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Influence of learning strategies and motivation on anatomy test performance of undergraduate medical students

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ABSTRACT

To learn and comprehend the large amount of information in gross anatomy, undergraduate students must self-regulate their learning to be properly prepared for the exams within the available time. Even though there are many studies on learning strategies and their influence on test results and motivation, the aim of this study is to investigate characteristics of learning strategies in detail and in relation to the anatomy course of first semester students and how their use is related to anatomy test performance. For assessing the learning strategies, we used the short version of the questionnaire "Learning Strategies of University Students" (LIST-K) (Klingsieck, 2018). Further, we investigated potential influences of motivation and resources used during the self-regulated learning process. The participants in this study (N = 108) filled in the above-mentioned questionnaire LIST-K and a written multiple-choice anatomy test. A k-means cluster analysis revealed three groups of students differing in their self-reported use of learning strategies. Students used either (1) predominantly metacognitive and resource-related strategies, (2) predominantly cognitive strategies, or (3) no specific learning strategies at all. We found no significant overall relationships between the use of learning strategies and test performance. A stepwise linear regression identified the use of cognitive learning strategies (β =.269) as a significant predictor for test performance (R^2 =.149, p =.003), possibly as these specific learning strategies help with a systematic and effective approach while studying anatomy and retrieving large amount of memorized information. Further, motivation was identified as a negative predictor (β = −.277), which might be a result of the short time periods students have to study for exams. Overall findings underline the importance of self-regulated learning as a positive predictor for academic performance. By understanding these factors, a more student-centered approach could be adopted by educators to improve medical education and equip students with valuable approaches for their continuous education, even beyond university.

1. Introduction

During learning about gross anatomy, a large amount of information has to be learned and retrieved in a rather short period of time. Moreover, it is necessary for students to understand the anatomical functions of structures, as well as to memorize all Latin terms of muscles, bones, and anatomical pathways. To achieve this, each student has to organize the study material and available study time well. Preparation for the exams is mostly organized individually and is to a large degree self-directed. This process is referred to as *self-regulated learning* (Boekaerts and Corno, 2005; Pintrich, 2000; Zimmerman, 1990, 1989). Research on self-regulated learning dates back several decades, however in the 1970s and 80 s this topic gained a lot of attention and became a popular field of research in educational and psychological studies. Before getting into detail about factors and influences of self-regulated learning, it is crucial to understand how self-regulated learning is defined. One major characteristic of self-regulated learners is that they take a proactive approach to gaining sustainable knowledge and are aware of the benefits of

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investing effort into learning for their future in the field of study that they chose (Zimmerman, 2000). A well-composed student with well-rounded learning skills and techniques will not only be able to be successful in the short-term during exams, but also implement the kind of mentality and skill for lifelong learning. Especially medical doctors will face a constant need to further educate themselves and keep being up to date with the latest research. Being equipped with a broad skillset of adequate learning strategies, self-regulated learning will benefit the learner in most academic achievements. Typical strategies include cognitive strategies (e.g., elaboration, summarization, or practice testing), metacognitive strategies (e.g., goal setting, monitoring, or time management), or motivational strategies (e.g., intrinsic motivation, goal orientation, self-efficacy, or task value) (Boekaerts, 1997; Eccles and Wigfield, 1995; Pintrich and de Groot, 1990; Winne, 1995; Zimmerman, 2002). In conclusion, for the present study, we use the definition proposed by Zimmermann (1990) that self-regulated learners are "metacognitively, motivationally, and behaviorally active participants in their own learning" (Zimmerman, 1990, p. 4). In this context *metacognitively* can be understood as learners, who plan, set goals, organize, and regulate their own learning process. Regarding the motivational component, self-regulated learners have a high self-efficacy and initiate their own learning activities. Lastly, behavioral processes include finding and organizing the learning environment to optimize learning outcome and looking for resources and information that maximize the learning outcome (Zimmerman, 1989).

