Flexibility and Social Disconnectedness: Assessing University Students' Well-Being Using an Experience Sampling Chatbot and Surveys Over Two Years of COVID-19

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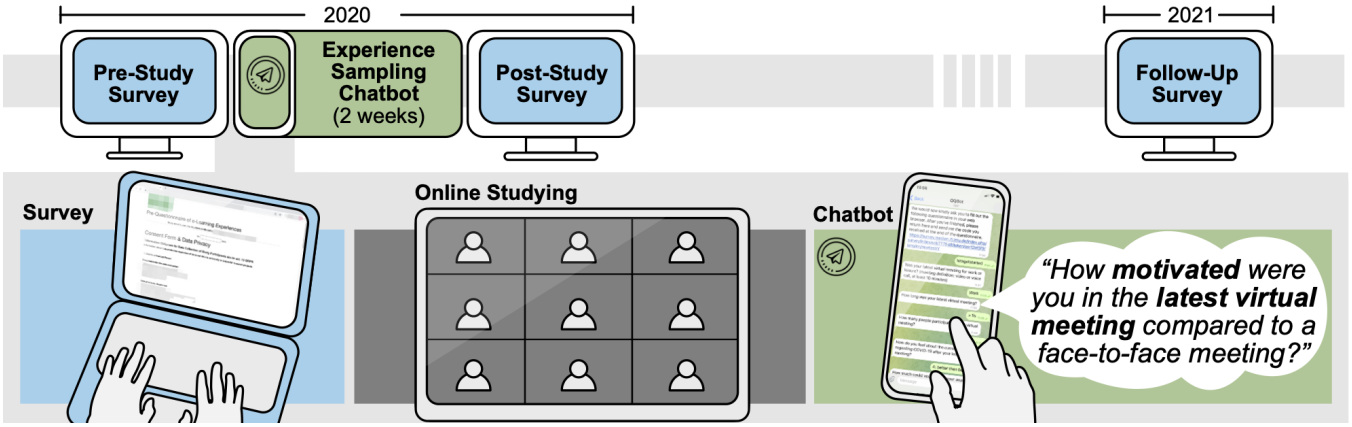

Figure 1: We conducted a hybrid study using an experience sampling chatbot and surveys to assess students' experience during COVID-19. The study timeline consists of a pre-survey, a 2-week student experience sampling through a chatbot, and a post-survey in 2020, with a follow-up survey in 2021. The three storyboards illustrate study scenarios in which students filled out surveys on laptops, experienced virtual meetings for online studying, and answered chatbot questions on their phones.

ABSTRACT

COVID-19 caused an abrupt switch from face-to-face to online teaching. This led to unknown challenges and consequences for students and lecturers. In the first semester after its outbreak, we developed a messenger-based chatbot to perform an experience sampling study to evaluate students' well-being and experiences ($n = 31$) with the radical changes in higher education. Finding a decrease in students' perceived motivation but an increase in productivity, we conducted a follow-up survey to compare the development a year later ($n = 41$). Our results revealed two main student profiles, one feeling severely impacted by the persisting social distance in their study performance and the other appreciating the flexibility and expended free time due to the changes in the teaching formats. Based on our findings, we introduce implications for the overall design of higher education and show the benefits and challenges of combining chatbot-enabled experience sampling with traditional surveys.

CCS CONCEPTS

• **Applied computing** → **Distance learning**; • **Human-centered computing** → *Empirical studies in HCI*; *Field studies.*

KEYWORDS

chatbot, experience sampling, distance teaching, higher education

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1 INTRODUCTION

The COVID-19 pandemic – in spite of all its negative aspects – has widely been recognized as a driver for digitization [3]. Contact restrictions have caused online services to thrive, and classroom teaching was replaced by online formats within days. While this certainly pushed many lecturers to explore novel formats, it also created a number of documented problems: The lack of social interaction and communication among students and lecturers led increasingly to students' demotivation toward their studies and mental health issues [10]. Students who started their studies during the pandemic are particularly affected by it [30]. Additionally, students and were confronted with technical limitations, unreliable internet connections [35, 43], and the question of how to transfer all practical courses into the digital world [40]. Prior work explored the early student experiences during COVID-19, for example, with the "emergency remote" teaching formats [44, 51] and perceived privacy threats with platforms such as Zoom [56]. Other studies have assessed general challenges in distance education (DE) from a student perspective. For example, they found that good time management is crucial [42] and that the lack of interactivity [18] is a major problem in online teaching.

However, few studies systematically assessed students' study experiences and coping strategies in near real-time and evaluated how they managed to consolidate and reshape their habits over the continued development of the pandemic. Moreover, the lack of direct (non-)verbal feedback achieved at in-person events, made it harder for lecturers to continuously perceive and adapt to what their students were experiencing. Therefore, we conducted a study with students, asking them about their experience with virtual teaching, changes in their study habits, connectedness to peers and lecturers, as well as their perspective on higher education in the future. For this study, we used a combination of surveys and experience sampling. With the surveys, we were able to gather detailed information during the summer semester of 2020, after the exam period in 2020, and after the exam period in 2021. With a self-developed experience sampling chatbot, we augmented this "one-shot" data with questions on the day-to-day experience with virtual meetings for two weeks. Thus, we could track variance in the students' experience and avoid biases caused by the situation in which respondents filled in the surveys. In contrast to existing ES tools, our self-developed ES chatbot requires no additional installation because it is used from within Telegram, a popular messenger application. In addition, we could apply an encouraging conversational style, directly deploy surveys at scheduled times, and update configurations. Furthermore, by integrating surveys and ES questionnaires in our chatbot, we ensured users' easy access to the entire study from a single user interface.

We found that some students were able to cope very well with the overall situation, particularly over time, while others experienced the situation as mainly challenging. Notably, several students appreciated the change to asynchronous teaching, including prerecorded lecture videos, which enabled them to manage their time flexibly and improve their efficiency. Others felt that the quality of communication and collaboration deteriorated. The fact that it was more difficult to connect to peers, especially for some first-year students, even led to a feeling of isolation. Students who had a more positive attitude toward virtual teaching also tended to report a more positive experience in the virtual meetings as assessed with the experience sampling bot. When envisioning future studies, students saw a benefit in organizing lectures as a primarily remote course type, while they preferred practical courses as in-person events.

In sum, we contribute by providing empirical insights summarizing students' online study experiences and well-being, including personal coping strategies and challenges, teaching styles, and the overall development and outlook under two years of COVID-19 restrictions. Two learner profiles resulted from our data: one severely suffering from the distancing and isolating situation and one appreciating the benefit of the increased independence and liberty. We discuss our findings in light of designing higher education in the future, concluding that a hybrid format seems the most promising to support students in their studies. Additionally, we discuss the novel methodology of combining experience sampling with surveys for momentary and summative data collection and its potential for other researchers. Finally, we share recommendations and lessons learned for such a combined approach using messenger-based chatbots, including conversation flow and implementation.

2 RELATED WORK

In this section, we summarize past work on the student perspective in remote teaching in higher education and discuss how experience sampling can help monitor critical aspects such as student motivation and stress. Where already available, we refer to studies that explicitly discuss the effects of formerly physical teaching that was moved online due to the COVID-19 pandemic. Additionally, we include studies conducted in distance education contexts.

2.1 Benefits and Challenges in Online Teaching

The sudden pandemic-induced shift was challenging for lecturers and students alike [16, 44, 48], forcing them to become accustomed to studying online in a very short period of time [35, 43]. Many lacked experience with online teaching, the technical equipment (software and hardware) was missing, and adapting course designs to the new format was difficult (e.g., lab courses in which students build hardware or grow bacteria). In many cases, lecturers transitioned from live lectures to video recordings, adding a temporal to the physical distance. This shift resulted in even fewer cues to accurately interpret the effect a lecture has on the students [47]. Yet, asynchronous teaching formats make it possible to follow a variety of topics based on individual pace and interests [42]. Learners can complete exercises whenever it suits them, with some platforms even on the move.

