19) Entlang welchen Muskels verläuft der Ramus superficialis des N. radialis am Unterarm? (1P)

_____ (1 Antwort)

20) Der N. medianus wird verletzt. In welcher Bewegung ist der betroffene Patient am wahrscheinlichsten eingeschränkt? (1P)

(A) Pronation des Unterarms
(B) Adduktion des Daumens
(C) Supination des Unterarms
(D) Streckung im Ellenbogengelenk
(E) Extension im Handgelenk

C: Anatomy immediate post-test

MC-Fragen: jeweils nur eine Antwort korrekt

Korrektur der Antwort: Kreuz für falsch ausgewählte Antwortmöglichkeit durchstreichen und Kreuz links neben Buchstaben der gewünschten Antwortmöglichkeit (z. B.: X (A))

2. Anatomie-Fragebogen (30 Punkte)

1) Nach einer langen OP klagt ein Patient unter anderem über Extensionsschwierigkeiten des Ellenbogengelenks. **Welcher Nerv** wurde auf **welcher Höhe** des Oberarms wahrscheinlich beschädigt? (Es ist nach dem **Hauptnerven** gefragt) (2P)

_____ (2 Antworten)

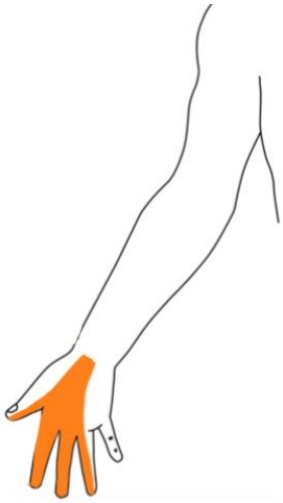
2) Auf welcher Höhe ist der N. medianus ungefähr verletzt, wenn ein Patient unter anderem das Symptom der so genannten Schwurhand (nur Finger IV und V können partiell gebeugt werden) hat? (1P)

(A) Palma manus
(B) Retinaculum flexorum
(C) Proximaler Unterarm
(D) medialer Unterarm
(E) distales Oberarmdrittel

3) Welche Strukturen treten gemeinsam durch den Trizepsschlitz? (2P)

_____ (2 Antworten)

4) Welche Nervenäste versorgen das markierte Areal sensibel (Es ist **nicht** nach dem Hauptnerven gefragt)? (1P)



_____ (2 Antworten)

5) Ein Nerv wird im Sulcus nervi radialis verletzt. Welche/s Areal/e wird/werden von diesem Nerven trotz Verletzung wahrscheinlich noch sensibel versorgt? (1P)

_____ (1 Antwort)

6) Ein Nerv wird bei Kompression zwischen den beiden Köpfen des M. pronator teres geschädigt. Welches Symptom tritt am wahrscheinlichsten auf? (1P)

(A) Die Kuppe des Daumens kann die Kuppe des kleinen Fingers nicht mehr berühren
(B) Streckung des Handgelenkes nicht mehr möglich
(C) Schwund der Muskulatur des Kleinfingerballens
(D) Drehung des Unterarms nach oben bei gestrecktem Arm nicht mehr möglich
(E) Streckung in den Fingergrund und -mittelgelenken nicht mehr möglich

7) Was beschreibt am besten das Autonomiegebiet des N. radialis? (1P)

_____ (1 Antwort)

8) Aus welchem/welchen Faszikel/n des Plexus brachialis entspringt der N. medianus? (2P)

_____ (2 Antworten)

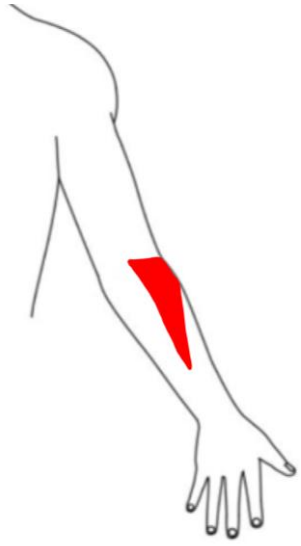
9) Die Sehne welches Muskels muss man beklopfen, um einen Reflex auszulösen, der die Funktion des N. radialis überprüft? (1P)