1.1. *Learning strategies*

Current literature on investigating effects of learning strategies on students' academic achievements reports positive correlations between certain students' learning strategies and academic achievement. Sets of different assessment tools are being used in the respective studies. The Learning and Study Strategies Inventory (LASSI), Motivated Strategies for Learning Questionnaire (MSLQ), and the Learning Strategies of University Students (LIST) can be found in a variety of different scientific papers on learning strategies and learning processes of students. The MSQL (Pintrich, 1991) is assessing students ́motivational beliefs, such as intrinsic and extrinsic goal orientation, self-efficacy or task value and self-regulated learning strategies in an academic context. The LASSI (Weinstein et al., 1987) was created to evaluate students learning and study strategies in ten different areas related to academic success, such as time management, information processing, or concentration. The questionnaires consist of scales and items that are investigating students ́ self-reported learning strategies, behaviors, and beliefs. The LIST was created to investigate students learning strategies, self-regulated learning, and evaluation of learning strategies and consists of components of cognitive, metacognitive, and resource-related learning strategies, as well as motivational aspects (Wild and Schiefele, 1994). These questionnaires can be applied in educational research and provide educators with information about students ́learning strategies and how to support students' academic growth and success.

Cano (2006) identified affective strategies and goal strategies as significant predictors of students performance, whereas cognitive monitoring strategies were not. Data collected with the LASSI, with its ten subscales for different learning strategies, showed that affective strategies and goal strategies are a better predictor for test performance than cognitive monitoring strategies. Schutz and colleagues (2013) found that from these ten subscales mostly anxiety, concentration, and goal orientation are positively related to academic achievements. Khalil and colleagues (2017) found that anxiety, selecting main ideas, and test strategies as three of the ten subtests of the LASSI are correlated with students ́performance in medical schools. Another study from Khalil and colleagues (2018) pointed out that besides test strategies, motivation also plays a significant role in academic achievement. When looking at the MSLQ scales for cognitive learning strategies in pre-clinical medical students, Zilundu and colleagues (2021) emphasized elaboration, rehearsal, and organization as typical strategies in anatomy that have a positive impact on test performance. These skills are associated with deep learning (O'Sullivan et al., 2012).

In conclusion, when looking into the current literature about the associations between learning strategies and academic achievement in medical education and more specifically in anatomy education, some strategies are mentioned more often as having a positive correlation with test performance than others. Those learning strategies are listed in the LASSI as information processing, selecting main ideas, or test strategies, which are summarized under the major component of skill. Some studies (Khalil et al., 2017) suggest organizing the ten LASSI subscales into the three major components skill, will, and self-regulation. Furthermore, the strategy concentration of the major component self-regulation is another skill predictive of a positive correlation towards test performance. However, this is dependent on other factors such as the year in which medical students' learning strategies were assessed, for example, first-year medical students compared to third-year medical students (Khalil et al., 2017). This study suggests that the assessment of learning strategies is more a reflection of students' own strategies. Therefore first-year medical students will most likely reflect on their behavior and learning strategies on undergraduate performance, whereas third-year medical students have the experience of the specific learning requirements to succeed in exams and had the chance to adapt their study strategies over the course of time. Further, mediators like intrinsic or extrinsic motivation and self-efficacy need to be considered when investigating academic achievements (Stegers-Jager et al., 2012; Wu et al., 2020). Very recent literature indicates that there is also a test anxiety component with effects on test performance and self-regulated learning (SRL). By identifying different SRL profiles, a more person-centered approach can be initiated by educators to help students to have a better performance outcome (Broks et al., 2024). Furthermore, having a deeper understanding of different learning techniques can help to define specific learning processes and how to approach these students as medical educators (Otto et al., 2024).

1.2. *Motivation*

Motivation as a potential variable in learning strategies and test performance was assessed in several studies. Wu and colleagues (2020) explained that motivation is necessary in medical education due to the time-consuming and challenging curriculum. Both extrinsic and intrinsic motivation are positively correlated with self-efficacy and learning engagement. However, only intrinsic motivation, the inherent drive to engage in an activity or field of interest (Ryan and Deci, 2000), is also positively correlated with test performance. Whereas extrinsic motivation is based on external rewards or pressures. These findings are confirmed and replicated by numerous other studies (Walker et al., 2006). As presented by Yun and colleagues (2021) there are different expression of motivation that resulted in specific use of learning strategies. One example is that „goal orientation motivation is associated with more use of the elaboration strategy" (Yun et al., 2021, p. 121). Yun et al. also stated that goal orientation motivation is a predictor for learning engagement. Overall, motivation is associated with cognitive learning strategies and this in return promotes better academic outcome. In terms of predictors of motivation itself, there are factors like interest or importance of the study material as relevant information for the ongoing academic education (Schiefele et al., 2003). Pressure to perform can be associated with extrinsic motivation. Other studies reported a link between motivation and task value, goal orientation, and self-efficacy (Zilundu et al., 2021).