At the same time, online courses also face several challenges, which lead to low completion rates [18, 29, 63]. Reasons include a lack of peer or lecturer support, an inappropriate level of difficulty, a lack of interactivity [18], and too much passivity [17]. Moreover, in the absence of fixed schedules, learners need to self-regulate to stay on track [39], causing increased demotivation toward their studies and mental health issues [10]. To some extent, these issues can be addressed by adapting the course design. For example, supporting learners in setting goals [33] and visualizing the learning

progress [54] can improve the learners' time management and adherence. Another approach is gamification, where game elements such as badges and levels provide incentives to achieve learning goals [53]. Activities such as role-plays, problem-based learning, and discussions foster interactivity and social interaction [14]. However, the success of such strategies is highly individual.

2.2 Effects of the COVID-19 Pandemic on Student Well-being

At several universities studies were performed to assess the effects of distance teaching and social distancing on students. Results from studies at US universities show a general increase in stress and anxiety among students and the numbers of students seeking psychological help compared to previous years [52, 60]. The most reported effects were concentration issues, fear of health, decrease in quality of sleep and fear for one's academic performance. Similarly, a longitudinal study on the mental health of undergraduate students conducted at the beginning of the COVID-19 pandemic showed a significant increase of depression and anxiety and a decrease in mental health after the first switch to remote teaching [28]. Students with pre-existing mental illnesses reported worsening symptoms. Findings from other parts of the world report similar findings and emphasize the pressing need to approach vulnerable students with support and strategies to dampen the effect of the pandemic and stress the need for further investigation [2, 21, 34, 36].

2.3 Learner Personalities and Strategies in Online Teaching

The (perceived) suitability of online teaching methods for learners depends on their personality [27] and individual learning strategies. For example, Ivankova and Stick found that students with a higher level of self-motivation were more likely to complete an online doctoral program [29]. Moreover, learners who set learning goals tend to be more persistent [26]. Similarly, effective time management is an important predictor of academic achievements in distance education [42]. Overall, students who manage to apply meta-cognitive self-regulation achieve better results than students with simple cognitive strategies, e.g., rote learning [42]. In addition, emotions influence learning success on a day-to-day basis [46, 50]. For example, positive emotions with respect to a learning activity have a beneficial effect on learning outcomes. On the other hand, both positive and negative emotions that are unrelated to the learning activity can cause distractions. In sum, from a lecturer's perspective, it makes sense to support students in managing their time and encourage reflection on emotions and the learning process.

2.4 Experience Sampling for Real-Time Analysis in an Education Context

In light of the high dropout rates in online education, it is crucial to immediately address problems when they arise. Several studies have applied experience sampling (ES) to track changes in learning-related factors, often for a longer period of time. ES is a method where subjects are repeatedly triggered to provide in-situ self-reports to collect authentic data [15]. For example, in the StudentLife study, the researchers assessed changes in students' stress levels and well-being from the beginning to the end of a term at university [59]. Specifically, they combined data from assessment probes and sensor data and identified correlations between factors such as conversation times and the reported feeling of solitude. Another study assessed emotions experienced by students while they were engaged in activities for a university course, with the goal of increasing self-awareness and improving self-regulation [41]. In a mobile learning context, contextual data and experience sampling were used to measure the effects of interruptions on learning [20]. An earlier project analyzed the match of learning contexts and learning materials in a diary study [62]. Overall, real-time assessment methods, including experience sampling, can provide insights into current student behaviors and needs. They enable immediate reactions from instructors, such as an updated selection of learning material or adaptation of teaching methods. In contrast to a summarized evaluation of an entire term, continuous methods can also reduce noise caused by daily mood fluctuations when identifying continuously relevant challenges.

2.5 Methods for Experience Sampling

Experience sampling methods have evolved from paper-based questionnaires completed upon timer prompts [15] to advanced systems that capture events of interest in the respondents' context (e.g., [58]). When designing experience sampling set-ups, important considerations include the trigger timing, expiry settings, and the number and type of questions [5]. For example, experience sampling questions can be triggered by a participant's location [1] or relevant activities detected on their device [20]. In particular, triggers should be sent when participants are not currently engaged in an activity, as interrupting them can harm the data quality [38]. Notification expiry is also important for data quality, as respondents more clearly remember events that happened recently [5]. However, if the expiry time is too short, this may affect compliance rates. Compliance rates also depend on the number and type of questions, as respondents are typically more willing to complete short and simple questionnaires [5]. Furthermore, researchers need to choose a platform that suits the specific needs of their experiment. For example, standalone applications deployed on mobile devices can use device sensors and are, therefore, suitable for context-dependent ES [49]. Researchers either implement their own apps or use tools such as Jeeves, which provides a configurable ES environment [49]. For decreasing the burden on participants in studies where the exact context is less relevant, past work has used SMS messages [12] or a chatbot integrated into a messenger application [4, 9, 25]. This has the added advantage that respondents do not need to install additional apps. Moreover, applying a conversational message style in a chatbot can improve data quality compared to a web survey [31] and elicit higher levels of participants' engagement [61]. The interaction can be simplified further by suggesting possible responses (including an option to add alternative responses so users do not feel limited in their expressions) [55].

3 CONCEPT AND SYSTEM DESIGN OF THE QUARANTINE BOT

The goal of the study presented in this paper was to analyze student experiences with online teaching during university closures

due to COVID-19. In particular, we aimed to track experiences as they occurred and to compare participants' immediate versus overall study experiences. To this end, we implemented experience sampling using a chatbot integrated into the popular messenger Telegram[1]. The Telegram bot handled the entire interaction with the user, which included participant on- and off-boarding, daily timed messages, and storing answers in a database.

3.1 Design and Implementation Details of the Quarantine Bot System

Using a Custom Messenger-Based Chatbot. We built the ES chatbot on top of an established messenger application, which has several advantages with respect to user experience and technical realization: From a participant's perspective, many smartphone users already use Telegram, which eliminates the first hurdle of having to install a new app. This can increase the willingness to participate in a study [24] and avoids novelty effects and learning time [5]. Sampling questions are presented to the user in a familiar chat environment, which can be adapted to individual tastes and requirements. Adopting this texting-based approach, "freeloading" in an environment used for everyday communications, keeps compliance high as switching off the app would mean switching off all other conversations, too [24]. We adopted an interactive conversational style to promote data quality [31] and engagement [61] Although first explorations suggested that chatbots might also be useful for the collection of daily questionnaires [4, 9], i.e., experience sampling, little is known about how these chatbots should be designed to address the specific needs of the experience sampling method. Hence, we describe our implementation details below to allow other researchers to use these descriptions to develop similar bots for their experience sampling needs.

On the technology side, building on an already existing messaging system alleviates the need for designing a user interface. In addition, colors and font sizes can be adjusted in the Telegram app, which increases accessibility in case of visual impairments [22] while removing the effort to implement these features for the researcher. Specifically, we decided to use Telegram because it is open-source, widely used (with more than 500 million users worldwide[2]), and offers an open API to deploy programs such as chatbots. The bot API allows for implementing individual logic while supporting a solution integrated in an environment familiar to the participants and running on a wide range of platforms. Developing an own application would likely have been limited to one operating system, excluding lots (circa 25%[3]) of potential participants [24, 49] and lacking in performance and aesthetics.

Implementation Details. We implemented the chatbot application in Python using the *python-telegram-bot*[4] package. For external surveys, the survey web-app *LimeSurvey*[5] was integrated. Participant responses are stored with *MongoDB*[6]. We mapped commonly used ES question types to Telegram's pre-defined and pre-designed message types: Participants can be sent *free-text*, *single-choice*, *multiple-choice* questions, and prompts to complete *external surveys*. Questionnaires are dynamically loaded into the application daily so that they can be modified while the app is running. They can be exchanged automatically by defining start and end date of their validity. The question type is mapped at runtime (see Figure 2). Routing and piping inside a questionnaire are realized by referencing follow-up questions in the Answer object itself. For external questionnaires, a survey link amended with a unique token is sent to the user. It is stored with the external survey's results to link sampling with survey data without using personal information. The app uses a set of timers to prompt users for the experience sampling: A daily routine sets timers for sending the invitation at a random time as well as reminders as specified in the configuration file (e.g., up to three reminders with an interval of 60 minutes). Additionally, if the user last responded to an invitation n working days ago, a message is sent prompting an immediate response for not being excluded from the study.