_____ (1 Antwort)

10) Ein Nerv, der durch den Sulcus bicipitalis medialis verläuft, wird im weiteren Verlauf verletzt. Der Patient kann unter anderem seinen Daumen nicht mehr abduzieren. **Welcher Nervenast welches Nervens**, der unter anderem für diese Bewegung verantwortlich ist, ist wahrscheinlich verletzt? (Es ist nach dem **Hauptnerven und** dem **Nervenast** gefragt) (2P)

_____ (2 Antworten)

11) Das sensible Versorgungsgebiet welches Nervens spiegelt das markierte Areal am ehesten wieder? (Es ist nach dem **Hauptnerven** gefragt) (**Ansicht von dorsal**) (1P)



_____ (1 Antwort)

12) Der N. medianus wird oberhalb des Ellenbogens geschädigt. Welches Symptom tritt wahrscheinlich auf? (1P)

(A) Krallenhand (Überstreckung der Fingergrundgelenke bei gleichzeitiger Beugung in Mittel- und Endgelenken)
(B) Fallhand (keine Dorsalextension im Handgelenk möglich)
(C) Pronationsschwäche des Unterarms
(D) sensibler Ausfall im dorsalen Daumen

(E) Streckung im Ellenbogengelenk gestört

13) Ein Patient zeigt das klinische Bild einer Fallhand (keine Dorsalextension im Handgelenk möglich). Wo ist der betroffene Nerv am wahrscheinlichsten geschädigt? (1P)

(A) Zwischen den Köpfen des M. pronator teres
(B) Auf der Membrana interossea
(C) Im Radialistunnel
(D) Auf Höhe des Humerusschaftes
(E) Im Supinatorkanal

14) Welcher Nervenast innerviert den M. pronator quadratus? (Es ist **nicht** nach dem Hauptnerven gefragt) (1P)

_____ (1 Antwort)

15) Ein Patient leidet unter Sensibilitätsstörungen an Thenar und der Radialseite der Hohlhand. Weitere Symptome hat er keine. Wo ist der betroffene Nerv am ehesten geschädigt? (1P)

(A) Im Karpaltunnel
(B) Über dem Retinaculum musculorum flexorum
(C) Nach dem Karpaltunnel
(D) Über der Membrana interossea
(E) Unter dem Retinaculum musculorum flexorum

16) Ein Patient ist in der Funktion geschwächt seinen Daumen zu opponieren. Zwischen welchem Muskel/welchen Muskeln ist der betroffene Nerv am ehesten geschädigt? (1P)

(A) M. flexor pollicis brevis
(B) M. pronator teres
(C) M. triceps brachii
(D) M. supinator
(E) Radialisgruppe

17) Ein Patient stellt sich mit Schmerzen im lateralen Ellenbogen und verminderter Streckfähigkeit der Hand vor. Sie diagnostizieren einen sogenannten Tennisellenbogen bei dem die Ansatzsehen der Radialisgruppe durch Fehlbelastung Mikrotraumata, Entzündungen und Rissen aufweisen. Welche Muskeln gehören zu der Radialisgruppe? (3P)

_____ (3 Antworten)

18) Ein Patient geht nach einer Femurfraktur mehrere Wochen auf Achselkrücken, wobei eine Kompression am Oberarm stattfindet. Welcher Nerv wird dabei aufgrund seiner Lage am wahrscheinlichsten verletzt? (Es ist nach dem **Hauptnerven** gefragt) (1P)

