Teaching Eye Tracking: Challenges and Perspectives

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Fig. 1. Example stimuli from the students' eye tracking studies overlaid with visual outputs of the recorded eye movement data.

Eye tracking studies are more complicated to design, conduct, and to evaluate than traditional studies solely based on performance measures like error rates and response times. This is typically due to the more complex hardware setup, the calibration procedures, and the spatio-temporal nature of the recorded data that must be analyzed, visualized, or statistically evaluated. As a benefit, eye movement data contains patterns of visual attention over space and time that are not observable in standard error rates, completion times, and qualitative feedback. Students in the field of visualization, human-computer interaction, and user experience represent an interest group that would benefit from the application of eye tracking during their studies and in their future careers. Consequently, instructing them how to design, setup, conduct, and evaluate an eye tracking study is of special interest to current researchers involved in teaching. We describe education in eye tracking in five courses with 79 students from bachelor, master, and PhD levels. We outline our concept and discuss the challenges to raise people with no experience in eye tracking to a level of knowledge that allows them to apply this emerging technology to different scenarios including visual stimuli and related research questions. We discuss our teaching strategy in two course setups (summer school and traditional university lecture), the results of the students' eye tracking studies, and which challenges they and the teachers faced during the course.

CCS Concepts: • **Human-centered computing → Visualization design and evaluation methods**.

Additional Key Words and Phrases: Eye tracking, Teaching, Education, User studies, Information visualization.

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1 INTRODUCTION

Eye tracking [22, 26] includes concepts and tools to evaluate how people perceive [53] and interact with visual stimuli, for instance, how people read text [4], how they interact with software [45], or how they behave in interaction with visual analytics tools [38], user interfaces [27], during game playing [17], or even how they communicate with others [19]. Knowing how to design and setup

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Fig. 2. Education in eye tracking: Theoretical lecture units are combined with practical design and conduction of eye tracking studies. The recorded data is analyzed with statistics, algorithms, and visualizations due to the complex spatio-temporal characteristics of the eye movement data. (Photo edited with Stable Diffusion)

an eye-tracking experiment is important in many research fields involving static and dynamic visual stimuli. How this knowledge can be transferred to undergraduates and which challenges occur lets us start with a research question:

> *What are the challenges and perspectives for non-experts in eye tracking when learning and applying eye tracking concepts and tools [11, 22, 26] for their research questions at hand?*

Our research addressed students from the field of Computer Science, with a focus on user experience (UX) [3], human-computer interaction [20], visualization [51], visual analytics [29], media and arts [24], as well as psychology [33]. We taught them theoretical and practical concepts to design and conduct eye tracking studies. We were also interested in the challenges during teaching [18] and whether it is possible to reach our goals in one university semester (less than 3 months) or in a two weeks summer school. The benefit of this research is twofold:

(1) **Student perspective:** We introduced newcomers to the field of eye tracking. They could become future researchers conducting user studies on visual attention and gaze behavior in general.
(2) **Teacher perspective:** The teachers learned the difficulties and challenges newcomers face when getting started with the topic. These findings are important to improve future lectures.

In this paper, we introduce the (successful) teaching concept that was built on multiple stages with a mixture of theoretical lecture units on eye tracking (see Figure 2) and practical parts introducing the stages involved when designing and conducting an eye tracking study [35] (see Figure 1 for some results from the eye tracking courses as visual examples and Section 4.1 for textual explanations of some of the eye tracking projects).

The courses on *eye tracking* ran 3 times at the University of Applied Sciences in Chur, Switzerland and at two summer schools at the University of Zadar in Croatia while they lasted 12 weeks (4 ECTS, European Credit Transfer and Accumulation System) as well as only two weeks in a summer school (also 4 ECTS). The 79 students in the 5 courses had never used an eye tracker before, and only two of them mentioned that they had heard about this technology for investigating research questions based on visual attention [25].

We could identify several design flaws in the courses' setups, the time schedules, the linking of the topics, and the challenges the students faced. Moreover, we learned which topics are relevant to teach, which caused challenges for the students, and which were time-consuming. We also had to engage the students to keep them interested, for example, by 10 weekly (or daily in the summer school course) assignments that had to be solved individually to keep everybody involved in the projects.

The guiding questions in the teaching setup were:

R1 Theoretical: How can we engage students and teach the required theoretical concepts of eye tracking?

R2 Practical: How can we prepare them for conducting a practical eye tracking study in our laboratory and for successfully applying their knowledge in future scenarios?

We consider the results of the courses as a positive assessment of our approach to address these questions (see Table 2 and the outcomes in form of eye tracking studies). The course led to positive outcomes like a published paper [55].