Participant Experience. User interaction starts directly within the app by finding the bot and initiating a conversation. By using a chatbot, we aimed for a more dialog-like, casual interaction, as previous work pointed to the advantages for data quality of a casual conversation style in a survey chatbot [32]. Therefore the general conversation style drew from the diction used by most students when chatting with friends, including emojis and entertaining animations as a thank you for completing a daily questionnaire. When it comes to prompting the user for the daily sampling, it is important to design the process to be as time-effective as possible. Participants can select predefined answers from a custom keyboard. This minimizes the time a participant is interrupted, reduces annoyance, and helps keep up response rates [13]. Additionally, the user can set their preferred interaction times, which reduces probe intrusiveness [12]. We decided to remind the user three times every two hours after a probe request was sent. When a reminder message is sent, the previous request message is deleted to avoid notifications piling up, preventing participant overload [5]. The actual questionnaire flow starts when the user indicates their availability by replying to the prompt. This responsive interaction pattern allows participants to answer when it is most suitable for them, increasing flexibility and reducing pressure [24].

Data Security. We used two third-party services, Telegram and Limesurvey. Telegram stores and processes personal data (phone number, e-mail address, and name) with heavy encryption.[7] Limesurvey only stores survey responses under a unique identifier created by us. Neither system shares the data with any other parties, thus complying with European data protection regulations. Participants can ask for the deletion of their data at any time. Server and database access are completely separated thanks to the Telegram API. For security reasons, we further prevented groups and other bots from interacting with our bot. We obtained approval for our data processing from our institution's data protection officers.

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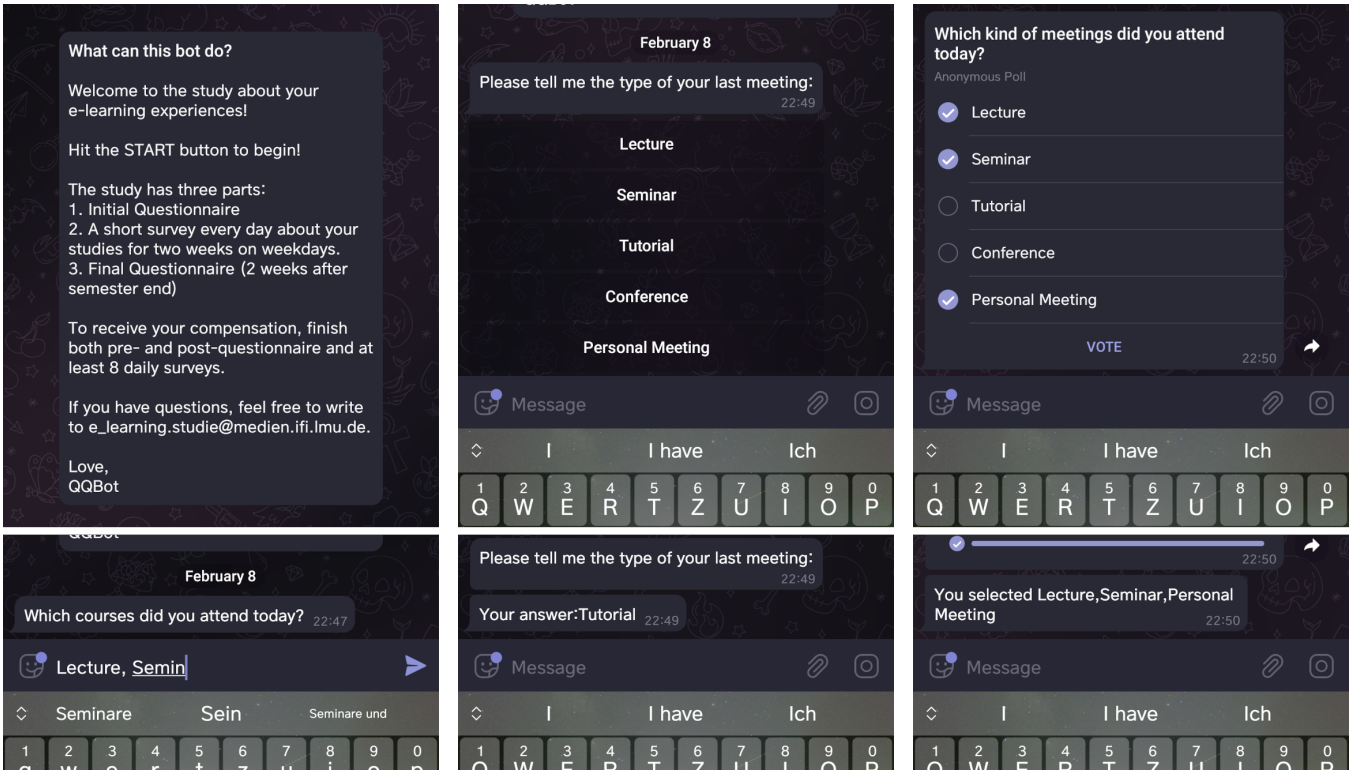

Figure 2: Left Column: (Top) Welcome Message shown upon finding and selecting the Bot on Telegram. (Bottom) Free-Text Question. Middle Column: (Top) Single-Choice Question. (Bottom) Response after selecting an option. Right Column: (Top) Multiple-Choice Question in form of a poll. (Bottom) Response after voting in the poll.

4 STUDY ON STUDENT EXPERIENCES WITH ONLINE TEACHING

We assessed student experiences during COVID-19 with a hybrid study using the ES chatbot and surveys. The study was conducted in three parts: (1) a deployment of the ES bot in the summer term 2020 (the first semester affected by COVID-19 in our country), (2) a survey on overall experiences deployed after the exam period, and (3) a follow-up survey in 2021, partly with participants of 2020 and partly with additional students. In the ES, we asked students about their latest meeting experience before opening the chatbot. The surveys were added to obtain a more detailed view of the participants' experiences.

4.1 Procedure and Questions

We conducted the experience sampling between the 8th and 12th week of the semester (which has 16 weeks overall). Participants initiated the study by searching for the Quarantine Bot on Telegram and tapping "Start". This triggered the pre-survey, including a consent form. Within the next two weeks, the Quarantine Bot sent an ES trigger at a random time within that time range every day within a user-defined time range. Shortly after the examination period, the chatbot triggered the post-study survey as the last step in 2020. The questionnaire in 2021 was also sent out shortly after the examination period. We visualized our study timeline in Figure 1.

The surveys included demographic questions and questions on the participants' current study situation. They consisted of a mix of demographic, 5-point Likert scale, and open-ended questions. In the pre-survey, we included questions about the participants' technical and general equipment used for their studies and their living situation. In post2020 and 2021, we further asked about the development of habits and tricks to keep their motivation or productivity, their overall meeting experiences, and their opinion and suggestion on future hybrid semesters, including what types of courses they would prefer to take place online and which ones they would like to attend in person. In all surveys (pre, post, and follow-up), we asked them to report on the communication and social interaction with lecturers as well as other students, their general level of motivation, productivity and satisfaction, challenges, and improvements in comparison to the respective experience in the prior year (from 2019 to 2020 and from 2020 to 2021). Thus, the survey in 2021 revisited questions from both pre2020 and post2020, with an additional focus on the consolidation of student attitudes and well-being after three semesters of teaching restricted by COVID-19 measures.

The ES questionnaire asked about the latest meetings (not) attended on that day, using a mix of single choice and 5-point Likert scale questions. Single-choice questions included the meeting length and the number of participants based on prepared clusters[8].

[8]For further details, we provide the ES questions in our supplementary material.

The Likert-scale questions aimed to assess the participants' personal motivation, perceived personal productivity, learning, and communication with lecturers and other students. Sampling requests were sent out at random times. As we aimed to capture impressions from a variety of different meetings instead of a particular event, the exact timing of ES probes was not important. Therefore, we only set an expiry time at the end of each day. If a participant did not respond, we sent up to three reminder messages.