_____ (1 Antwort)

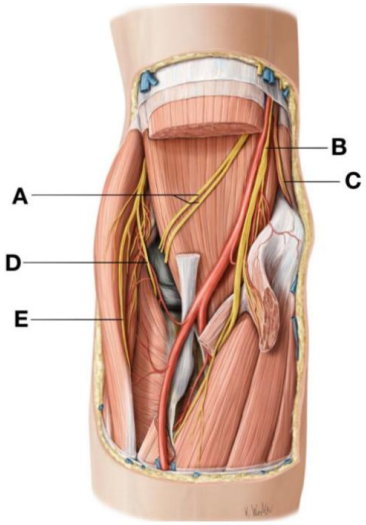
19) Ein Patient verspürt eine Sensibilitätsstörung im ersten Zwischenfingerraum und in den radialen 2 1⁄2 Fingern. Sonst treten keine weiteren Symptome auf. Wo ist der betroffene Nerv am wahrscheinlichsten geschädigt? (1P)

(A) In seinem Verlauf entlang des M. brachioradialis
(B) Beim Durchtritt durch den Supinatorkanal
(C) Vor Aufspaltung in R. superficialis und R. profundus
(D) In seinem Verlauf entlang des M. brachialis
(E) In seinem Verlauf auf der Membrana interossea

20) Wo setzt der M. brachialis an? (1P)

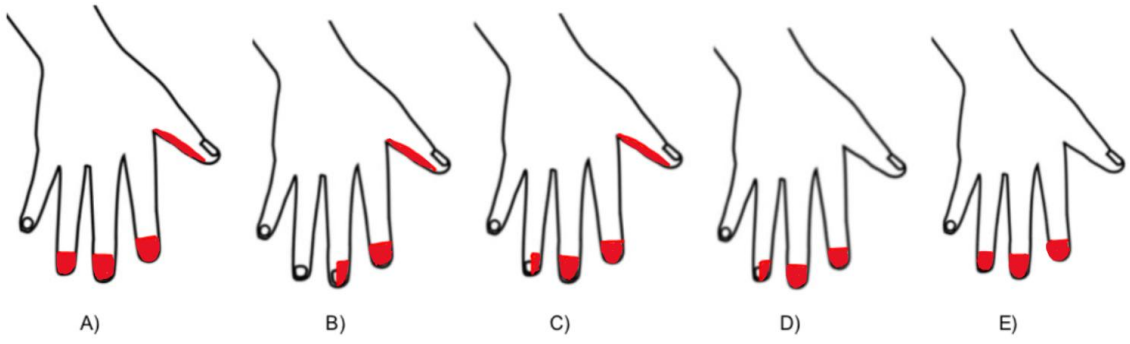
(A) Tuberositas ulnae
(B) Tuberositas radii
(C) Lateraler Radius
(D) Laterale Ulna
(E) Membrana interossea

21) Der R. profundus des N. radialis ist im folgenden Bild mit dem Buchstaben .... markiert. **(Ellenbeuge, rechter Arm, Ansicht von ventral)** (1P)



(A) A
(B) B
(C) C
(D) D
(E) E

22) Ein Patient kommt zu Ihnen in die Praxis und klagt über eine Sensibilitätsstörung an der Hand. Welches Areal ist wahrscheinlich betroffen, wenn der N. medianus geschädigt ist? (**Ansicht von dorsal**) (1P)



(A) A
(B) B
(C) C
(D) D
(E) E

23) Von welchem Nerven wird der M. extensor pollicis longus innerviert? (Es ist nach dem **Hauptnerven** gefragt) (1P)

_____ (1 Antwort)

24) Bei einem Unfall wird bei einem Patienten die Membrana interossea verletzt. Welches Symptom tritt am wahrscheinlichsten durch eine Schädigung eines dort entlang verlaufenden Nervens auf? (1P)

