Students' Experience with Video Conferencing Tools for Social Interaction during the COVID-19 Pandemic

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Abstract

The Covid-19 pandemic has significantly impacted university students' social interaction by transitioning to hybrid teaching and remote study, which has had snowballing effects on their settling into and benefiting from university life. Video conferencing (VC) systems, also known as video call or video chat systems (or software/tools/apps), resemble face-to-face interaction, through the use of live image and sound together with other features that create a shared visual space. At the same time, VC systems have been increasingly used in many university courses to replace in-person university activities, and some educators have also organised online social activities for students via VC. However, the variety of VC systems available makes it difficult to choose the one that best supports students' needs for social interaction. This project aims to provide a guide to students on how to choose the most appropriate VC system and software developers on how to build better VC systems for university students. The project will:

1. Review background literature on university students' social interaction

2. Conduct a) a user study with University of Edinburgh students and b) a systematic review to extract student experiences with using VC tools for social interaction during the pandemic, as well as a set of beneficial features of VC systems for students

3. Review more literature on beneficial sub-features of the features identified in step 2

4. Conduct an evaluation of the VC systems identified in step 2 in terms of including the beneficial features from the same step and their sub-features from step 3; conclude on the best overall VC systems, and the best for different features

5. Recommend improvements to the design of VC systems

The findings will reveal the student experience, the best VC systems, and how they could be improved to enhance student social interaction.

Acknowledgements

Research Ethics Approval

This project obtained approval from the Informatics Research Ethics committee.
Ethics application number: rt#7076 Date when approval was obtained: 2022-10-26
The participants' information sheet and a consent form are included in the appendix.

Declaration

I declare that this thesis was composed by myself, that the work contained herein is my own except where explicitly stated otherwise in the text, and that this work has not been submitted for any other degree or professional qualification except as specified.

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Chapter 1

Introduction

1.1 Rationale

The Covid-19 pandemic had a tremendous impact on all aspects of our lives, with the vast majority of countries imposing major restrictions on businesses, schools, social gatherings, domestic movement and international travel[94]. The time period that is referred to as 'COVID-19 pandemic' in this dissertation is between March 2020, when WHO declared COVID-19 a pandemic, and March 2022, when the UK government lifted most COVID-19 related restrictions [19]. The aim of the restrictions to stop the spread of the virus, however it also had a negative impact on people's mental health, since it fundamentally changed our way of socialising [72]. With so many restrictions on in-person social gatherings, many people resorted to online tools to fulfil their basic needs for social interaction and alleviate feelings of loneliness and depression.

The impact of quarantine was especially significant on university students. University is a transitional period for most students, as they are at an age when they are for the first time becoming financially and socially independent from their families[46]. Under normal circumstances, students would rely on social interaction to regulate their emotions and achieve self-management and emotional stability [95]. However, after the lockdown many students, lost their support system and were overtaken by fear and anxiety. With university closure and all course activities being delivered online, COVID-19 also deprived students of any opportunity for interaction during their courses, which is equally significant for their psychosynthesis and the development of basic social skills as extracurricular socialisation[62].

Video conferencing (VC) software is a form of remote interaction that became significantly more popular during the pandemic[57]. However, there are so many options for such software on the market right now, each offering different features and aiming at different target audiences. Hence, it is hard for students to know which VC systems have the most useful features for remote socialisation, especially given that the tools they are accustomed to using for university might be tailored to the needs of remote learning rather than casual social interaction. Additionally, based on the research that was conducted as part of this project, when it comes to the study of VC tools in the context of the pandemic, the focus so far has been on the tools' remote learning or

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work-from-home functionality (e.g. Okabe-Miyamoto[93] and Camilleri[39]). Even in case the social aspect was examined, the focus was rarely on students. Therefore, the aim of this study is to fill these research gaps.

1.2 Aims and Research Questions

The aim of this study is to answer the research questions (RQs) shown in Figure 1.1:

1. How do we define beneficial online social interaction?

2. How did university students make use of video conferencing tools during the pandemic?
   (a) from the perspective of the existing literature?
   (b) from the perspective of the students of the University of Edinburgh?

3. What was university students' experience with online social interaction using VC tools and their different features during the pandemic?
   (a) What features were beneficial according to the literature?
   (b) What features were beneficial according to students?
   (c) What features were harmful according to the literature?
   (d) What features were harmful according to students?

4. How do the most popular VC tools compare in terms of social interaction among university students:
   (a) overall?
   (b) based on specific features and feature implementations?