4.2 Participants

In total, we received 117 responses in three surveys: 44 responses in the pre-survey (2020pre), 31 in the post-survey (2020post), and 41 in a follow-up survey (2021). Below, we present the demographics data gathered from 2020pre and 2021. In 2020, 44 participants were recruited from the university mailing lists (Age $M = 24.8$, $SD = 5.95$, $min = 18$, $max = 49$, 22 female, 22 male). All but one participant lived in Germany. More than half ($n = 36$) shared a household with others. Only eight participants had no prior in-person study experience at LMU Munich, while ten were enrolled for one semester, 22 for two to four semesters, and four for more than four semesters. Most of them were enrolled in Bachelor's ($n = 31$) and Master's ($n = 10$) programs of Media Informatics ($n = 24$) with an average of 4.93 courses ($SD = 2.08$) during the summer term 2020. Out of these 44 participants, 31 completed the two-week experience sampling through our chatbot and finished the post-survey. In 2021, we recruited 41 participants from the same mailing lists (Age $M = 25.2$, $SD = 4.93$, $min = 19$, $max = 41$, 23 female, 17 male, 1 non-binary) for a follow-up online survey. All of them lived in Germany and more than half ($n = 32$) shared a household with others. All the participants had prior in-person study experience at LMU Munich, in which more than half ($n = 23$) were enrolled for more than six semesters, nine for three to four semesters, and the remaining for five to six semesters. The majority were enrolled in Bachelor's ($n = 21$) and Master's ($n = 10$) programs of Media Informatics ($n = 6$), Computer Science ($n = 6$), and Physics ($n = 4$), with an average of 5.66 courses ($SD = 3.97$) in the summer term 2021.

4.3 Data Evaluation

4.3.1 Quantitative Analysis. We assumed that the level of factors such as perceived learning (es0112, see ES question codes in the supplementary material), motivation (es0108), and productivity (es0107) reported in the experience sampling would correlate with the overall attitude toward online teaching. Therefore, we grouped the participants in 2020 by the share of teaching they favored to have online in the post-survey (0%, 25%, 50%, 75%, or 100%). As there were only two people responding with 100%, we merged the 75% and 100% splits for numeric analyses; there was no participant in the 0% split. Whenever we compared groups, we computed an ANOVA with Bonferroni-corrected post-hoc tests at a significance level of $\alpha = 0.05$. We checked for violation of homogeneity with a Levene test and applied a Brown-Forsythe correction whenever necessary.

4.3.2 Thematic Analysis. Two researchers evaluated the open-ended questions using an inductive approach with the thematic analysis by Braun and Clarke [6] in six steps: (1) data familiarization, (2) initial code generation, (3) broader theme construction, (4) themes revision, (5) themes definition, and (6) the consolidation and reporting of the findings. Each researcher first independently coded the same five questions resulting in an inter-rater agreement of 85%. The misaligned 15% were due to the consideration of different levels of detail. After alignment, each researcher coded half of the remaining questions before consolidating them into one joint coding scheme. In the report below, we add the share of participants who mentioned an aspect in parentheses, grouped by the surveys *2020pre*, *2020post*, and *2021*. The two researchers conducted this inductive thematic analysis independent of the quantitative data analysis.

5 RESULTS

Overall, Figure 3 shows that online meetings were common for many course types in 2020 and 2021. The largest time share was reserved for lectures, followed by practical courses and seminars. Only five students in 2020 and three in 2021 reported that they had online meetings for lab tutorials. This section reports details on these meetings as gathered from the experience sampling in 2020. We then extend our analysis with the survey data collected in 2020 and 2021 from a quantitative and qualitative perspective: for each subsection, we first report the quantitative findings from the Likert-scale and numeric questions and subsequently relate the findings of the thematic analysis that address the same topic.

5.1 Perception of Meetings as Reported in the Experience Sampling

The 31 study participants who completed all steps of the 2020 study, including the post-survey, provided 300 instances of ES responses. Of these, 50% were answered within 21 minutes or less and 75% in under 90 minutes after receiving a notification prompt. In 152 cases, the respective participant had already had a meeting on that day. Of these, 18 meetings had only two participants, 59 were in small groups of three to ten people, and 75 had 11 participants or more. In 52 cases, participants also reported their reasons for not participating in meetings, which was mainly due to seeing no benefit in joining (12 times), not being motivated (11), or having another appointment in parallel (11). Additionally, they mentioned the meetings to be scheduled too early (5), to have technical issues (1), or did not specify (12). Nineteen meetings lasted 30 minutes or less, 44 lasted 30 minutes to one hour, 81 between one and three hours, and 8 more than three hours.

In the post-survey, we asked participants to estimate what percentage of teaching they would like to have online. For each participant where this information was available, we then analyzed the variance in the ES responses. For example, Figure 4 shows the variance in the reported feeling about the last virtual meeting. Here, we can observe large individual differences: five participants shown at the very right of the plot continuously reported a relaxed attitude toward their meetings, while some other participants' responses ranged from a high level of stress to a relatively relaxed feeling. The plot also illustrates that participants who prefer teaching in person tended to feel more stressed about virtual meetings than those who prefer online teaching. In fact, an ANOVA showed that the

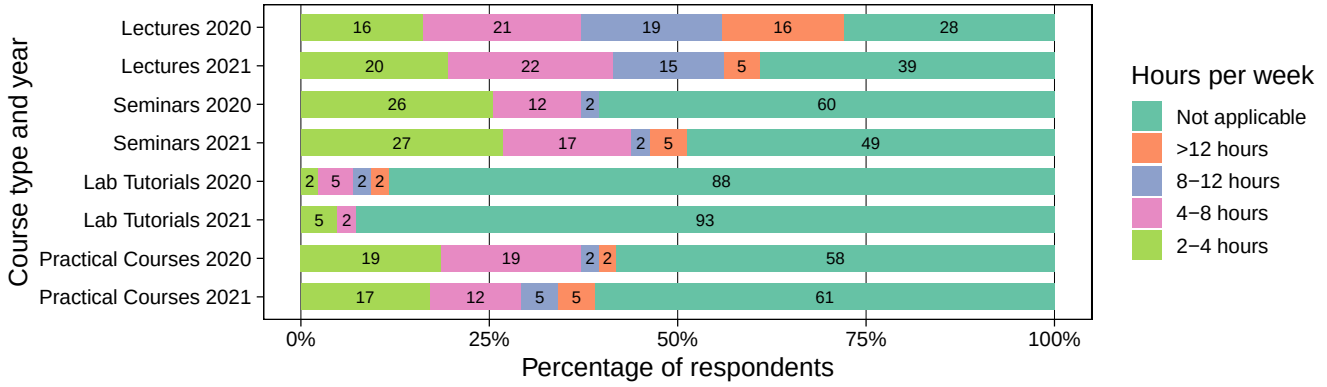

Figure 3: Attendance to different forms of online classes in 2020 and 2021 in hours per week. Attendance increased in seminars but decreased everywhere else. "Not applicable" indicates that a student did not attend any online meetings of this course type.

mean average reported feeling about virtual meetings significantly differed for the preference splits ($F(2, 28) = 9.009$, $p < 0.001$). A post-hoc test showed a higher value for participants who reported a 75-100% preference than for the 25% split ($t = 4.153$, $p < 0.001$) and also for the participants in the 75-100% compared to the 50% split ($t = 2.606$, $p < 0.044$).

As a second step, we performed an aggregated analysis. Specifically, we computed the average values per participant for the Likert-scale questions in the ES questionnaire (provided as supplementary material). Figure 5 shows a summary of the ES responses. Subsequent ANOVAs suggested significant differences between online preference groups for the questions on perceived learning ($F(2, 28) = 4.104$, $p = 0.027$). Specifically, post-hoc tests showed that participants who had reported an online preference of 75% or more were significantly more likely to feel that they had learned something in their virtual meeting than participants in the 25% ($t = 2.853$, $p = 0.024$) group. Similarly, there was a significant difference in the perceived quality of collaboration ($F(2, 27) = 5.562$, $p = 0.009$), specifically, between the 25% and 75-100% groups ($t = 3.306$, $p = 0.008$), as well as for perceived productivity ($F(2, 28) = 3.990$, $p = 0.030$), although the post-hoc tests were not significant ($t = 2.518$, $p = 0.053$ for the 25% group in comparison to each of the other groups). There were no significant differences in the motivation, course design, and communication, but as apparent in Figure 5, the ratings of participants in the 25% group were consistently lower than of those in the 75-100% group.

5.2 Survey Data and Thematic Analysis

The thematic analysis of all open-ended questions resulted in five themes: *Teaching*, *Self-studying*, *Lacking Social Interaction*, *External Influences*, and *Development*, comprising $n = 190$ codes, in total. Below, we summarize these themes and additionally include a quantitative overview of student responses in the pre- and post-surveys 2020 and the survey 2021 grouped based on the same themes.