(A) Sensibilitätsstörung der Palmarfläche von Daumen, Zeige-, Mittel- und Ringfinger
(B) Sensibilitätsstörung der Palmarfläche vom Ring- und Kleinfingers
(C) Fallhand (keine Dorsalextension im Handgelenk möglich)
(D) Krallenhand (Überstreckung der Fingergrundgelenke bei gleichzeitiger Beugung in Mittel- und Endgelenken)
(E) Affenhand (Daumen bleibt in Flexion in Ebene von anderen Fingern)

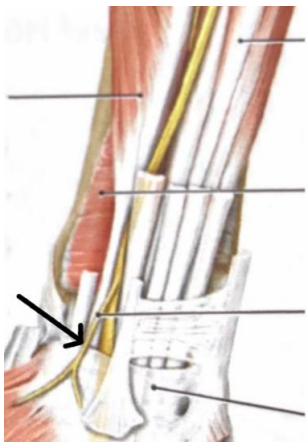
D: Anatomy delayed post-test

MC-Fragen: jeweils nur eine Antwort korrekt

Korrektur der Antwort: Kreuz für falsch ausgewählte Antwortmöglichkeit durchstreichen und Kreuz links neben Buchstaben der gewünschten Antwortmöglichkeit (z. B.: X (A))

3. Anatomie-Fragebogen (30 Punkte)

1) Ein Patient kommt zu Ihnen in die Praxis. Über welches Symptom klagt der Patient wahrscheinlich, wenn der markierte Nerv geschädigt ist? (**Ansicht von ventral,** rechte Hand) (1P)



(A) Funktionsausfall des M. abductor pollicis brevis
(B) Sensibilitätsstörung auf Dorsalseite des Daumens, Zeige- und Mittelfinger
(C) Funktionsausfall des M. adductor pollicis
(D) Sensibilitätsstörung an Thenar und Radialseite der Hohlhand
(E) Sensibilitätsstörung an Endphalanx des Kleinfingers

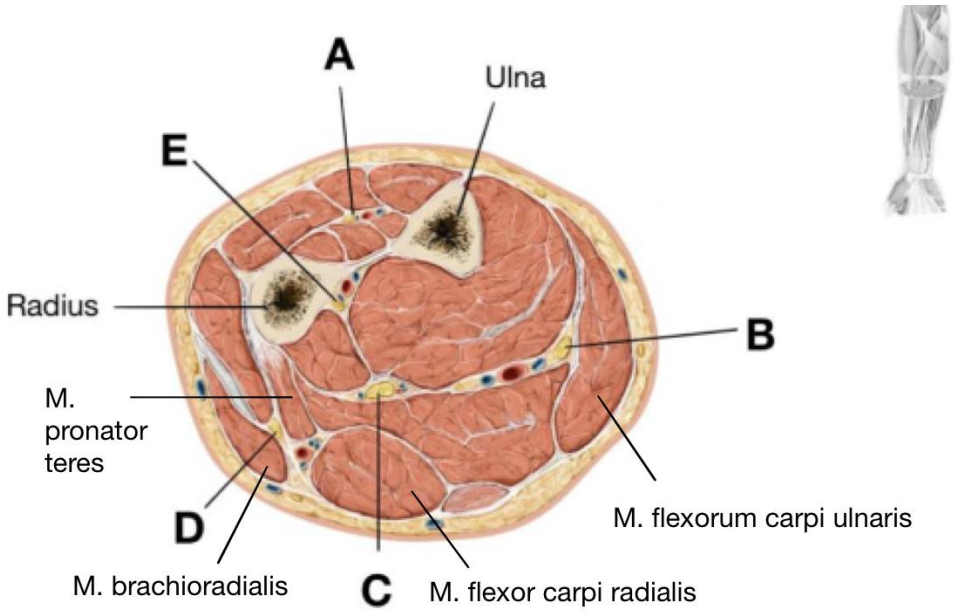
2) Durch einen Unfall wird der N. medianus beschädigt. Welcher Muskel ist demnach durch die fehlende Innervation in seiner Funktion am ehesten eingeschränkt? (1P)