2 RELATED WORK

Table 1. Previous eye tracking courses including teacher(s), teaching formats, population, location, teaching years as well as missing topics related to our eye tracking courses: T = Theoretical, P = Practical, U = Undergraduates, G = Graduates

Teacher(s)	Formats	Students	Location	Year(s)	Refs.	Missing topics
A. Duchowski	T/P	U	Clemson	2023	[21]	Visual analytics
D. Niehorster	T/P	G	Lund	2023	[42]	Visual analytics
V. Sundstedt	T/P	U	Karlskrona	2016	[48]	Data analysis
K. Smet	T/P	U	Leuven	2024	[47]	Visual analytics
M. Burch	T/P	U/G	Zadar	2022/2023	[12, 14]	Data science/AI
M. Burch	T	U	Eindhoven	2020	[10]	Study design
F. Andersson	T/P	U	Abo	2018-2022	[1]	Visual analytics
A. Klavina et al.	T	U	Jelgava	2020	[32]	Visual analytics
P. Kiefer et al.	T/P	U	Monte Verita	2016/2023	[31]	Visual analytics

There is a lot of research in the field of eye tracking in education [13, 15]. But most of these approaches use eye tracking to monitor the visual attention of students or teachers [30]. The recorded data can be analyzed as a post process or in real-time with the intention to improve the teaching style and to figure out where and when possible negative issues in the teaching strategy occur [13, 39, 52]. Apart from monitoring, eye tracking is also used as a tool to interact, for example, in gaze-assisted interactions during lectures, for example for supporting a pointing task on large wall-sized displays [5]. All of these concepts are different from the work described in this paper. We do **not** primarily **apply eye tracking** in the course, but instead, we **teach eye tracking** as a topic [10], to facilitate the understanding of the technology to make newcomers [43] apply it and to ease the burden for future applications involving eye tracking.

Not much research can be found focusing on educating people **in** eye tracking (not **with** eye tracking). In our opinion, this step is important since it builds basic knowledge, and serves as a starting point to conduct eye tracking experiments successfully [46]. To this point, how to conduct eye tracking experiments with specific hardware is demonstrated and applied hands-on in sessions organized by hardware and software vendors, often as an additional service accompanying the purchase of the respective product. Other options are seminars introducing new hardware, or summer [12, 14] and winter schools [31] organized by academic institutions. However, these summer and winter schools typically lack time to teach all of the involved ingredients, theoretical as well as practical, to make the design, setup, conduction, and evaluation of the study and study results a success. Some tutorials, with a focus on how to analyze the data are also offered at conferences. Table 1 summarizes existing research with a focus on teaching eye tracking. Most of these courses are quite novel (mainly after 2020), focus on theoretical and practical parts, and are teaching undergraduates or graduates in separate courses. They also focus on the study design around eye tracking and the recording of the data. Only in rare cases they also take into account concepts of data science and artificial intelligence, or topics such as visual analytics [11] which combine those aspects with interactive visualization as options to analyze and visualize the visual attention data. In our work we created a teaching strategy that is easily adaptable and applicable to both, undergraduates and graduates, in different and also in the same courses.

Teaching eye tracking is a challenging task, in particular for newcomers in this emerging technology which is typically caused by the multi- and interdisciplinarity of eye tracking in general. Burch [10] describes a teaching concept based on visual analytics [29] and how a given eye tracking dataset can be visually analyzed [2] to derive patterns and insights from it. Although the data stemmed from an eye tracking study [41] the students in this teaching concept were not actually involved in designing and conducting their own eye tracking experiment, more in understanding what eye tracking is and how the data can be analyzed and visualized, which was mainly due to time limitations in the course and the fact that the focus of the study program was more on data science and not on usability and user experience.

Duchowski [21] teaches eye tracking for undergraduates focusing on various subtopics, the course is only for undergraduates while Niehorster [42] also includes graduates. Sundstedt [48] uses gaming applications as well as gaze-assisted interaction to illustrate the usefulness of eye tracking while Smet [47] introduces eye tracking on a more general basis. Anderson [1] comes up with several iterations of an eye tracking course while the education style of Kiefer et al. [31] is more block-based in the form of a winter school. All of them integrate theoretical and practical concepts while Klavina et al. [32] and Burch [10] only look into theoretical aspects. The teaching of Burch [10] also focuses more on the analysis of eye tracking data, but less on teaching eye tracking as a discipline to record visual attention. The only summer school variant of eye tracking teaching is related to the work of Burch [12, 14]. Most of the existing teaching styles do not really include eye tracking data analytics, either by visual analytics or data science.

There are different teaching styles [50], depending on the topic of the course the teaching style has to be adapted to the given situation. In particular for eye tracking, the course design requires a mixture of related topics from which the students must get some experience to successfully design and conduct eye tracking studies [34]. In this special case we have to deal with research fields like visualization [40, 51], human-computer interaction, perception and cognition [25], usability and user experience, psychology, data analysis, data science, statistics, artificial intelligence, machine learning, just to mention a few, and eye tracking itself [22, 26].