5.2.1 Teaching. Figure 6 shows that there were large individual differences in how the perceived overall motivation, satisfaction, productivity, and confidence changed from before COVID-19 to the first semester during COVID-19 and from this first semester to the semester one year later. In particular, there was a trend toward higher perceived productivity from 2019 to 2020, while motivation tended to decrease from 2020 to 2021, after a longer period of online teaching.

Some of these changes are explained by the participants' opinions about teaching organization, equipment, styles, and demands. Repeatedly mentioned aspects in both years concerned the lack of communication between students and lecturers and among students, leading to a decrease in motivation (2020post: 2/31; 2021:9/41) and the reduced course quality (2020post: 8/31; 2021:7/41), requiring more structure and rules for online sessions. Rule suggestions were, for example, to require every student to *"[...] switch on their camera"* or to include more group exercises to motivate students to interact and reach out to each other. In various lectures, neither the content nor the format had been adapted over the year, making it hard for students to follow and focus. They suggested improving live online sessions by shortening the duration and accepting only smaller student groups. However, other students also reported an improvement in the course material (2020post: 6/31; 2021: 6/41), the lecturers' availability (2020post: 1/31; 2021: 4/41), and an increase in activities supporting social exchange (2020post: 2/31; 2021: 6/41), such as remote group work or breakout room discussions comparing their situation in 2020 and 2021. Nonetheless, practical courses would still greatly lack a good transition to an adequate online format causing frustration in students in need of the practical experiences (e.g., *"You can only learn how to do experiments/work in [the] lab if you actually do it. You cannot learn by just watching other people do it!!!!"*). In turn, lectures were increasingly recorded so that students could learn independently at home and watch the videos at their preferred speed. For online teaching formats that require mainly remote attendance, some students appreciated the independence and flexibility (2020post: 6/31; 2021: 1/41).

5.2.2 Studying Remotely. With the migration to online teaching in 2020, 55.8% reported a higher workload than before COVID-19, but the majority (60.5%) still felt confident about the change to digital teaching (cf. Figure 7). The figure also shows that some students were more engaged and active in online meetings than they had previously been in face-to-face meetings.

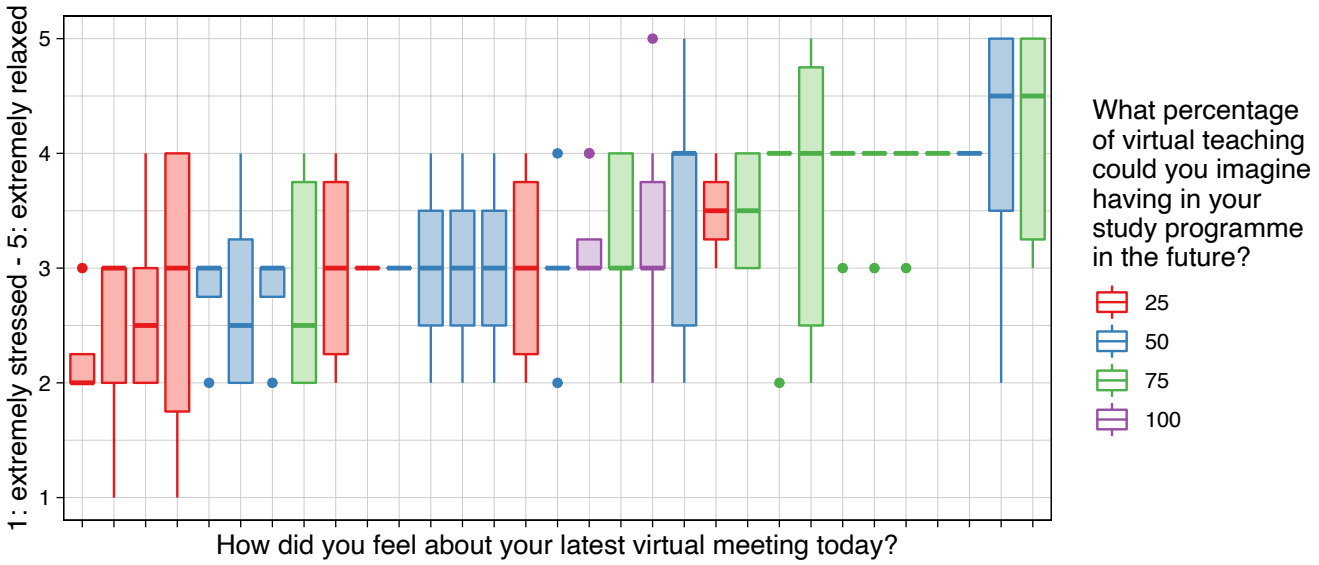

Figure 4: Participants' overall average relaxation/stress level in the online meetings within the two weeks, including their indicated preferences about the amount of teaching sessions being held online. Each boxplot represents one participant, sorted by average relaxation level. Students who prefer face-to-face meetings in their studies tend to feel more stressed about their online meetings.

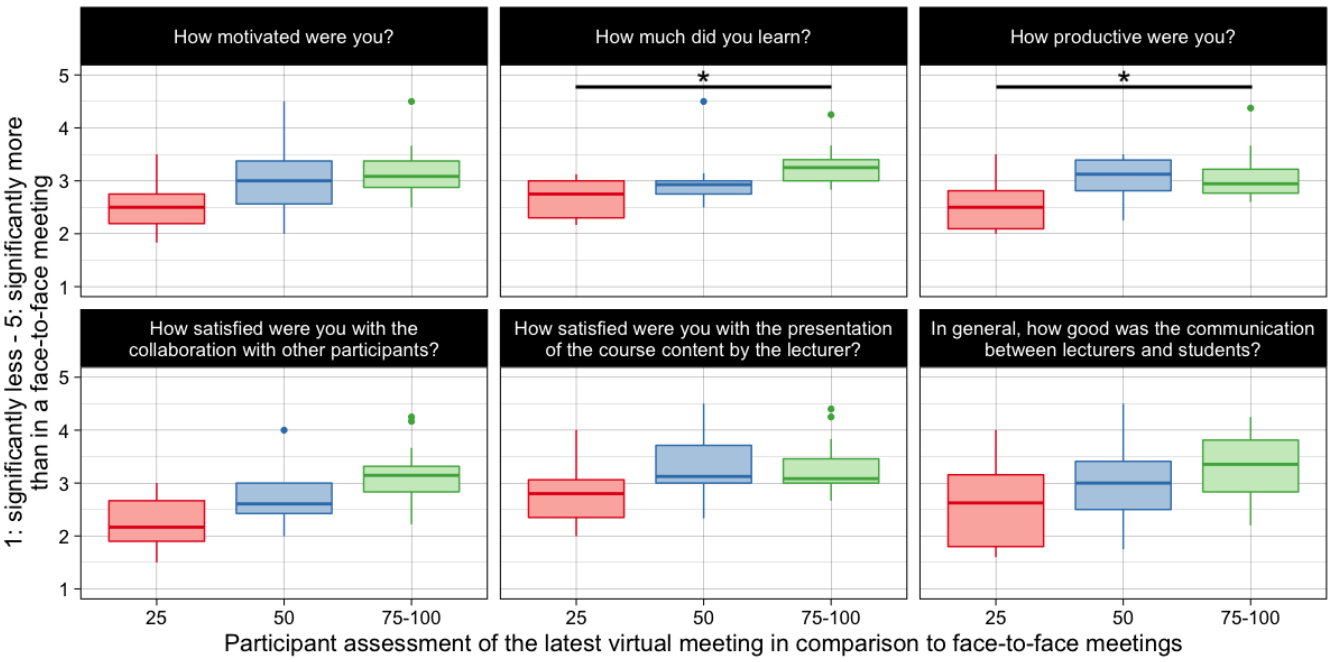

Figure 5: Assessment of the participants' virtual meetings (average by participant). The participants are grouped by the percentage of teaching they would be willing to have online. Significant differences ($p < 0.05$) are marked with an asterisk

The thematic analysis of self-studying reveals further details on the students' perception of their study performance, setup, motivation, as well as their mental and emotional state. Here, statements showed three different types of attitudes and ways of handling the remote learning situation. In 2021, 14 participants did not experience much change from their perspective, but none had any issues