(A) M. triceps brachii
(B) M. supinator
(C) M. pronator quadratus
(D) M. extensor pollicis longus
(E) M. brachialis

3) Welcher Nerv innerviert das Caput superficiale des M. flexor pollicis brevis? (Es ist nach dem **Hauptnerven** gefragt) (1P)

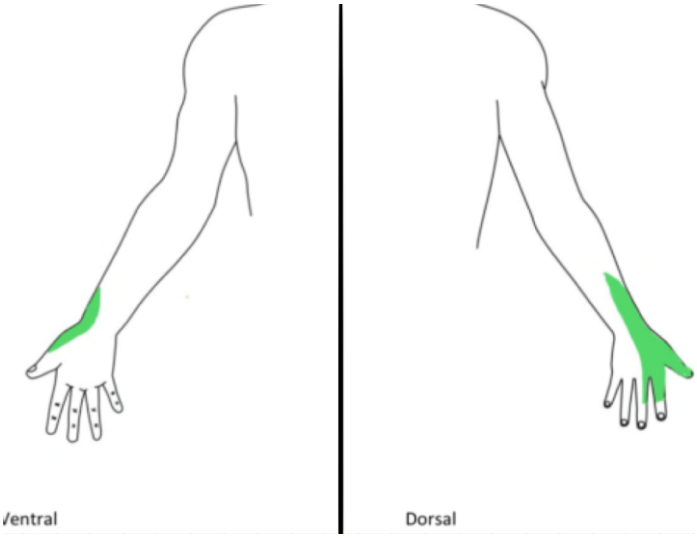
_____ (1 Antwort)

4) Welcher Buchstabe markiert den Ramus superficialis eines Nervens? (Querschnitt Unterarm, **Ansicht von distal**) (1P)



(A) A
(B) B
(C) C
(D) D
(E) E

5) Welcher Nerv versorgt die gezeigten Areale sensibel? (Es ist nach dem **Hauptnerven** gefragt) (1P)



_____ (1 Antwort)

6) Bei einer Reizung des N. medianus ist das Beklopfen welcher Struktur wahrscheinlich schmerzhaft? (1P)

(A) Hohlhand
(B) Epicondylus medialis
(C) Fovea radialis
(D) Karpaltunnel
(E) Supinatorkanal

7) Welcher Nerv versorgt das markierte Gebiet sensibel? (Es ist nach dem **Hauptnerven** gefragt) (**Ansicht von dorsal**) (1P)

dorsal

_____ (1 Antwort)

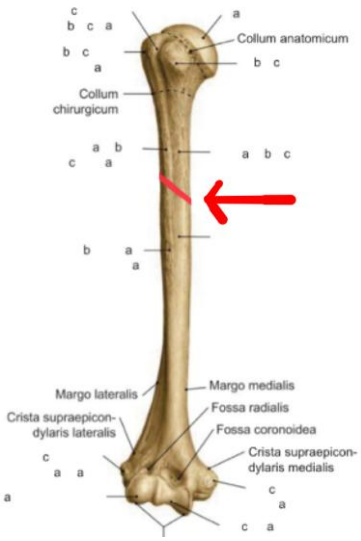
8) Was ist der Leitmuskel (Führungsmuskel, an dem der Nerv entlang läuft) des N. medianus am Unterarm? (1P)

_____ (1 Antwort)

9) Wo spaltet sich der N. cutaneus brachii posterior von seinem Hauptnerven ab? (1P)