Overall, it is not sufficient to assess motivation, but instead it is important to consider the source of motivation in combination with applied learning strategies. A holistic approach to examining academic success is necessary to predict strengths and weaknesses in learning strategies as well as promoting students ́interest and motivation during medical education. Preferably early on, to support students ́professional development and limit anxiety to a minimum, which is one factor that hampers test performance (Green et al., 2016; Khalil et al., 2017).

1.3. The present study

With the complexity of learning strategies and a variation of different influences on the self-regulated learning process, it is a research field in medical education that is continuously evolving (Fabry and Giesler, 2012). However, to contribute more insights on how medical students learn at the early stage of medical school and more specifically in anatomy education, our study aimed to investigate the connection between students' learning strategies, motivation, and their performance in an anatomy test during the first-year anatomy course. Specifically, our research questions were:

RQ 1: What is the influence of learning strategy on undergraduate medical students' anatomy test performance?

RQ 2: What is the influence of motivation on undergraduate medical students' anatomy test performance?

2. Methods

2.1. Ethical approval

Written informed consent was obtained from all participants before participation in the study. All students were informed about the study, chances, risks, rights, obligations, and the voluntary nature of the study. Data were collected in pseudonymized form. Participants also agreed to the publication of the data in anonymized form. They could revoke their consent without incurring any disadvantage. Ethical approval for this study was obtained from the ethics committee at Ludwig-Maximilians-Universität München (no. 20–1115).

2.2. Design and participants

In a quantitative one-factorial comparative study design, we used learning strategies as the independent variable and anatomy test performance as the dependent variable. We also sought to explain variance in anatomy test performance through the predictive value of motivation and learning strategies. In order to collect data to these modalities, we distributed questionnaires regarding motivation, learning strategies, and a multiple-choice anatomy test. The anatomy course takes place over the course of the first two semester and is divided into 5 major topics with an oral exam after each block. We designed our study and the multiple-choice anatomy exam according to the topics within the anatomical curriculum.

An a priori power analysis for a one-factorial ANOVA using G*Power (Faul et al., 2009) was conducted with alpha =.05, and an expected effect size of Cohen's f =.30 and power =.95 for three groups. It suggested that a total of 177 participants was required. Students were notified about the study through the anatomy course, zoom lectures, and with help from teachers, student tutors, and social media.

Over the course of two semesters, a total of 195 students out of 919 in the winter semester 2021/22 and summer semester 2022 participated in the study, however only 108 participants (74 females and 34 males) completed the whole study, consisting of four questionnaire parts and a multiple-choice anatomy test. The gender distribution corresponds to the overall student population. The mean age was 21.5 years (*SD* ±3.21). The participants were novice medical students at the Ludwig-Maximilians-Universität in Munich.

2.3. Measures

2.3.1. Demographics and prior knowledge

Besides demographic information regarding age, gender, or final grade of high-school diploma, we assessed the highest academic degree and prior study fields, if applicable.

2.3.2. Study resources for knowledge acquisition and rehearsal

We divided the questions into analog (6 items) and digital media use (7 items), as well as a time-related use of these resources to get information on their use in the knowledge acquisition and rehearsal phase, respectively (16 items each). Items were rated on a 5-point Likert scale (1=never, 2=rarely, 3=sometimes, 4=often, 5=always). In addition, participants could provide more detailed information with open-ended items on specific learning platforms, apps, or question-banks they were using during these phases (e.g., literature with more/less than 300 pages, online lecture slides, study groups, anatomy apps).