Moreover, the course has to switch between theoretical and practical units to make the learned concepts applicable which means another burden for the teacher who has to be familiar with the theory and the technological aspects at the same time [23]. This twofold teaching strategy requires more time than a traditional course with just theoretical lectures. Consequently, to reduce the time spent for the course, we decided to let the students solve the theoretical exercises individually but the practical part of the course has to be studied in groups, also meaning that the students have to collaboratively find solutions to the given problems, as an active learning scenario [44].

3 TEACHING STYLES, PARTICIPANTS, AND LECTURE UNITS

The courses were split into a theoretical and a practical part (see Figure 3). The theoretical part covers aspects required to understand the technology of eye tracking, the conduction of user studies, and the evaluation of the recorded data. The practical part demands for investigating a

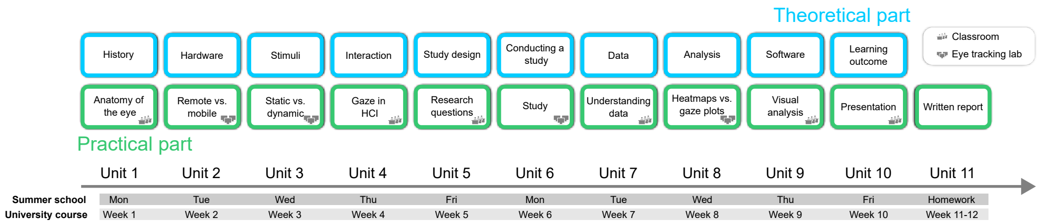


Fig. 3. The lecture units consist of 10 theoretical and 11 practical parts while the practical parts are based on the theoretical parts and temporally occur after each theoretical unit (to study the theory before starting with the corresponding practical unit).

research question by means of a real study guided by assignment sheets that have to be solved individually and practical assignments solvable in project groups. Consequently, the practical part is actually linked with the theoretical part unit by unit with one extra practical unit that is the reflection in form of a written report, i.e., the students first get familiar with the theory before they learn to apply them in a real setting. This combination generates learning effects step-by-step that accumulate to deeper methodological knowledge in the end.

Since we have summer schools and university courses we have to adapt the teaching units to each situation.

- **Summer schools:** Such a course runs over 2 weeks with 5 teaching days each, resulting in 10 teaching days in total. This means we can distribute the theoretical and practical teaching units equally over the days, i.e., each day one unit. The 11th practical unit (written report) is solved as home work. Each teaching day starts with a theoretical unit at 9 a.m. until 11:45 a.m with two 15 minutes breaks. After the lunch break we continue with the practical unit starting from 1 p.m. until 3:45 p.m, also with two 15 minutes breaks. This means each day consists of 6 subunits of 45 minutes, 3 theoretical ones and 3 practical ones. The summer schools were taught in English due to an international audience, including graduates and undergraduates.
- **University courses:** Such a course runs over 12 weeks (one semester) with one teaching day per week. This means we can teach the 10 theoretical and practical units on the first 10 teaching days while the last two remain for completing the eye tracking project as well as starting with the written report which is also part of the home work. Each teaching day starts with a theoretical unit at 1 p.m. until 2:45 p.m. followed by a practical unit at 3 p.m. until 4:45 p.m. This means we only have 4 subunits of 45 minutes, 2 theoretical ones and two practical ones, including three 15 minutes breaks. However, the course runs over a whole semester, meaning the students are not under time pressure as in the summer school setting and can also work from home to reach their goals. The university courses were taught in German.

The 79 students (42 females/37 males) were at an average age of 24.3 years (19 years the youngest/41 years the oldest). 72 of them were undergraduates while 7 were PhD students. 55 were students from user experience (UX), 9 from media and arts, 4 from design, 3 from psychology, 3 from data science, 3 from data visualization, and 2 from computer science.

3.1 History and Technologies

We decided to provide a brief historical background about the field of eye tracking [22]. This lets the students understand the challenges in the early days and how the technology advanced to bring more and more improvements into the field, making eye movement data more exact and the eye tracking devices less invasive. For this reason we introduced the core ingredient in each eye tracking study, the human eye, from an anatomical perspective.

We explained typical technologies based on the use of cameras, videos, infrared light, and pupil detection. The technologies were demonstrated by examples from the web while we brought some eye trackers like the Tobii Pro Fusion, Pro Glasses 2, or Pro T60XL to the classroom. The teacher demonstrated a simple eye tracking experiment.

Practical Unit 1: Eye Movement Observation (in the Classroom). The human eye is relevant since students understand which anatomical issues can cause problems when conducting an eye tracking study. Sometimes this leads to calibration problems with the device, or study participants cannot see visual objects correctly. Students learn how to check for color deficiencies, color blindness, or visual acuity problems, for example, using an Ishihara test and a Snellen chart.