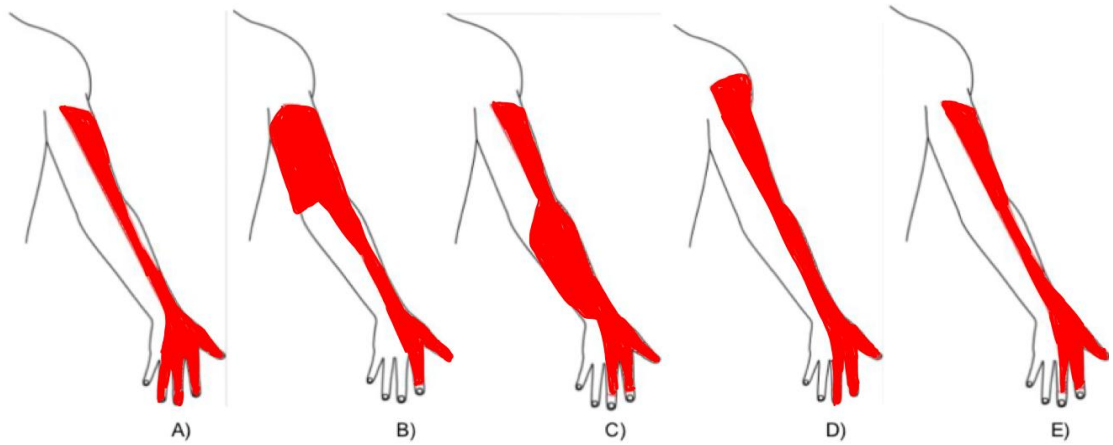
(A) Im Sulcus nervi radialis
(B) Vor dem Sulcus nervi radialis
(C) Nach Sulcus nervi radialis
(D) Im Sulcus bicipitalis medialis
(E) Vor dem Sulcus bicipitalis medialis

10) Welcher Nerv wird bei einer Oberarmschaftfraktur (Ort mit rotem Pfeil auf Bild markiert, **Ansicht von ventral**) am ehesten verletzt? (Es ist nach dem **<u>Hauptnerven</u>** gefragt) (1P)



_____ (1 Antwort)

11) Welche Antwortoption zeigt am wahrscheinlichsten das sensible Versorgungsgebiet eines Nervens? (**Ansicht von dorsal**) (1P)



(A) A
(B) B
(C) C
(D) D
(E) E

12) Bei einem Patienten sind die Mm. lumbricales I und II in Ihrer Funktion eingeschränkt. Wo geht der Ast, der diese Muskeln innerviert, von seinem Hauptnerv ab? (1P)

(A) Zwischen Köpfen des M. pronator des
(B) Im Supinatorkanal
(C) Über dem Retinaculum musculorum flexorum
(D) Auf dem Handrücken
(E) Nach dem Karpaltunnel

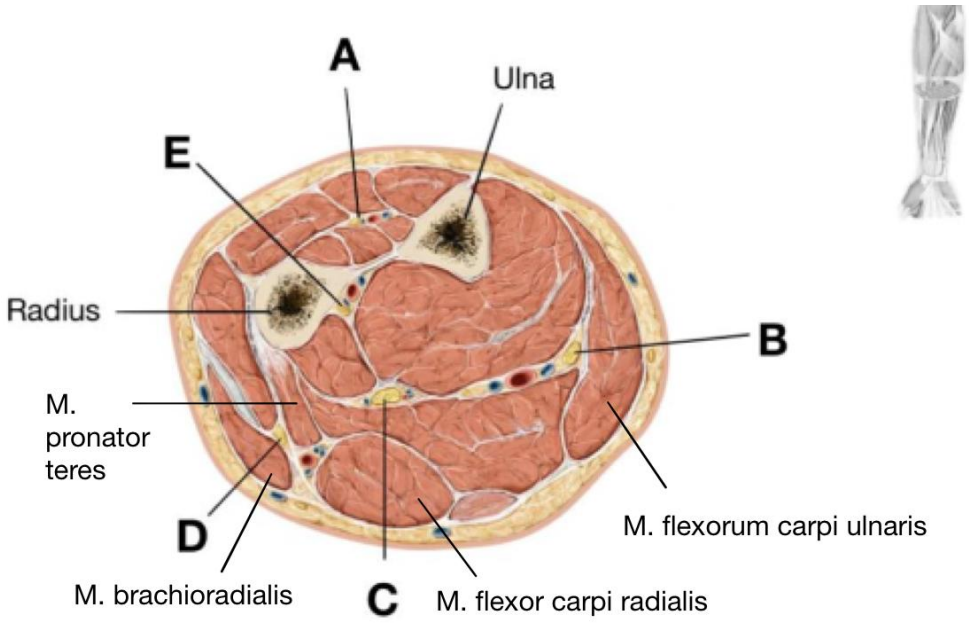
13) Welche zwei Muskelbäuche begrenzen den Trizepsschlitz? (2P)