5. What guidelines can we draw for the following:
   (a) usage guidelines for university students in order to achieve maximum benefit of video conferencing tools for social interaction and behaviours that should be avoided for that purpose.
   (b) design guidelines for software designers when designing video conferencing software in order to make it more efficient for social interaction between university students.

Figure 1.1: Research Questions

1.3 Summary of Dissertation

Chapter 2 is my methodology, i.e. the steps I followed to complete this project and the expected outcomes. Chapter 3 introduces the terminology that will be used throughout this dissertation, and discusses past relevant research. Chapter 4 talks about planning the user study, methods used and conclusions drawn. Chapter 5 thoroughly analyses how I used the PRISMA[77] framework to plan and structure the review, and how I used thematic analysis to make useful deductions from the collected results. Chapter 6 discusses the hands-on review of popular VC tools based on beneficial features for students' social interaction. Tools were tested and given a score based on their beneficial features and the tools that scored the highest are discussed in greater detail. Finally, chapter 7 is where I list usage guidelines for students to socialise effectively over VC, as well as design guidelines for software developers to make optimised VC tools for students' needs.

Chapter 2

Methodology

The methodology of this project consisted of a combination of a user study, a systematic literature review, as well as a hands-on review of VC tools, all of which aimed to answer the RQs in section 1.2. A summary of the methodology steps and their outcomes is shown in figure 2.1:
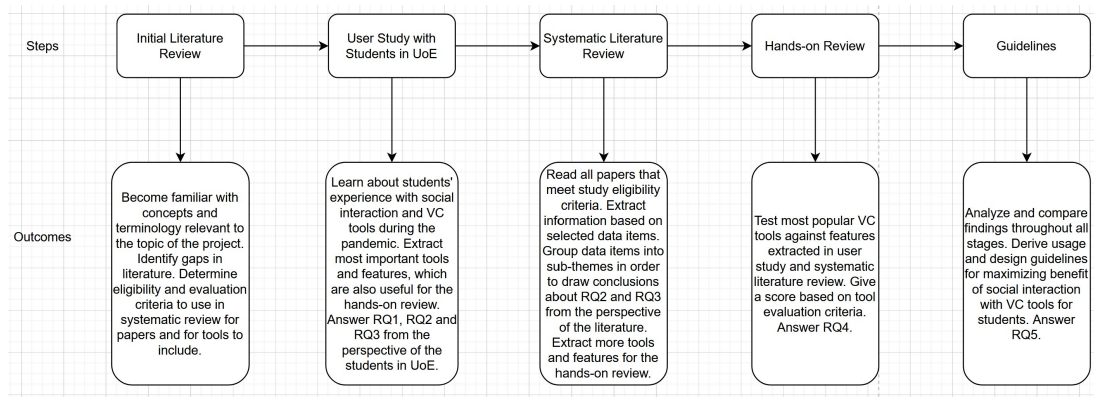
Figure 2.1: Outline of steps followed to complete research in this project and their respective outcomes

Initial Literature Review: At this stage the main aim was to get a better understanding of the concepts relevant to the project, as well as get an initial overview of the relevant topics addressed in the already existing literature. For example, I researched about the importance of social interaction, how online is different from face-to-face interaction, and what makes online interaction beneficial, which helped me answer RQ1. I also did some research on topics relevant to RQ2 and RQ3, in order to identify gaps in the literature and determine what unique contributions my own research could make in the field. Finally, I determined eligibility and evaluation criteria for the sources that I would include later in my systematic literature review, as well as for the tools that I would end up classifying as VC tools and focus on in the later stages of my research.

User Study: after the first stage, I concluded that there exists very little research that focuses specifically on students' experience with social interaction using VC tools

during the pandemic. Even though a lot of useful information can be drawn from the existing literature, it was necessary to conduct new research to get the most relevant results. I used a questionnaire as my data collection method, which targeted the students at the University of Edinburgh and answered any questions that hadn't been answered by the initial literature review. The goal here was to get first-hand information from members of the target group of my project, i.e. students, on topics pertaining to the first three RQs. Also, by noting the features of VC whose effect on socialisation was discussed by the participants, I could determine the ones that were most important or useful for students' social interaction during the pandemic, and so I was able to make a list of what to examine during my hands-on review (step 4).