It is important to understand how the eye muscles work to perform typical movements for saccades and fixations [53] that can be found in the eye movement data. For practical reasons we let them work in groups of two: One student gives a task and a visual stimulus (e.g., reading text on paper or finding Waldo), the other student is trying to solve the given task. During the task, the student who gave the task should observe the eye movements of the student solving the given task. This illustrated that humans do not make smooth eye movements, but the eyes jump in saccades and stay relatively still during fixations for most tasks that do not include smooth pursuits of moving objects.

3.2 Hardware and Devices

In this stage, we explained the differences in eye tracking devices and their applications, typically depending on the stimulus involved to investigate a research question. Wearable head-mounted and remote eye tracking devices were introduced. Since our laboratory is equipped with both, remote and head-mounted eye tracking devices, we conducted test studies with the students in the laboratory with each type separately. These tests gave them a first impression about each setup and how the hardware worked.

Practical Unit 2: Remote vs. Mobile Eye Tracker (in the Lab). This unit was held in the lab to avoid moving the eye tracking devices to the classroom and to show the students the room in which an eye tracking study might be conducted isolated from many outside distractions (in case no mobile eye tracker is used in the outside world like in a field study). The students can use the provided eye tracking devices to get a first connection point and to experiment with the technology. The idea in this unit is trial-and-error which finally results, at least in our opinion, in learning effects.

The students can use their own stimuli but they can also use the ones provided by the eye tracking devices as some kind of test setup. They learn the typical steps that are required when starting an eye tracking study, including the accommodation phase, the calibration procedure, the parameter setting, and the like. They just make first primitive experiments to get prepared for the real eye tracking study that has to be conducted in a later stage in the courses.

3.3 Stimuli

There are various types of stimuli in the real world to examine in an eye tracking study. The students first formulated a research question that determined the corresponding visual stimuli (see Section 4.1) to investigate. The stimuli can be static or dynamic, they can stem from the real world. Static stimuli might be pictures, screenshots, or paintings while dynamic stimuli might be interactive visualizations and diagrams, user interfaces, web pages, videos, animations, or even the real world. In the theoretical lecture the stimuli types are discussed with various visual examples.

Practical Unit 3: Static vs. Dynamic Stimuli (in the Lab). Depending on the stimulus the students had to decide for a specific eye tracking device. They had to formulate their research question, think about possible stimuli, and play through a real scenario with the stimuli, as a first step without including an eye tracking device.

This procedure should show them the difference between studies with and without gaze recording. Without eye tracking this kind of data would not be recordable in its fine granularity. After the aforementioned steps they had to integrate the found stimulus in an eye tracking device. The biggest challenge in this stage is to figure out whether the stimuli can be shown to the study participants and if the eye movement data is recorded in the way it is required to find hints about the answer to the research question. Moreover, if several stimuli have to be shown in some kind of sequence it can be a challenge to setup the corresponding experiment with pauses between the several stimuli.

3.4 Gaze-Assisted Interaction

Instead of just looking at a stimulus, we also taught the students that the eyes can be used as an interaction modality, to actively change or modify the content of a stimulus. Designing an eye tracking study involving gaze-assisted interaction is challenging since it requires analyzing the recorded eye movement data in real time and to link the eye tracker with the stimulus to actively change its content. This requires experience in software development and data analysis to achieve an efficient system that reacts on users' eye movements in fast rates.

We did not expect the students to develop a research question focusing on this topic but for reasons of completeness, we introduced this topic. The problem here is that the students need profound knowledge in programming and software engineering. Moreover, challenges related to the Midas touch problem [49] might occur demanding for several interaction modalities in addition to gaze-based interaction. The Midas touch problem is a popular challenge during gaze-assisted interaction since each visual element in a user interface might be a candidate to interact with and to activate even when there is no intention to do that. The problem is that the eye is always switched on.

Practical Unit 4: Gaze in Games vs. HCI (in the Classroom). We provided them with an already implemented system supporting gaze-assisted interaction and let them experiment with the included features. They realized the Midas touch problem and ways to get around it by combining further interaction modalities like voice/speech, touch, or gestures.

For the gaming experience with gaze support we let them read a scientific paper [17] and report on the challenges. They should discuss the possible combinations with other interaction modalities as well as the different display options like small-scale, medium-scale, or large-scale ones including smart phones, standard computer monitors, or large displays.

3.5 User Study Design

User studies can come in at least two ways: an exploratory way like understanding the user-friendliness of a web page or in a comparative way like comparing two or more variations of shown stimuli. The variations are mostly based on the independent variables that are tested for their impact on dependent variables, for example error rates, response times, or eye movements [11].

Also typical performance studies measuring error rates and response times should be taught to explain the general study procedure. Hence, we consider a special case of a user study, with eye tracking devices involved as supplemental means of evaluation measuring and recording an additional dependent variable in form of spatio-temporal gaze distributions [16] containing fixation positions, fixation durations, saccade lengths, saccade orientations, and more statistical-like measures [6] that might be used to find answers to the formerly stated hypotheses and research questions.