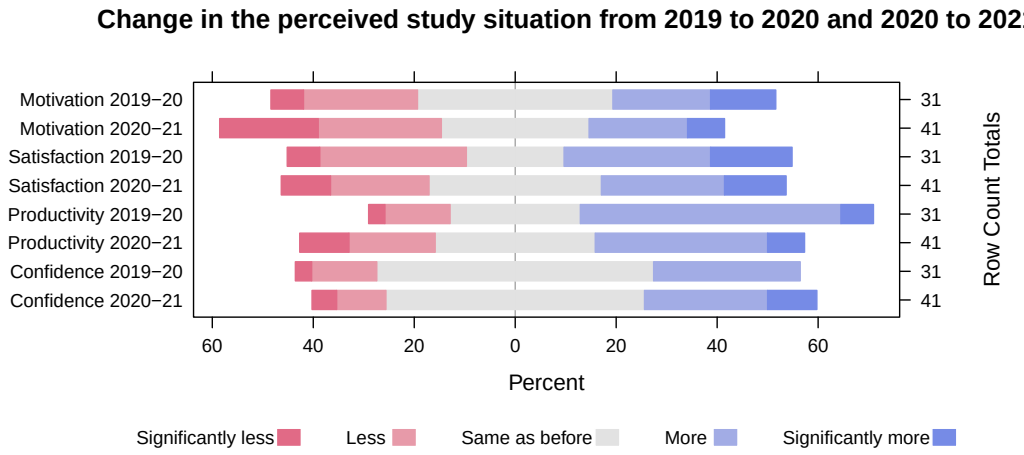

Figure 6: Perceived change of student motivation, satisfaction, productivity, and confidence from 2019 to 2020 and from 2020 to 2021

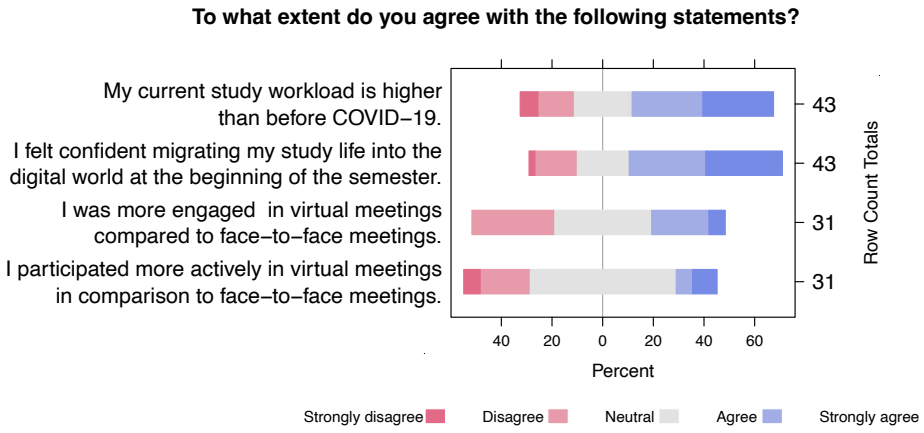

Figure 7: Survey responses indicating how key aspects of studying remotely were perceived in 2020.

with remote studying. About another third (15/41) reported that they had adapted to the situations and appreciated the increased flexibility and the additional availability because they no longer had to commute. They noted that they usually studied alone anyways, so the changes fostered their ability to focus rather than hindered it. For those participants, the self-organization greatly improved compared to the prior year, and they had learned from prior experience what strategies and tricks would help them stay motivated and focused. For example, five mentioned having established daily routines, including regular cooking, study times, and physical exercise. Students also felt more confident overall with themselves and the situation, e.g., *"it was just way, way better since both mentally and physically I was ready to tackle anything on my way from home, just because I already knew how everything was."* The study setup and available equipment also influenced how they felt about the situation (9/41). For example, one person had moved to a new apartment within the year and appreciated the greatly improved change of environment. However, others also experienced interruptions through flatmates, outside noises, or pets.

The remaining participants (13/41) indicated a rather opposite experience toward the development of their study situation over the last year. They reported feeling highly demotivated and lonely because of the lacking social interaction and change of scenery: *"[I] feel more isolated and alone."* or *"I am not motivated at all to study anymore. Even though I am interested in the things I do study. There is no change in day."* It also led to them missing teaching formats from before the pandemic and a lack of perspective (*"Nobody can see when this situation ends, so I have no perspective to work."*) Two reported being unable to focus and of becoming tired of online meetings. Another two participants also said that having received bad grades reduced their motivation even further. Finally one person mentioned that they faced additional financial challenges because they had lost their job.

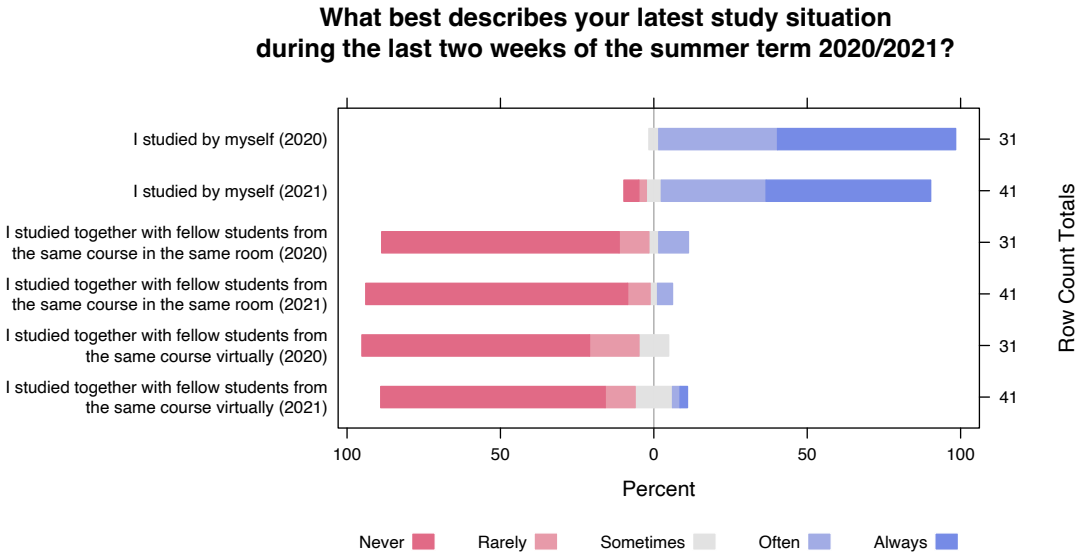

Figure 8: Survey responses indicating how often students studied alone or with others, and whether they met in person or met virtually.

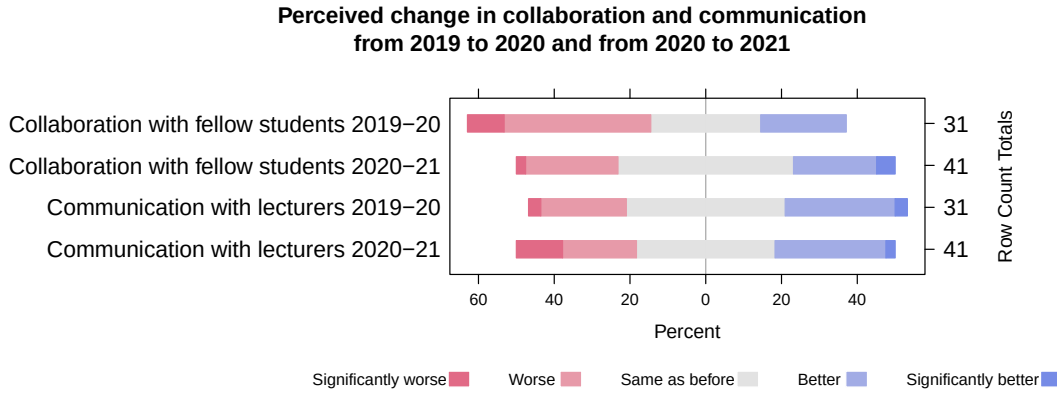

Figure 9: Survey responses indicating how participants perceived changes in communication and collaboration quality.