Systematic Literature Review: I aimed to answer RQ2 and RQ3 both from the perspective of the students of UoE and from the perspective of the literature, since that would allow me to compare my findings with past research and and check how representative the student sample I recruited was of the general students population. I planned this step using the PRISMA checklist [77] (see background chapter). This checklist provides 27 steps that ensure the systematic literature review is clearly and adequately documented and that there is consistency in the way it is conducted. It prompts the researcher to settle on research and evaluation methods, including eligibility and evaluation criteria for the papers that will be included in the review. After the planning stage, I conducted the review by reading all eligible papers and summarising and evaluating the findings. The outcome was to make a list of all VC tools that matched the eligibility criteria established in the first methodology step and extract the features which were common among all of them and had impact on the quality of social interaction among students.

Hands-on Review: This methodology step involved identifying the names of specific VC software that came up in the user study or systematic review and getting some hands-on experience with them so as to give them a score reflecting their benefit for social interaction based on the established tool evaluation criteria. When this step was complete, I was able to identify the VC tools that are better catered towards students' social needs out of the ones tested. I also commented on tools that did the best job at implementing specific beneficial features, as well features that were poorly implemented across all tools. This step answered the fourth RQ.

Guidelines: This step answers RQ5. One of the main goals of this dissertation was to provide students with guidance as to how they can improve their VC experience, in order for them to avoid going through such a hard time in the future, should face-to-face interaction become infeasible again. The final product of this process was a list of VC tool design guidelines, as well as usage guidelines for students socializing over VC, so that the quality of the social interaction can be maximized. These were derived by combining, comparing and critically analysing the results obtained from all previous stages of the project.

Chapter 3

Background

3.1 Introduction to VC Systems

VC is a type of online interaction between two or more people via the use of platforms that allow "live, visual connection between two or more remote parties over the internet that simulates a face-to-face meeting"[43]. These platforms are referred to as VC systems / tools / apps / software, and in the context of the latter they can also be referred to as video call or video chat systems[65], thus these terms will be used interchangeably throughout the paper. The basic features a system must have to be considered a VC system are live video and audio transmission, simultaneous multi-party communication, as well as group and private messaging options during calls[18]. Other typical features are screen sharing, screen interactivity, ability to record sessions and switch devices mid-call, group and private chat boxes, background noise reduction, filters, embedded augmented reality (AR) games, virtual whiteboard, talk indicator, as well as breakout-room functionality. VC software became significantly more popular during the pandemic[57], since it is very efficient in simulating in-person interaction, and therefore it was mostly preferred by people[100].

3.2 Systematic vs non-systematic literature reviews

As part of this research, I first conducted a non-systematic literature review. The goal of a non-systematic review is to read a small number of papers on each of a wide range of sub-topics that are to some degree related to one main topic. [99]. It also includes some discussion or critical evaluation of the findings.

I also conducted a systematic literature review. The difference here is that a systematic review looks into all of the existing literature that is very closely related to the project topic[99]. It requires to be rigorously planned before it is conducted and there must be a clearly documented methodology of how papers were deemed eligible to be included in the review and how the results were critically analysed.

3.3   Introduction to PRISMA

PRISMA (or Preferred Reporting Items for Systematic Reviews and Meta-Analyses) is a checklist developed to assist in maintaining consistency in the way that systematic reviews are documented by providing a skeleton for how they should be structured[77]. It provides a checklist that specifies all the elements that should be reported when it comes to the methodology followed in planning and conducting the systematic review, as well as analyzing and evaluating the findings. The intended use for PRISMA is planning and reporting paper reviews, so I used it to plan the systematic literature review.

The PRISMA checklist consists of different sections, each focusing on a different aspect of planning the systematic review. Some of these are explained in detail in chapter 5, however here is a brief breakdown in Figure 3.1 [77]:

- **Eligibility Criteria:** These are the criteria that will be used to decide whether a paper is relevant to the topic of the systematic review and whether it should be included in the results analysis.
- **Information Sources:** The websites, databases, search engines, etc. used to retrieve relevant papers.
- **Search Strategy:** The ways in which the information sources were used in order to retrieve relevant papers. This includes specific steps followed, key words or limits used in order to filter out relevant results.
- **Selection Process:** This is the process followed to ensure each filtered result meets the eligibility criteria, and thus is suitable to be included in the results analysis.
- **Data Items:** The type of data or outcomes that are to be sought and collected from each selected result.
- **Data Collection Process:** The methods used to identify and collect the data items from the selected papers.
- **Study Risk of Bias Assessment:** The methods used to evaluate the probability that the studies described in the selected results are biased in any way.
- **Synthesis Methods:** Methods used to prepare, tabulate or visually display the data items collected. Also includes analysis methods used to derive useful information from the collected data and compare outcomes across different papers.
- **Reporting Bias Assessment:** Methods used to evaluate the possibility of reporting bias, i.e. the probability that the synthesis methods introduce bias in the conclusions drawn due to missing data.
- **Certainty Assessment:** Methods used to evaluate the probability that an outcome is accurate based on the evidence presented for it in the papers where it is presented.