2.3.3. Motivation

We assessed motivation towards anatomy in the medical curriculum (3 items), as well as a self-rated estimate of studentś own performance within the anatomy course (3 items), and the general importance of anatomy for obtaining a medical degree (2 items). Items were created based on common models of motivation (Ryan and Deci, 2000) containing intrinsic interest, attainment, and extrinsic values, as well as task difficulty (e.g., "Ím interested in learning about anatomy", "Itś easy for me to study anatomy", "I think knowledge of anatomy is rather important in the further course of my studies"). Items were rated on a 4-point Likert scale (1=strongly disagree, 2=disagree, 3=agree, 4=strongly agree). The internal consistency as a measure of the reliability was determined based on our sample (Cronbach's α =.78).

2.3.4. Learning strategies (LIST)

To measure learning strategies, we applied the LIST questionnaire ("Lernstrategien im Studium"; questionnaire to assess learning strategies of university students") created by Wild and Schiefele (Wild and Schiefele, 1994), a validated instrument developed from the Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich, 1991) and the Learning and Study Strategies Inventory (LASSI) by Weinstein (Weinstein et al., 1987). The LIST distinguishes three groups of learning strategies, cognitive strategies, metacognitive strategies, and resource-related strategies. Each group is divided into sub-categories. Cognitive strategies deal with direct information acquisition and processing, sub-categories include elaboration, organization, fact retention, and critical checking. Metacognitive strategies can be explained with goal setting, monitoring, planning, and verifying of the learning processes. Resource-related strategies include sub-categories such as choosing an optimal learning environment, time management, allocating attention, regulating effort investment, literature-research, or studying with colleagues. Principal component analysis revealed that the original 77 items can be assigned to eleven sub-scales (Wild and Schiefele, 1994). A validation of the original version was conducted by Boerner and colleagues (2005) with principal component analysis and Varimaxrotation that extracted 13 factors (organization, elaboration, critical checking, rehearsal, controlling, regulating, planning, attention, effort, time management, studying with colleagues, literature-research, and learning environment) as sub-scales explaining 64 % of total variance for this version. A short version with 13 sub-scales and 39 items was tested regarding factor structure and reliability by Klingsieck (2018). Confirmatory factor analyses support the scale values at sub-category level. Given that the short version is as reliable as the original one, we decided to use the short version for economic reasons (Cronbach's α =.80, based on our sample). All 39 statements on how often a specific activity has been done during the learning process are rated on a 5-point Likert scale (1=very rarely, 2=rarely, 3=sometimes, 4=often, 5=very often). In SPSS, a z-score for each strategy (cognitive, metacognitive, and resource-related) was calculated, which later presented the dominant study strategy during statistical analysis.

2.3.5. Anatomy test performance

The multiple-choice anatomy test (30 items) addressed the current study topic as well as the content students were tested on in the oral-practical exam. Each question scored one point, yielding a total of 30 points. The course during the fall semester dealt with anatomical pathways and upper and lower extremities. In the spring term the topic was on abdominal and pelvic anatomy. Both questionnaires consisted of an equal number of text-only questions or pictures where structures had to be identified, as well as factual or transfer knowledge (e.g., “Which is the supplying artery for the hamstring muscles?”, “During an axillar lymph node resection, the Nervus thoracodorsalis was damaged. Which movement in the shoulder joint is most likely restricted?", or “A patient comes into your practice with a problem with his right hand. During examination it turns out that when he is asked to close his hand, fingers 1 – 3 remain extended. Which nerve is most likely damaged?”). The internal consistency of the test was calculated based on our sample as an indicator for its reliability (Cronbach's $\alpha = .778$, $M_{30\ items} = 0.326–0.926$, $SD_{30\ items} = 0.069–0.253$)

2.4. Procedure

The study was conducted online via the learning platform *med. moodle*, due to the COVID-19 pandemic with limited accessibility to university premises. Every enrolled student has access to this platform as it is used by the medical faculty to provide information and study materials for each subject and course topic. As an incentive, participants were able to use the multiple-choice questions of this study as an additional study resource and to check, whether they have gaps in their knowledge about the current study topic. The study consisted of two parts, the learning strategies questionnaire, and the anatomy test. Only after answering all 39 items on the questionnaire, participants were able to work through the 30-item multiple-choice anatomy test. The study was accessible two weeks prior to the end-of-semester oral exam. The questionnaire had no time limit to answer, whereas the multiple-choice test was limited to 45 minutes. After finishing the test, participants had continuous access to all items to review their answers and use the items for studying purposes and exam preparation.