We emphasized the importance to start with a research question, build hypotheses focusing on this research question and then identify the independent, dependent, and confounding variables. Also, the study design in form of between-subject, within-subject, or mixed designs is important. The recruitment of participants with additional questionnaires about demographics and post-study qualitative feedback and the value of pilot studies were also discussed.

Practical Unit 5: Research Question and Design of the Study (in the Classroom). The practical part consisted of brainstorming in the group and to design the study with all of its ingredients required to successfully conduct the study. Conducting a pilot study was mandatory to uncover many problems before running the real eye tracking study.

To get feedback to improve the eye tracking study, the students prepared a preliminary oral presentation. This was commented from all other students and the lecturer to avoid design flaws in the study before the real experiment had to be conducted. This helped the students to get started and to feel much safer before inviting study participants.

3.6 Conducting an Eye Tracking Study

The real project starts with conducting the study after the design step. This phase starts in this unit and progresses over the following units. The students first had to come up with a research question. They got some initial coaching but after that, they had to tackle the problems alone, based on the gained experience from the course. They could ask for help during the experiments.

The students had to combine all of the aforementioned concepts. All of this required to find a research question, to create questionnaires and personal feedback forms, to design and setup the study, to find participants, to check and calibrate the eye tracker, to record data, to request after-experiment feedback, and several more.

Practical Unit 6: The Real Eye Tracking Study (in the Lab). The students had to inscribe themselves (as a group) in a suitable time slot to reserve the lab to conduct the study (also in several time slots if the study is complex or many participants are involved). This organizational step is required because we have several groups in the courses, all of them needing their own time slots, hence avoiding the possibility of time conflicts. The students had to recruit participants, focusing on age groups, genders, or personal preferences, even experts or non-experts from certain application domains.

The real study comes with surprises and unexpected events that were not included in the study design. The learning outcome in this unit is that the students actively conduct such a study to see eye tracking working in real life, with all of its benefits and drawbacks. Learning-by-doing is the best option to apply the theoretically learned concepts in a practical environment. Even if we discussed various concepts and aspects in the theoretical units, a real study finally shows the effects in real life that cannot be learned and experienced purely theoretically.

3.7 Eye Tracking Data and Recording

The spatio-temporal nature of eye movement data makes the storing and data handling complicated. The students learned about the structure of the data and the data types, in which data format it can exist, and what the most important attributes in the data are. Apart from the space and time components of eye movement data we can also observe and compare individual participants or groups of them, bringing them into some kind of relational behavior, for example, following certain common visual task solution strategies [2]. Moreover, eye movement data can be complemented by additional physiological measures which might generate big data [6].

We also taught the students to keep an eye on the formerly stated research questions and hypotheses when exploring and analyzing the eye movement data. This step is important to focus on the most important data ingredients to make it a valuable source to find patterns in the data, over space, time, and participants that can be remapped to claims made in the research questions and hypotheses. There is a large repertoire of data analysis and visualization techniques [7].

Practical Unit 7: Understanding Eye Tracking Data and Physiological Measures (in the Classroom). In the practical part they got an eye movement dataset from a formerly conducted eye tracking study [41]. This data was given in a readable format in a text file and had to be inspected visually but also from a more statistical perspective. This step helped getting familiar with eye movement data in general and how the features of the eye movements are included.

Exploring the data given in a text file is important since the students learn how to apply a method to find useful insights, i.e., they are freed from the provided software integrated in each eye tracking device. Moreover, in this practical unit they learn how to download and export an eye movement dataset in its raw form and can link the formerly learned data features with the features contained in the exported dataset from their own eye tracking study.

3.8 Data Analyses and Visualizations

Before starting with data analysis concepts, we explained ethics and privacy issues related to the recorded data. Moreover, we looked at statistical approaches to find insights, patterns, and correlations in the data. We also showed and explained some algorithmic concepts to analyze eye movement data, involving ordering/sorting, clustering, dimensionality reduction [9], data mining [8], and the like. General techniques from the field of data science were introduced to provide them more ways to analyze the data. Apart from algorithms we also explained visualizations [7].

The best way to experiment with the data analyses and interactive visualizations is by means of the eye tracking devices and their integrated software. Although there is already some support, the eye tracking software can only create the most prominent visualization techniques, however also those are already difficult to learn and to apply.

Practical Unit 8: Heatmaps vs. Gaze Plots (in the Lab). In the practical part the students had to experiment with the device-integrated software for data analysis and visualization. They learned about visual attention maps and gaze plots, we explained the usefulness of AOIs and many more techniques. They started a first attempt to explain the eye movement data in terms of visual attention behavior from the study conducted earlier (Section 3.2).