5.2.3 Lacking Social Interaction. In the surveys, we asked participants how they usually studied for their courses—alone or with classmates—and whether they met in person or virtually. Figure 8 shows that both in 2020 and 2021, students predominantly studied on their own: 96.8% often or always studied alone in 2020 and 87.8% in 2021. Conversely, 80.6% never physically met classmates for studying in 2020 and 82.9% in 2021. The study situation was also closely related to the participants' impression of their collaboration with and connection to peers. In 2020, 48.4% felt that their collaboration with other students had become worse or significantly worse than in 2019, compared to 22.6% for whom it had improved or improved significantly (cf. Figure 9). An additional question on their perceived connectedness with peers showed that they were also less likely to feel connected to their peers than in 2019 (46.5%, versus 27.9% for whom the connection improved). In 2021, there was no clear trend, with 26.8% each reporting a (significantly) better or worse level of collaboration with fellow students. However, fewer participants felt (somewhat) connected (28.1%) to fellow students than (somewhat) disconnected (56.1%).

The thematic analysis also unveiled that this was a major concern of the students throughout the online semester. More than half of them (2020pre: 21/44, 2021: 23/41) found their communication with the other students (significantly) worse than before, especially because it was difficult to establish new connections in online courses. We identified exclusive social interaction among some students who maintained a certain amount of effective social interaction in a small circle of well-known friends. For example, they self-organized regular meetings to keep connected, usually within the senior generation. This meant that some other students felt left out: *"A lot of my fellow students had a circle of other fellow student friends, now they mostly interact with each other and don't*

want to communicate with someone they don't know so well, regardless of whether it's a Zoom-Meeting or WhatsApp chat." For those who had just started at a new university, it was difficult to reach out to other fellow students or seniors (*"As I just recently moved to Munich, I only have a few good friends to study with. I think it's extremely hard to meet new people during online courses."*)

In comparison, communication with lecturers was perceived mostly the same as before (cf. Figure 9). On the one hand, online messenger tools facilitated fast communication, *"I usually visit the lessons so I am still able to ask questions via Zoom or Discord."* On the other hand, they rendered private one-to-one communication between the student and the lecturer more difficult, *"[...]it became less anonymous and private: previously, I could ask a question before or after the class, now my options are limited to either writing my question in email or asking it during a Zoom session, where 20-100 other students can hear it."*

5.2.4 External Influences. The online semester experience was influenced by multiple external factors, such as study conditions and technical setup. As mentioned above, the majority studied alone (cf. Figure 8). Some found this improved focus and efficiency in studying. Others complained about lacking fun and motivation compared to discussing and collaborating with classmates in normal study environments like the library and the lecture hall. Few of them hold the neutral stand, *"Most of the time, I studied alone in my room because that was easier to organize, and I am more efficient when learning by myself, even if it does not make [sic] fun that way."* Other technical problems, such as internet connection and hardware limitations, negatively affected the study situation.

5.2.5 Development and Outlook. After an increasing experience with online teaching, the students overall developed a good transition from physical to virtual studying through improved self-organization. For example, *"I coped with this situation and learned to regulate my productivity in [COVID] semesters."* They appreciated the flexibility in online teaching with access to course material like lecture recordings at any time, anywhere. Thus, they envision the future of studying as a mix of in-person and remote education, depending on the course type.

Figure 10 shows that most participants (2020post: 80.6%, 2021: 68.3%) were generally in favor of having some online lectures. Practical courses and seminars should preferably be held in person, and meetings for final theses could be a mix of in-person and virtual meetings. On average, students in 2020 said that 54.8% (SD = 22.7%; min = 25% and max = 100%) of courses could be held online. In 2021, the average value was 56.1% (SD = 33.4%; min = 0% and max = 100%). Notably, four students in 2021 said that they preferred not to have any virtual teaching at all.

The thematic analysis confirmed that the theoretical courses, such as lectures and seminars that are less interactive, can be held online with prepared course media, *"It would be helpful to have lectures virtually when the material is being recorded and uploaded in order to get back to it when needed."* In contrast, the practical courses, such as lab tutorials, that require interaction and participation of students and lecturers should be held in person, *"For everything connected with practical work in-person meetings are inevitable for good learning since one has to see closely what is done or has to work with certain equipment."*

6 DISCUSSION AND OUTLOOK

Our work aimed at identifying the situational and overall learning experience of students in higher education (incl. motivation, challenges, and needs) with the changes brought by COVID-19, for which we combined ES and survey results. As few studies have conducted a similar methodological approach, we discuss our experiences considering the approach, followed by the development of students' experiences of distance learning over the course of a year. We conclude this section by discussing the future potential of hybrid formats in higher education.

6.1 Combining Surveys with a Chatbot for Experience Sampling

Using a chatbot for experience sampling allowed us to collect data in near real-time and track the variance in the participants' experiences. Lecturers could use information such as the variance in perceived stress as shown in Figure 4 to individually approach students and to follow up on the reasons, whether this involves personal counseling – e.g., whether someone with continuously elevated stress levels would need additional support – or improving the meetings themselves. On the other side, students could use the ES probes as an opportunity to reflect on their current situation [57]. However, ES probes provide only a limited level of detail because they have to be kept short to sustain compliance [5]. Therefore, we added the surveys to capture detail and collect summative assessments with a long-term perspective. The combination of ES and survey data showed that the general attitude toward online education correlated with the average perception of meetings with respect to satisfaction, productivity, and learning in the ES. Thus, the analysis from a past semester (2020) can inform the assessment of student perspectives in subsequent semesters (2021). In general, the correlation between ES responses and survey data confirms that a hybrid experience can be useful to continuously track a small set of variables and enrich the information with additional questions with a small number of more extensive surveys. In our case, the surveys were sent on a specific date, but they could also be triggered when a context sensing system (e.g., [58, 59]) detects unusual activity. To preserve privacy, users could be asked to confirm context data before sending it [7].

From a technical perspective, the messenger chatbot was very useful for quickly deploying the experience sampling. The web-based surveys (2020pre and 2020post) could be sent out through the bot on a predefined date. We achieved high compliance rates and were able to quickly resolve the few issues that arose. However, there were some technical and conceptual challenges. Notably, one challenge was a consistent state and error handling. The system architecture defined several states that were necessary to map the current conversation flow between the bot and a human user. Therefore, we combined several persistent data storage methods (see Section 3.1) and added a mechanism for administrators to reset the user status. Rough et al. [49] stress the importance of a "testing environment for simulating different times and contexts" to ensure that a malfunctioning sampling tool cannot be published. We realized this requirement by launching a parallel instance of the same bot under a different ID, to which only developers had access. This way, we could test the functionality without affecting the

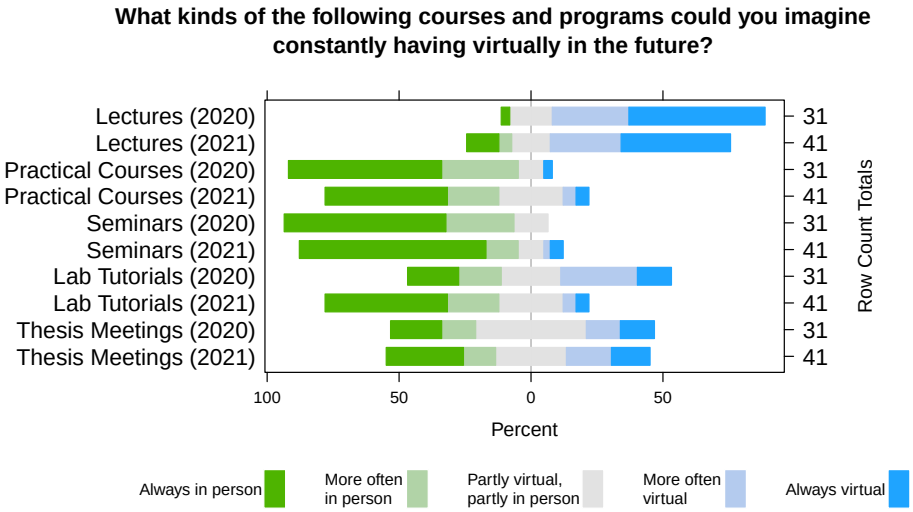

Figure 10: To what extent could different course types be moved online?

running bot instance. Participants tended to respond quickly to the randomly timed prompts. This means that we were able to capture events at different times of the day. To avoid disturbing participants and achieve even lower response times, contextual factors can be considered for sending prompts, e.g., if the participant is already in the app or background noise levels are high. However, this is a more privacy-invasive approach and depends on the chat application's capabilities. In comparison, other platforms like Viber [9] require to host their own web servers entailing security challenges but offer similar APIs. Thus, the lessons learned in our project can likely be generalized across platforms, supporting future practitioners who plan to develop ES chatbots for other platforms.