2.5. Statistical analysis

The analyses were completed using IBM SPSS Statistics for Windows, version 28 (IBM Corp., Armonk, NY). Descriptive statistics were calculated for media use distribution during different learning phases.

We performed an exploratory factor analysis to test whether the LIST items and factors match our data. KMO- and Bartlett test ($p < .001$), Kaiser-Meyer-Olkin (.609), total variance of 13 factors with Eigenvalue > 1 explained 60.036 %.

A cluster analysis was used to identify similar groups of different learner characteristics of our participants. Results of the LIST were z-standardized. Initial k-means cluster analysis was performed with two clusters. A following analysis with a three-cluster solution expressed the optimal distribution of participants in each cluster. Optimal results show a rather heterogenic distribution between groups and homogenous within the groups. To confirm the three-cluster solution a hierarchical cluster analysis was performed.

To identify differences in test performance between the clusters, we conducted an ANOVA with cluster as independent and test performance as dependent variables. Further, we performed Pearson-correlations between motivation and different learning strategies. A pairwise comparison for the different clusters on test performance with post-hoc test (Turkey-HSD) was conducted. Lastly, a stepwise linear regression was performed to investigate learning strategies and motivation as potential predictors for test performance. The significance level for all statistical analyses was set to $\alpha < .05$.

3. Results

Media Use for Studying. While studying new information, mostly used media resources were books with more than 300 pages (*M= 2.41, SD= 1.35*), own notes (*M= 2.36, SD= 1.23*), online lectures (*M= 2.69, SD= 1.31*), and learning platforms (*M= 2.48, SD= 1.49*). During rehearsal phase prior to the exam students used own notes (*M= 2.37, SD= 1.40*) and learning platforms (*M= 2.64, SD= 1.53*) for the most time. For both knowledge acquisition (first percentage value) and rehearsal (second percentage value), they were using *Quowadis* (*44.4 % - 41.7 %*) and *Amboss* (*29.6 % - 26.9 %*), both German learning platforms. Quowadis has a focus on anatomy only, whereas Amboss is a complete medical knowledge platform for every topic taught in medical school and beyond. For apps, the students were using *Visible Body Atlas 3D* (*46.3 % - 40.7 %*) and *Amboss* (*11.1 % - 10.2 %*). Question banks were previous exam questions from the anatomy course (*25.9 % - 25.0 %*) and test exams on the *Amboss* platform (*16.7 % - 19.4 %*).

Learning Strategies and their Relation to Student Achievement. We performed a k-means cluster analysis, revealing three groups of students differing in their self-reported use of learning strategies: Cluster one ($n = 29$) employed predominantly metacognitive and resource-related strategies, cluster two ($n = 33$) predominantly cognitive strategies, and cluster three ($n = 46$) very few and no specific learning strategies, see Fig. 1. The cluster analysis revealed two clusters with students who are engaging in learning strategies (57.4 %), whereas 42.6 % of students made up the third cluster with no relevant use of any above-mentioned learning strategy. Cluster one consists of the smallest number of students and a predominant use of metacognitive and resource-related strategies. We call this group of students the *meta-strategy-learners*. Students in this group presented good time management skills as well as having enough social support and knowing about effective study environments for their learning. In addition, they have good skills in monitoring and supervising their learning strategies. Cluster two consisted of students who engage mainly in cognitive learning strategies. Consisting of deep-learning and surface-processing (e.g., rehearsal), we call this group of students *cognitive-strategy-learners*. And lastly, the third cluster with the highest number of students, are those who do not engage in any specific learning strategy (*mixed-strategy-learners*). An ANOVA with the clusters as independent variable and test performance as dependent variable showed no significant effect $F(2,105) = 2.922$, $p = .058$, partial $\eta^2 = .053$. However, the probability value near the chosen significance level and visible descriptive differences in test performance between the clusters (cluster one $M = 16.21$, $SD = 7.05$, cluster two $M = 20.18$, $SD = 5.78$, and cluster three $M = 18.70$, $SD = 6.64$) prompted pairwise comparisons and post-hoc tests (Table 1). These hinted inconclusively at possible significant differences in test performance between cluster one and two (pairwise $p = .018$; Tukey HSD $p = .047$).