We also explained them the eye-mind hypothesis [28] and let them think about how reliable and expressive their eye movement data really is to find hints about research questions and formerly stated hypotheses.

3.9 Analysis and Visualization Software

We showed them interactive analysis and visualization tools [36, 37], even visual analytics tools to explore and analyze the eye movement data. Two types of tools were introduced, those for static stimuli and those for dynamic ones like videos. The tools were equipped with algorithms like clustering, AOI detection and annotation, dimensionality reduction, ordering and sorting, as discussed before. Moreover, many interaction techniques [54] are incorporated.

The goal was to show more advanced tools, those that are typically not integrated in eye trackers. However, getting the software run for the recorded eye movement data is more complicated than when using the integrated software.

Table 2. Evaluation of the practical units: For each unit we explain some negative issues that occurred while we also evaluated each unit by giving a number of reached points. The percentage value over all project groups gives an evaluation score for each unit.

Practical unit	Description of unit	Issues	Evaluation score (in percent)
1	Eye anatomy	Shy students/not communicative	95.6
2	Remote vs. mobile	Getting started	96.7
3	Stimuli	Dynamic stimuli	92.3
4	Gaze in HCI	Interaction modalities	92.3
5	Research questions	Questions too general/variables	90.4
6	Real study	Recruiting participants/starting	92.3
7	Understanding data	Data format/statistics	91.0
8	Heatmaps vs. gaze plots	Overlaying of data	89.8
9	Visual analysis	Getting the tools installed	86.4
10	Presentation	Presentation speed/improvable results	91.3
11	Written report	Missing content	92.5

Practical Unit 9: Experimenting with More Advanced Software for Visual Analytics (in the Classroom). We made the tools accessible for the students and gave them the task of uploading their own data to find patterns, correlations, and insights. The tools provide more functionalities than the traditional software integrated in the eye tracking devices, but negatively, the learning effort is higher to get started with such a data analysis and visualization tool.

3.10 Learning Outcomes, Oral and Written Reflection

We explained how to structure a presentation related to eye tracking studies by showing them other Powerpoint presentations from related topics. Moreover, they got an introduction in Overleaf which is a way to collaboratively write LaTeX documents. The goal of these two presentation stages was the reflection of the learned concepts, with the goal to describe the formerly designed and conducted study step-by-step. This stage helped to show the audience, i.e. all other students, which research question was tackled by the others and what results have been achieved.

Practical Unit 10: Powerpoint Presentation (in the Classroom). We asked them to create a Powerpoint presentation of 15 minutes containing the most important concepts while using the terminology from the course. The final presentation in the university courses is two weeks later, to give the students some time to prepare and polish their slides. In the course they presented first ideas and collect some feedback. In the summer school setting the students do not create a thorough and structured Powerpoint presentation, they gave preliminary results from their eye tracking experiments. However, each group member should present a few minutes. After the presentation the audience should ask questions before the lecturer started asking questions. The oral presentation has an impact on the final grade in the eye tracking courses.

Practical Unit 11: Reflection in a Written Report (at Home or in a Meeting Room). As a final practical unit the students had to collaboratively reflect on their findings in a written report. This report is based on a given LaTeX template to get similar characteristics for the layout, font styles and sizes, visual appearance of the reports, with the goal to allow the lecturer the evaluation on a comparative basis. We also set the page limit to four pages plus one for references, as in scientific publication organs. In the summer school setting they create the final report as a pure home work and have to hand in the result 4 weeks later. In the university setting the students start the writing in the practical unit 11 and receive some useful hints and improvements. Also in this course setting they have to hand in the final result 4 weeks later.

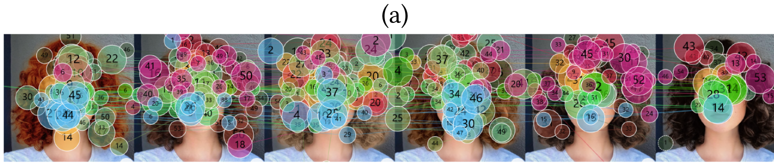
4 RESULTS FROM THE COURSES

We received different types of results from the courses which could be classified into the eye tracking projects themselves (practical part (not graded directly)) (Section 4.1)), the grading outcomes (theoretical part: exercises (25 percent), oral presentation (25 percent), written report (50 percent)) (Section 4.2), and the general outcomes based on the practical units (not graded directly) (Section 4.3). Table 2 gives an overview about the outcomes of the practical units in form of an evaluation score computed by the reached points divided by the maximum points over all project groups. Moreover, we describe negative aspects that we encountered after the evaluation of each practical unit. From the evaluation score we can see that the students were able to solve the tasks more or less successfully.

4.1 Eye Tracking Projects

Since there were 79 students having taken part in the five courses, we created 23 groups of 2 to 4 students each. All of them had to come up with an interesting and relevant research question. Here are a few examples:

(a)



(b)

Fig. 4. Static stimuli (photos) of women with varying hair colors: Overlaid with a visual attention map (a) and a gaze plot (b).