Overall, despite the challenges during development, the chatbot successfully served as a flexible and reliable study tool for our use case, especially with the possibility to include web-based surveys. It has already been applied in other projects of our research group (currently under review).

6.2 Student Experiences with Distance Education

In line with the prior work [11], we found that students experienced the three semesters since the outbreak of COVID-19 in very different ways. Furthermore, we roughly clustered them into two learner profiles. Each included students' attitudes toward adapting to and handling the changed study situation. The overall attitudes can be clustered into two learning types representing the two extremes of the scale: One type (Type 1) made use of the advantages, such as the increased available personal time, the flexibility of applying their own learning style, or the fewer distractions. The other (Type 2) severely struggled with the loss of structure, the lacking social exchange and activities, and general immobility. The learner type relates to students' skills of being self-organized and their confidence in independent learning [39]. One individual student is not necessarily always a Type-1 or Type2 student; their attitude may also depend on a particular course or their current circumstances. However, the two learner types can serve as a guide to identify potential pitfalls in course design. Besides the students' personality and intrinsic motivation, external factors strongly impacted their experience. Reoccurring factors were the (shared) living situation, bad performance reviews, or a general feeling of loneliness. Comparing the students' day-to-day meeting experience from the ES to their overall semester experiences in 2020 (see Figure 5), the daily report generally showed a moderate to low motivation to participate, whereas the students seemed still rather motivated overall (see Figure 6). Here, we see that the students still dealt mentally better with the abrupt changes in the first semester while not necessarily liking online teaching sessions than in 2021. Yet, we also observed a negative trend in students' motivation in the follow-up study, supporting their statements on "Zoom fatigue" and showing that the situation takes its toll, particularly due to the lack of perspective. Both the diverse requirements of different learner types and the negative motivation trend toward higher education are essential challenges in higher education. They introduce questions such as how higher education should be designed in the future: Should it revert to face-to-face or transition to hybrid sessions? How can we design it to be inclusive for both (and more) learning types? And what tools and methods can we develop to take countermeasures against the negative trend in students' mental health and learning motivation?

6.3 How to Design Education in the Future?

Our results revealed that a hybrid university education could serve as a compromise most likely to suit all students' needs. It encompasses a larger scale of students from anywhere with higher teaching quality through digitized material and lower commuting costs than a conventional in-person format. Regarding the derived learner profiles, a hybrid format would further allow the students to decide on joining sessions remotely or in person, depending on their

[9] https://developers.viber.com/docs/api/python-bot-api/, last accessed Feb. 10th 2022

preferred learning setup. When preparing courses, lecturers can select the course format according to its content and interaction requirement (see Figure 10). For example, for theoretical studies with limited interactivity like lectures, online teaching with pre-recorded videos can benefit students by customizing playbacks and taking notes at any time. In contrast, we saw that practical courses with intensive interaction like lab tutorials require in-person formats to enable quicker communication, multi-modal learning, and closer supervision. There are additional practical reasons for in-person lab sessions, such as being able to directly translate demonstrations into practical exercises. Besides, practical courses allow for more social interaction during the session, which could further motivate students with a tendency to Learner Type 2. Yet, we also expect an increasing workload for teaching and learning in the transition phase toward a hybrid norm due to unclear and distinct codes of conduct between virtual and in-person formats. As voiced by some students, they found that the lack of anonymity and privacy when they have to ask questions in front of a large audience in online classes was a deal-breaker. To address this problem, lecturers could mirror an essential aspect of in-person classroom interaction, allowing students to stay and ask individual questions after the course. Nonetheless, such new rules should be conveyed explicitly and clarified at the course start due to unfamiliarity with neither the in-person nor online formats.

When anticipating the future of higher education, we see a strong potential in increasingly digitalized student experiences given the identified advantages in our study, such as flexible access to teaching materials and comparable communication with lecturers. However, it is still unclear what role digital technology should play when designing such a new norm. Ideally, the aim should be an optimal trade-off between students' efficiency in studying online and their in-person social interaction. Pursuing this incorporation of in-person and online education, we discuss the potential opportunities and challenges in reshaping future student experiences through technology below: Recent advances in VR technology promise a *Metaverse* [19] including a variety of daily activities in a virtual universe beyond the physical world, such as meeting and working with others online. Online studying provides limited in-person social interaction among students and lecturers (Figure 9). In line with prior work, we envision future higher education employing VR for remote collaboration and social interaction between fellow students considering multiple design factors such as feedback setup in virtual teaching space [37], avatar design of virtual peer-learners [23], and accessibility for targeted learner groups [45]. Such virtual spaces could complement lecture recordings and enable students to collaborate synchronously in remote situations and learn efficiently with fun. We call for future studies examining the impact of various VR classroom setups on hybrid education. In addition, ubiquitous computing can empower lecturers to promptly probe students' studying and health states through one-to-one supervision via chatbot, with personalized questions and conversation styles dependent on individual physiological states or the study context [8].

6.4 Limitations & Next Steps

While our study revealed valuable insights into positive and negative student experiences in times of a pandemic, better comparability across years could have been achieved by repeating the experience sampling in the second year. Moreover, experience sampling for more than two weeks, possibly even for the entire semester, would have enabled us to derive more general trends and to correlate responses with external events, such as changes in COVID-19 regulations. However, this would also have increased the load on the (already busy) students and might have led to high drop-out rates [57]. Future studies could, for example, find a compromise by reducing the ES frequency to weekly instead of daily prompts.

So far, we have looked at one university only, with a majority of media informatics students in 2020. It can be assumed that students in this program generally have above-average knowledge and skills using digital media, which can have a positive bias on results of the first study. In 2021, the share of media informatics students was only 14%. All but one participant resided in Germany so local regulations in force at that time could also have had an influence. However, regulations on distance teaching at universities were fairly similar throughout Europe. Comparative studies in different countries at additional institutions with different teaching customs and a diverse set of educational subjects could provide a broader view on student experiences.

Although we selected participants from the same target population via our university mailing list, we had distinct participants for the second study phase in 2021. We did not exclude these new participants, in order to first gather diverse feedback about the semester one year after COVID-19. However, this can impair the consistency when comparing the results across years. Future studies could control the sampling across surveys, for example, by incorporating the survey sampling into the university's semester feedback system.

Regarding the implementation of the chatbot, a UI tool for managing questionnaires and parameters for the experience sampling would ease and accelerate the creation and maintenance of questionnaires and pave the way to use the bot every semester (cf. Section 6.1). The mechanism mentioned in Section 3.1 to realize questionnaire logic proved to be effective. The dynamic JSON-based questionnaires increased flexibility but also the complexity of defining the questionnaire sequence. This, in turn, sometimes led to users being stuck in the conversation logic. The aforementioned UI would help lay out the conversation structure and identify inconsistencies.

7 CONCLUSION

In this paper, we introduced a novel methodological approach of combining an experience sampling chatbot for daily and more immediate participant feedback with two surveys gathering data of overall semester experiences over the summer semesters in 2020 and 2021. We focused on student experiences with remote teaching in higher education resulting in implications for the design of future higher education and two identified learner profiles. In addition, we presented the system architecture of the chatbot, which was implemented as a Telegram bot and could, thus, use a popular messaging app. The bot can be flexibly configured with questions in JSON format and provides several question types such as single and multiple choice or free text.

The results of our study show that students have ambivalent attitudes toward online teaching. Generally, students who reported higher levels of motivation and learning during the experience sampling period also had a more positive overall attitude toward virtual teaching. The surveys conducted in 2020 and 2021 gave additional insights into the benefits and challenges of virtual teaching. Notably, students appreciated the flexibility achieved with asynchronous teaching formats. With increased experience with online teaching, many students also managed to establish habits that helped them maintain their motivation and productivity. However, the fact that it was difficult to get to know peers and the general lack of social interaction led to a feeling of isolation for some. Consequently, virtual teaching methods were seen as a better fit for less interactive formats such as lectures rather than for practical courses. We recommend that lecturers closely monitor the students' engagement and encourage them to collaborate to mitigate the effects of the distributed settings. We have seen that experience sampling can be helpful to (anonymously) track changes, while surveys provide a more detailed overview of overall experiences. Our learnings about student experiences during Covid-19 through a self-developed chatbot integrating surveys and ES questions can offer insights for future research on higher education and practitioners to develop future chatbot-based ES.

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