To further test whether individual strategies (rather than the membership of students to a certain strategy pattern) would be related to performance, a stepwise linear regression identified cognitive learning strategies ($\beta = .269$) and motivation ($\beta = -.277$) as significant predictors for test performance ($R^2 = .149$, $p = .003$) (see Table 2). To further explore how motivation would be related to the use of certain learning strategies, correlational analyses were run (see Table 3). Motivation was correlated with the use of metacognitive strategies, $r(108) = .255$, $p = .008$, and the use of resource-related strategies $r(108) = .435$, $p < .001$.

4. Discussion

To evaluate the effect of learning strategies on test performance, we grouped medical students into three different groups corresponding to their dominant use of learning strategies. When looking at test performance, the *cognitive-strategy-learners* reached the highest score, followed by the *mixed-strategy-learners,* and the *meta-strategy-learners* with the lowest performance. Even though the ANOVA showed no significant differences between clusters regarding test performance, there are visible differences in test performance between the clusters and a possible significant difference between the *cognitive-strategy-learners* and the *meta-strategy-learners*. Students who mainly engaged in cognitive strategies benefitted regarding test performance in the anatomy course. One potential explanation could be the study material itself, the type of

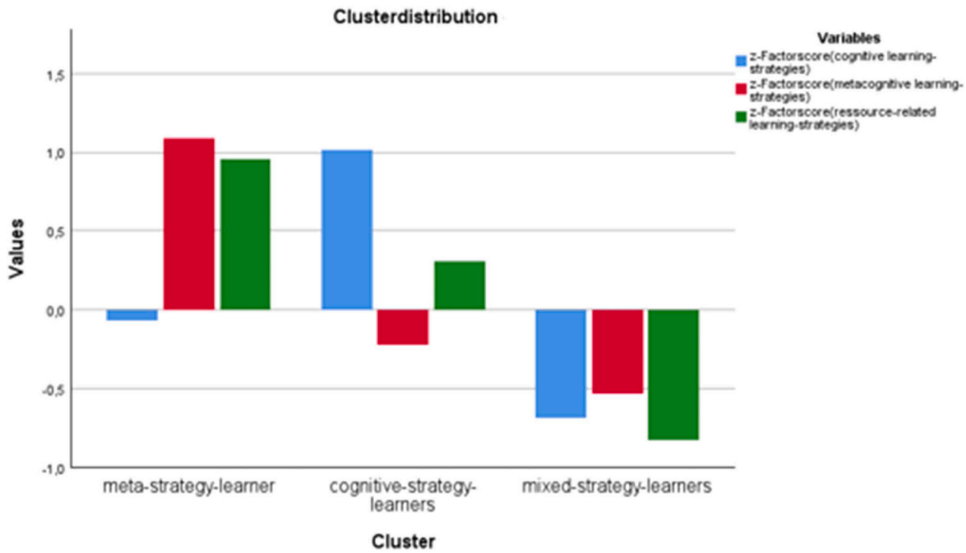

Fig. 1. Result of the k-means cluster analysis on students' use of learning strategies.

Table 1
Result of post-hoc test with test performance as dependent variable on different clusters solutions.

Multiple Comparisons

Dependent variable: Score_Test Performance

Tukey HSD

(I) Triple Clustersolution	(J) Triple Clustersolution	Mean Difference (I-J)	Std. Error	Sig.	95 % Confidence Interval	
					Lower Bound	Upper Bound
1	2	−3.9749*	1.65653	.047	−7.9132	−.0367
	3	−2.4888	1.54316	.245	−6.1575	1.1800
2	1	3.9749*	1.65653	.047	.367	7.9132
	3	1.4862	1.48469	.578	−2.0435	5.0159
3	1	2.4888	1.54316	.245	−1.1800	6.1575
	2	−1.4862	1.48469	.578	−5.0159	2.0435

Based on observed means.
The error term is Mean Square (Error) = 42.356.
* The mean difference is significant at the .05 level.