Watching News: The study focused on the question on which parts of news articles are paid visual attention to. The stimuli consisted of images and corresponding text that explains the news articles. The topics of the news articles varied and came from the field of sports, politics, or nature, to mention a few. 8 participants took part voluntarily in the study. The major results are that people mostly read the text below an image and seldomly visually attended the image itself.

Hair Colors: The major research question in this study was to find out which hair color is attracting the people the most or whether there are any differences in the visual attention behavior at all. The static stimuli were created by using the same face of a woman and by varying the hair color with an external tool. 9 participants were recruited (5 female and 4 male) who took part voluntarily. Figure 4 shows that the visual attention behavior is different from hair color to hair color and that many participants visually attended the face instead of the hairs.

Grayscale vs. Color: The general research question was given by the fact whether color in images is important for the efficiency of search tasks. The stimuli were static scenes from our everyday life, once in its full color and once artificially transformed into a grayscale image. The visual attention is very different in the grayscale images due to the longer fixation times. 8 participants took part voluntarily in the study.

4.2 Grading Outcomes

To measure the learning success the students achieved, based on our teaching concept, we got feedback in form of three different grading components. The components counted differently for the final grade: The theoretical exercise results for 25 percent, the oral presentation for 25 percent, and the written report for 50 percent.

Exercise results: The 10 individual and theoretical assignment sheets have been solved by all 79 students, meaning we got 790 solutions in total from the four courses with a maximum of 20 points for each solution. From the maximum of 15,800 points the students reached 14,883 points which means that more than 95 percent of the exercises have been solved correctly, i.e. we reached our goal in form of a learning effect, topic-interested, and enthusiastic students.

Oral presentation: The presentation of 10 to 15 minutes was given by each of the 23 student groups while each group member had to present at least 2 minutes. We asked questions to check if everybody participated regularly and was able to reflect on the study setup and the major findings. The maximum number of points for the presentation component was 200 with an average of 177 points, showing again that we were confident with the learned and presented concepts.

Written report: As a final step we asked them to write down a four-page report in form of a conference paper (all groups were provided with the same template). We gave them an example of such a report in Overleaf produced by using LaTeX. All of the groups were able to reflect on their study design and how they conducted the study while they also presented the results in form of insights that focus on the formerly given research question and the hypotheses. The maximum number of points for this component is 400 while on average they reached 341 points.

In general, all of the grading components uncovered that the students were able to apply the learned concepts related to eye tracking. The average grades were quite high and the study results in form of oral presentations and written reports were understandable and reproducible with interesting insights.

4.3 General Outcomes

We based our findings on the reached learning goals by evaluating the daily or weekly practical units. The tasks in these units were given verbally (not as written text as in the theoretical assignments) at the beginning of each practical unit. The teacher had a score sheet in which the reached points for each practical subtask were filled in, for each project group separately. By monitoring and interviewing the students during the practical units the teacher got a clear impression about the difficulty levels of the individual practical units per project group and could write down those difficulties and challenges the students faced (see Table 2 for percentage values of those results over all groups.) For example, for the practical unit 1 some students disliked that someone else observed their eyes. Asking them about this issue they mentioned that they were actually shy people.

- **O1** The students learned the challenges and pitfalls of eye tracking, in theory and practice, and which components are involved in this interdisciplinary field to get eye tracking studies running successfully. Apart from the special field of eye tracking they also learned about designing and conducting general user studies.

O2 Before starting to design the study they had to find a research question and hypotheses which brought into play stimuli and the required technology with a supported eye tracking device in our laboratory.

O3 The most practical part of the course was to conduct an eye tracking study with real participants. This real-world study showed that the learned concepts could be realized.

O4 The recorded eye movement data had to be taken into account and to be matched with the formerly stated research question and the corresponding hypotheses. To reach this goal they had to work with the recorded data, analyze it, visualize it, and identify patterns and correlations, either by using the integrated software or by using external analysis and visualization tools as presented in one of the lecture units.

O5 As a reflection step the students had to orally present their study design, setup, conduction, results, and lessons learned. Moreover, they had to prepare a written report in form of a scientific paper. The 10 individual and theoretical exercises already gave a lot of input for the written report.

4.4 Summer Schools vs. University Courses - A Comparison

When comparing the results of the courses, we can argue that the summer school seems to produce better results in terms of final grades (5.41 vs. 5.23 on a grading scale from 6 (best) to 1 (worst)). This advantage of summer schools over university courses holds for the practical units (5.73 vs. 5.49), the theoretical exercises (5.33 vs. 5.01), and the oral presentations (5.88 vs. 5.05). Surprisingly, the written reports are graded lower in the summer school settings (5.22 vs. 5.34). This might be due to the fact that some participants in the summer school do not have the pressure of getting a good grade, they just participate. However, we must also keep in mind that the participants in the summer schools are older in average (28.4 vs. 20.7) and hence might have gained more experience before. Finally, we cannot really say which course format is better or has advantages over the other one. Both of them result in good grades and learning outcomes.