_____ (2 Antworten)

14) Auf welcher Höhe ist der betroffene Hauptnerv am ehesten geschädigt, wenn ein Patient das klinische Bild einer Fallhand (keine Dorsalextension im Handgelenk möglich) aufweist? (1P)

(A) Auf Höhe des Handgelenkes
(B) Auf Höhe des Ellenbogens
(C) Auf Höhe des Humerusschaftes
(D) Auf Höhe des M. pronator teres
(E) Auf Höhe des M. supinator

15) Welche Struktur zeigt den N. medianus? (1P)



(A) A
(B) B
(C) C
(D) D
(E) E

16) Ein Nerv wird im Karpaltunnel verletzt, welches ist wahrscheinlich **kein** Symptom dieser Verletzung? (1P)

(A) Schwurhand (nur Finger IV und V können partiell gebeugt werden)
(B) Affenhand (Daumen bleibt in Flexion in Ebene der anderen Finger)
(C) Kuppe des Daumen kann Kuppe des kleinen Fingers nichts mehr berühren
(D) Schwierigkeiten beim Umgreifen eines Flaschenhalses
(E) Sensibilitätsstörung der radialen 3,5 Fingern von palmar

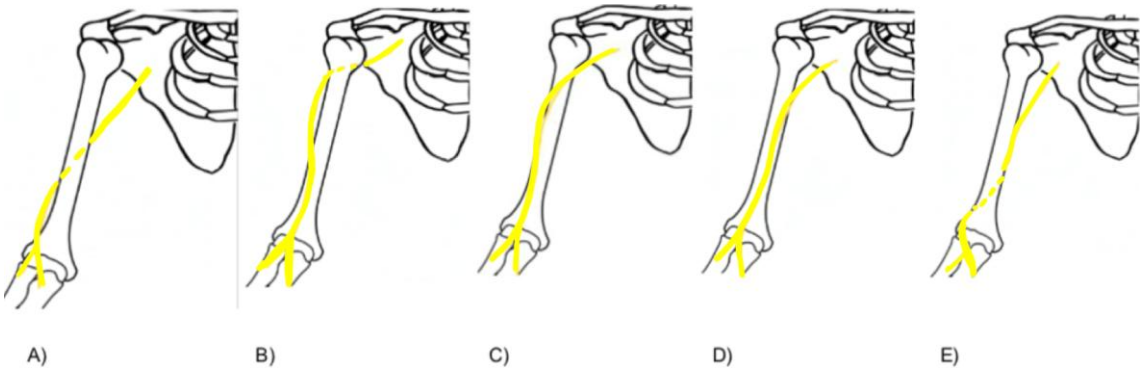
17) Aus welchen beiden Muskeln setzt sich der Radialistunnel zusammen? (2P)

_____ (2 Antworten)

18) Welcher motorischer Ausfall tritt unter anderem auf, wenn der N. medianus oberhalb des Ellenbogens geschädigt wird? (1P)

(A) Pronationsschwäche des Unterarms
(B) Ausfall der Adduktion des Daumens
(C) Ausfall der Flexoren von Ring- und Kleinfinger
(D) Supinationsschwäche des Unterarms
(E) Ausfall der Abduktion des Kleinfingers

19) Ein Patient stellt sich Ihnen unter anderem mit einem verminderten Faustschluss und einer geschwächten Supination, vor allem im gestreckten Arm, vor. Welche Zeichnung stellt den korrekten Verlauf des Nervens dar, der wahrscheinlich betroffen ist? (**Ansicht von ventral**) (1P)