Table2
Result of stepwise linear regression of learning strategies and motivation on test performance.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	27.536	3.123		8.818	<.001
	Score_Motivation	−4.832	1.634	−.276	−2.957	.004
2	(Constant)	18.096	4.363		4.148	<.001
	Score_Motivation	−4.853	1.576	−.277	−3.079	.003
	Score_Cognitive Learning-strategies	3.200	1.070	.269	2.990	.003

[a] Dependent Variable: Score_Test Performance

questions used in the test, as well as the knowledge assessed in the oral exam. Factual knowledge is a key component of this course and its exams, hence studying anatomy through memorizing every muscle, bone, anatomical pathways, and innervation by heart can be a successful strategy. Therefore, cognitive strategies like organization, elaboration, and rehearsal might benefit learners more during the anatomy course than metacognitive strategies on monitoring of the learning process (Pintrich and de Groot, 1990; Zimmerman, 2002). Another aspect that should be considered is the different take on deep learners that follow an intrinsic goal to understand and question the study material, whereas surface learners more likely memorize the material just for test performance purposes. This difference can be seen in the different learning strategies of the cognitive and meta-cognitive learners (Dolmans et al., 2016). Because of the rather short amount of time and the large amount of study material, students have for each study topic, it is necessary to find a strategy that fits to this specific learning challenge. Since metacognitive strategies need planning, monitoring, and eventually re-evaluating of the current learning strategies, these strategies rather serve to fully understand connections between, for example, different organ systems, pathologies, or effects of pharmacology on the human body, but also require more time. Potentially the metacognitive group might benefit in later courses with a stronger focus on connecting

Table 3
Result of the correlation analysis on students' use of learning strategies and motivation on test performance.

Correlations

		Motivation	Cognitive Learning-strategies	Metacognitive Learning-strategies	Resource-related Learning-strategies	Test Performance
Motivation	Pearson Correlation	1	.004	.255**	.435**	−.276**
	Sig. (2-tailed)		.964	.008	.000	.004
	N	108	108	108	108	108
Cognitive Learning-strategies	Pearson Correlation	.004	1	.238*	.325**	.268**
	Sig. (2-tailed)	.964		.013	.001	.005
	N	108	108	108	108	108
MetacognitiveLearning-strategies	Pearson Correlation	.255**	.238*	1	.482**	−.046
	Sig. (2-tailed)	.008	.013		.000	.636
	N	108	108	108	108	108
Resource-related Learning-strategies	Pearson Correlation	.435**	.325**	.482**	1	−.127
	Sig. (2-tailed)	.000	.001	.000		.191
	N	108	108	108	108	108
Test Performance	Pearson Correlation	−.276**	.268**	−.046	−.127	1
	Sig. (2-tailed)	.004	.005	.636	.191	
	N	108	108	108	108	108

* Correlation is significant at the .05 level (2-tailed).
** Correlation is significant at the .01 level (2-tailed).

different areas of the medical curriculum, as well as understanding anatomical functionalities (Cale et al., 2023; Langdon et al., 2019). Nevertheless, this group of students still performed well enough to reach the 60 % passing mark, necessary to pass a test at university level. Lastly, the *mixed-strategy-learners*, performed quite well in our study. A possible explanation could be that other factors than learning strategies need to be considered when it comes to test performance. The phrases and situations displayed in the LIST might not fully be transferrable to the medical curriculum or a broader assessment is required to adequately capture learning strategies. Possibly, questioning students in a more detailed interview-style data collection, instead of only text-based questionnaires could yield further insights into their specific self-directed learning process. It is also unclear how *mixed-strategy-learners* perform when study materials get more complex and intertwined. The development of learning strategies in any of our groups warrants further study over the course of the whole medical curriculum.

As mentioned in the beginning, one key component for learning strategies and academic success is motivation. It can be seen as a prerequisite for initiating learning strategies and being engaged enough to constantly optimize learning and using learning strategies to perform well in medical school (Collins, 2009; Pelaccia and Viau, 2017; Zimmerman et al., 1992). Examining potential predictors for test performance and the extent to which motivation and learning strategies predicted test performance, we identified cognitive learning strategies as significant positive predictor. However, one needs to keep in mind that the regression model only explained about 15 % of variance overall. In contrast, motivation is found to be a negative predictor for test performance. This result was rather surprising, since motivation is generally a positive predictor for test performance (Zilundu et al., 2022). A potential explanation for this finding can be the rather short time students have to study for a test. Having the motivation to fully understand and learn every aspect of the anatomy test might require more time than there actually is available, especially as students in the first semester might be overwhelmed with the new requirements. As the oral exam is one of the first examinations in the medical study program, another potential reason for this finding could be an increased level of anxiety (e.g., test anxiety) and fear of failure (Pekrun et al., 2002), given that oral exams is a test format that is not trained in undergraduate medical students. Assuming the overload of information in combination with the short time segments between each oral exam and the fear of failure, this could potentially result in students indicating high motivation but nonetheless low test performance. Further investigation regarding motivation in the context of a stressful environment should be evaluated to shed further light on this potential negative association.