Figure 3.1: Prisma sections description

3.4   Introduction to Social Interaction

The APA Dictionary of Psychology defines social interaction as "any process that involves reciprocal stimulation or response between two or more individuals" [23]. Since prehistoric times, humans have been social beings, meaning that our need to be part of a social group is fundamental[110, 79]. Socialisation allows people to demonstrate acceptance and interest in each other's needs[48], and this acceptance ultimately feeds their belonging needs. Past research has shown a correlation between gratification of one's belonging needs and their ability to exert self-control[32][29], as well as other useful social skills, like the ability to successfully collaborate with others[33]. People's ultimate goal is not to have various shallow conversations, but to build stronger bonds through these conversations identify with their social groups on a deeper level[35].

For university students, a big part of their social interaction happens within the university. Making small talk with course mates during lectures and tutorials, joining university societies, or attending networking events organised by the university are the main ways that students fulfill their social needs while on campus [24]. However, students also socialise outside of university, for instance by keeping in touch with their old friends from high school. The former type of interaction is important for meeting new people and expanding one's social circle, whereas the latter is necessary for potentially turning acquaintances into friendships. Socialisation is essential for university students to minimize stress, develop social skills and good study habits[75]. It also helps them feel

supported in their newly found independence, since for many of them this is their first time away from home and they are just now learning to navigate this new lifestyle.

3.5 Online Social Interaction Using VC tools

Online social interaction is any type of internet-enabled, computer-mediated social interaction. This can be over instant messaging (IM) apps, audio calls over VoIP, or VC, which is the focus of this dissertation.

According to Cambridge dictionary, being effective is the act of being successful in achieving desirable results[22]. Therefore, a tool or feature is effective in achieving the maximum benefit in online interaction when its functionality provides the user with the right environment for successful social interaction to flourish. What makes online social interaction successful or beneficial is what we need to answer in RQ1 of this paper.

It can be argued that VC meets belonging needs more effectively than other forms of online social interaction. It is well-known that in-person social interaction consists of both verbal and non-verbal cues (e.g. facial expressions, gestures, physical touch), both of which play an equally important role in solidifying bonds between individuals[86]. The non-verbal cues allow people to express emotions and reactions that are not revealed by their words. VC maintains the largest number of non-verbal cues in a conversation when compared with audio chats and IM[104]. More specifically, the number of times people laugh and smile during video chats is about the same as in-person interactions, and even though there is a decrease in nods and gestures, it is not as sharp as in other forms of online communication. Even though in IM there are other digital options to send affiliation cues (e.g. emojis, excessive punctuation), they do not have the same effect in social bonding as non-verbal cues that exist in in-person communication, and which are also present in VC tools.

Nevertheless, VC tools still lack in maintaining non-verbal cues when compared to in-person socialisation[53]. For example, low quality video may render it difficult to distinguish facial expressions, but also our observation of body language is limited, since we can typically only see the other person's face and shoulders.

Apart from that, gaze is another very important aspect of social interaction, i.e. perceiving the direction in which other people are looking, as well as using it to strategically direct the group's attention to something[40]. Gaze can give us information about the flow of the conversation (e.g. who is the current focus and who will speak next), about others' feelings, but can also hint at more subtle things, such as "threat and dominance, attractiveness or seeking for approval"[40]. Gaze awareness is hard to maintain in VC, since everybody is looking straight ahead, usually not even making eye contact with the camera, thus raising obstacles for indirect communication and leading to people constantly interrupting each other or misunderstandings in the way things are perceived.

Finally, it is important to realize that when we participate in video chats, we do not physically leave our own space, and thus we do not feel the need to make the call our priority[21]. We can join the call while simultaneously doing chores, or scrolling through social media, or while our family members or pets are requiring our attention.

By not concentrating on the other person, we remain absorbed in our own bubble and therefore do not reap the maximum benefits of the interaction. This also makes the other person feel ignored and neglected and weakens our interpersonal bonds. Some people take it one step further and turn off their cameras while on VC. Turning the camera off can be beneficial for students in some settings, such as during long or consecutive lectures, as it can enhance concentration[41]. However, when it comes to social video calls, turning off the camera can significantly damage the quality of the interaction.