(A) A
(B) B
(C) C
(D) D
(E) E

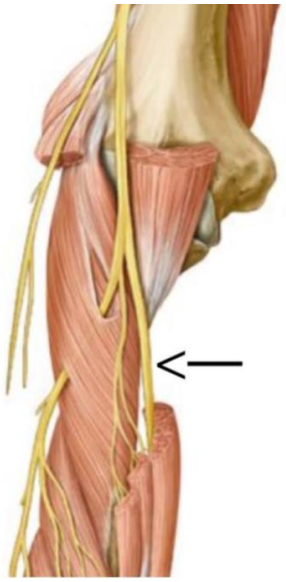
20) Welcher Muskel dient am ehesten als Leitmuskel (topographisch) für den R. profundus des N. radialis? (1P)

_____ (1 Antwort)

21) Der N. interosseus antebrachii anterior ist am ehesten ein Ast welches Nervens? (Es ist nach dem **Hauptnerven** gefragt) (1P)

_____ (1 Antwort)

22) Auf welchen Nervenast zeigt der Pfeil? (Es ist **nicht** nach dem Hauptnerven gefragt) (**Ansicht von ventral**, Unterarm in Pronation) (1P)



_____ (1 Antwort)

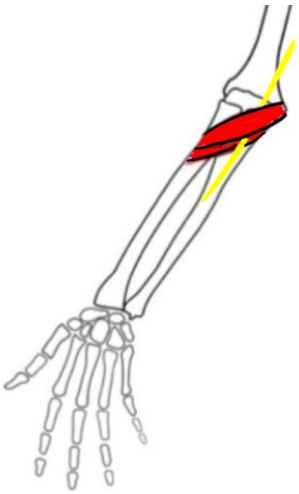
23) Aus welchem Nerven leiten sich die Nn. digitales palmares proprii und communes ab? (Es ist nach dem **Hauptnerven** gefragt) (1P)

_____ (1 Antwort)

24) Ein Patient kommt mit einer Luxation des Radiusköpfchens zu Ihnen in die Klinik. Die Handstellung ist soweit unauffällig und er hat keine sensiblen Ausfälle. Sie stellen fest, dass er ein Streckdefizit in den Fingern und einen verminderten Faustschluss hat. Wo könnte eine Läsion vorliegen? (1P)

(A) Im Bereich des M. pronator teres
(B) Im Bereich des Humerusschaftes
(C) In der Axilla
(D) Beim Durchtritt durch den M. supinator
(E) Im Bereich des Sulcus bicipitalis medialis

25) Welcher Nerv wird hier in Gelb dargestellt? (Es ist nach dem **<u>Hauptnerven</u>** gefragt) (**Ansicht von ventral**) (1P)



ventral

_____ (1 Antwort)

26) Welches Symptom tritt wahrscheinlich bei einer proximalen Läsion (in Axilla oder auf Höhe des Humerusschaftes) des N. radialis auf? (1P)

(A) Beugung in Hand- und Fingergrund-/mittelgelenken nicht möglich
(B) Streckung im Ellenbogengelenk nicht möglich
(C) Spreizung der Hand nicht möglich
(D) Sensibler Ausfall im zweiten Fingerzwischenraum dorsal
(E) Pronation des Unterarms ist nicht möglich

27) Welcher Muskel liegt dorsal des N. medianus in seinem Verlauf am Oberarm? (1P)

_____ (1 Antwort)

28) Der N. medianus wird verletzt, wo tritt am wahrscheinlichsten eine Sensibilitätsstörung auf? (1P)

(A) am distalen lateralen Oberarm
(B) am medialen Oberarm
(C) auf der ventralen Seite des Unterarms
(D) am lateralen Unterarm
(E) an den Kuppen von Zeige- und Mittelfinger

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