Another finding was the correlation between motivation and metacognitive learning strategies as well as resource-related strategies (Honicke and Broadbent, 2016). Even though these strategies made up our first and lowest performing cluster, it was a finding that again showed the relevance of motivation during medical school. Especially metacognitive learning strategies consist of a constant evaluation and monitoring of students' own learning strategies with the ability to adapt the strategies for a better learning outcome and better academic achievements in the long run (Cho et al., 2017). To investigate what keeps medical students motivated and what learning strategies they use to sustain a successful self-directed learning process during the years of medical school and beyond, further studies are needed. Potentially, a longitudinal study assessing students' development of motivation and learning strategies over the course of the six years of medical school can yield relevant insights.

5. Limitations

There are some limitations to this study. Firstly, compared to the total number of 919 first year medicals students, only 108 students filled out all questionnaires and answered the multiple-choice test. Since the study took place during the COVID-19 pandemic, most parts of the anatomy course were online and therefore we were only able to reach out to students via zoom sessions and social media platforms. Secondly, the study was completely online, and we were not able to monitor how the students answered the questions, especially the test. We also relied on self-reported answers on learning strategies and could only use the LIST as a type of data acquisition. However, as the reward for the study participants was formative feedback on their study progress prior to the final exam, we have good hopes that the students answered the test honestly. Thirdly, even though we acquired data from two different exams and time periods, we did not evaluate the complete semester and were not able to do a final examination of a potential adaptation of learning strategies over the course of time. We could not take into account the grade of the final oral exams to compare performance to the written test in our study, due to ethical restrictions and anonymity.

Lastly, we have no knowledge about the invested study time on the current test topic prior to taking part in the study.

6. Conclusions and recommendations

The study findings tentatively suggest that students employing mostly cognitive learning strategies achieved a higher test performance in gross anatomy. This can be explained with the type of questions used in the anatomy test, which were mostly assessing factual knowledge. A practical implication for medical education practice is to acknowledge the diversity of students' learning and motivational characteristics and implement teaching formats that benefit those who struggle with the fast pace and broad knowledge acquisition that is part of the medical curriculum. To keep students‘ motivation high, there should be a consideration of implementing clinical case studies to undergraduate classes, so that students have an idea of how the anatomy knowledge they are acquiring is necessary to understand why certain diseases cause specific symptoms and which therapy will be helpful. Using workshops to instruct on different learning skills, peer-teaching courses where test questions can be discussed, or problem-based learning classes where critical thinking and the relation to the later work as a medical professional can be taught. Students who reported higher motivation employed more metacognitive and resource-related strategies, which, however, did not benefit them in terms of test performance. We interpret the inconclusive probability values close to the chosen significance level as an indicator to replicate the study with a larger sample. Overall, this study stressed the relevance of learning strategies for self-regulated anatomy learning of medical students.

Ethical Statement

Written informed consent was obtained from all participants before participation in the study. All students were informed about the study, chances, risks, rights, obligations, and the voluntary nature of the study. Data were collected in pseudonymized form. Participants also agreed to the publication of the data in anonymized form. They could revoke their consent without incurring any disadvantage. Ethical approval for this study was obtained from the ethics committee at Ludwig-Maximilians-Universität München (no. 20–1115)

CRediT authorship contribution statement

Markus Berndt: Writing – review & editing, Supervision, Project administration, Conceptualization. **Laura Odontides:** Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Daniela Kugelmann:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Martin R. Fischer:** Writing – review & editing, Supervision, Conceptualization. **Thomas Shiozawa:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Katharina Scheiter:** Writing – review & editing, Supervision, Resources, Methodology, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.aanat.2024.152320.

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