5 LESSONS LEARNED

After the courses we are positively surprised how smoothly everything worked out (apart from a few negative issues (see Section 6) that could be easily fixed in the next editions of this course). Not only the students learned a lot on eye tracking but also the teachers learned a lot, also to improve future courses on the same topic.

5.1 From the Teachers' Perspective

The general structure of the course with 10 partially independent suptopics was adequate while the last lecture unit was used for the oral and written presentation. Also the order of the lecture units was well chosen and the topics were connected and built on each other. There are some major lessons that we learned.

(1) **Course components:** The splitting into theoretical and practical parts was adequate and let the students first learn the theory before applying it in practice.
(2) **Course grading:** The three grading components were reflecting the individual and group work and could show if the taught concepts were understood and could be applied.
(3) **Daily/Weekly assignments:** The daily/weekly theoretical assignments and exercises let each student participate day-by-day/week-by-week to learn the material and to avoid a learning load in the end.
(4) **Selected subtopics:** The subtopics were suitable to bring newcomers in the field to an experience level to design and conduct their own eye tracking studies.

There is room for improvements. We might consider additional topics related to eye tracking such as virtual and augmented reality with immersive analytics as one of the major techniques in the future. We also found the topic of gaze-assisted interaction useful but designing a study related to this topic is really challenging.

5.2 From the Students' Perspective

Apart from the learning goals in the eye tracking courses the students learned several other things. A student feedback after the courses reflected many insights on the lessons learned from the student side.

(1) **Group collaboration:** They learned how to work individually, but actually collaboratively design and conduct an eye tracking study in a group of people was positively received.
(2) **Teacher feedback:** Although the weekly assignments meant a lot of work they were accepted as positive, not only because of the continuous teacher feedback but also because they had to repeat each lecture unit.
(3) **Involving other people:** There are not many courses at the university that involve other people than those people already studying or working at the university. In the eye tracking course they could involve friends, colleagues, relatives, or strangers from the street, turning the eye tracking study to a socially engaging situation.
(4) **Scientific paper writing:** Writing a report is normally not liked but collaboratively writing text by using Overleaf and LaTeX was considered to be easy although in the beginning the students were skeptical.

6 CHALLENGES AND LIMITATIONS

For each challenge we provided some option to circumvent this issue in future editions, i.e., as a take-away for other teachers interested in education in eye tracking, be it in a summer school or in a university.

- **Device conditions:** We need to work with eye tracking devices to let the students conduct their studies reliably. It is important that the devices are always in good repair. This should be tested before using them.
- **Device functions:** One important function is the calibration, otherwise the study results are hardly interpretable. The teacher should check the calibration functionality before the students start their eye tracking study.
- **Missing participants:** Finding participants can be a daunting and time-consuming task. Here it is a good advice for the teacher to have some kind of backup of study participants that can help out.
- **Social problems:** The students need to collaborate, causing a barrier for some students. This should be discussed as early as possible and there should be a teaching assistant who is available when such problems occur.
- **Privacy issues:** Some research questions might cause ethical or data privacy problems. Some universities have an ethics commission that should be asked early enough.
- **Software issues:** The software integrated in the eye tracking device might not be working. Also in this case a teaching assistant or someone from the technical staff could help. Moreover, it is also advisable to ask the eye tracking companies for support in such situations.
- **Student drop out:** There are many reasons why students might drop out from a course. There is always an option to put together two groups. However, if they are already quite far with their eye tracking study, the groups must match topic wise.

- **Course scalability:** In our courses we typically allow up to 20 students. If many students are involved, the teaching, supervision, assignment correction load, and the number of eye tracking devices is much higher. One idea is to limit the number of students beforehand or to create larger project groups.

7 CONCLUSION AND FUTURE WORK

We presented a teaching strategy for courses on eye tracking, either as summer schools or university courses. 79 students took part in them and they had to follow theoretical lecture units and also practical ones. Daily/weekly individual and theoretical exercises were given to constantly check whether the students could follow the taught concepts. An oral presentation showed the eye tracking study and the results while a written report finally reflected on the findings. Given the fact that the grades were quite high and that the learning goals were mostly reached, we consider the courses to be successful. The major take-away is that eye tracking can be learned in a few days/weeks, even for non-experts with nearly no experience, both the theory behind it as well as a practical application in form of a self-designed eye tracking study. However, for future scenarios we plan to modify the teaching plan by providing them more time for the real eye tracking study. Moreover, we will adapt some of the subtopics to make them a better fit with the corresponding eye tracking studies.

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