3.6   Discussion of Previous Relevant Work

While performing my initial literature review I came across some relevant research work that has been conducted in the past. Relevant research refers to research that looked into some aspect of the topic I am tackling in this dissertation.

The vast majority of the research I came across on this topic is in the form of user studies. Many of these were one-on-one interviews with up to 15 participants [56]. For example, Candace B. Phaire[95] interviewed 14 college students to understand the impact that the lack of social interaction during COVID-19 had on the socio-emotional development of students and how colleges can help in that regard. She found that students recognised the impact that the pandemic had on their self-management skills, however they needed their college's help to be able to develop them. Another example is Julie E. Boland et.al.[34], who conducted a lab study with 55 participants to observe how VC affects our ability to preserve the natural flow of conversation. They found that turn initiation between interlocutors takes way longer over VC than in person, which could be due to misaligned visual and audio cues caused by temporal lag, or due to the unnatural feeling of seeing one's own video feed during a meeting. Phaire's paper[95] used thematic analysis as a data analysis method. Since the number of participants was small, the range of experiences captured was limited, however the paper offered great insight into the specific participants' views and perceptions. Boland's et.al. paper on the other hand presented a statistical analysis of numerical data, which is common for lab studies because they tend to gather quantitative data. One thing the studies had in common was that they used convenience sampling, i.e. recruited participants only from a specific region or university for convenience purposes [51]. With convenience sampling, participants are easily accessible, so it is an effective method for gathering large amounts of data. However, participants are likely to have similar backgrounds and share many common experiences, which introduces bias to the data. Even then, a larger number of participants makes the results more easily generalisable, at least to the population of the particular university or area that the participants were recruited from. In the case of interviews, qualitative data analysis is more difficult and time consuming, so fewer participants were recruited, which makes it harder to confirm that their responses are representative of a larger population or check if they are outliers. These limitations can be mitigated by using a combination of data collection methods to mitigate any limitations. Unfortunately, these papers did not do this.

Another type of user study I came across was research that examined students' experience with computer mediated communication (CMC) in general and compared it with face-to-face communication in terms of psychological need satisfaction, for

example the works of Lara Kroencke et.al.[71] and James Dimmock et.al.[50]. The first study conducted a survey on 139,363 college students and measured a higher degree of well-being in cases of face-to-face than CMC, but that CMC still has a more positive effect on well-being than no socialisation at all. The second study conducted a survey on 127 participants and agreed with Kroencke's study that CMC is important for well-being in times of social isolation. However, it also found no significant correlation between psychological need satisfaction and preferred means of communication (face-to-face or CMC). It is important to note that Dimmock's study only recruited participants from Australia, whereas Kroencke's recruited a much larger number of participants from multiple regions around the world, therefore this could be one factor contributing to the contradictory results.

Some other studies I came across conducted systematic reviews on topics that are somewhat, but not fully, related to this project. For example, Li and Yee[76] conducted a systematic review to understand VC fatigue and what causes it. They found that VC fatigue can manifest physically, emotionally, socially and cognitively, and that it may be caused by the mirror anxiety of watching one's own video feed during the meeting, or due to competing tasks requiring our attention when working from home. Another systematic review was conducted by Oh et.al.[92] and focused on predictors and impacts of social presence in virtual settings. They found that individuals who are fully immersed in the experience and that have positive attitudes towards social interactions are more likely to feel social presence in an online interaction,but it also has to do with each person's demographic and psychological characteristics. The first study used the PRISMA framework[77] for structuring and planning the review, whereas the second one did not explicitly mention using any particular framework, although many elements seem to be drawn from PRISMA (e.g. eligibility criteria, information sources, selection process). Li and Yee's study only identified 14 relevant papers, whereas Oh's study identified 152. This could be due to the fact that VC fatigue has only started being studied thoroughly during the COVID-19 pandemic, since it generally wasn't such a prominent problem before, whereas social presence in virtual settings is something that has been studied for much longer, so there is more relevant literature pertaining to this topic.

Overall, these two systematic reviews were the most relevant to the topic of this dissertation. I didn't come across any relevant hands-on reviews of VC tools. This dissertation differentiates itself from past work because it uses a combination of 3 data collection methods, survey, systematic literature review, and finally hands-on review of popular VC tools. By combining the benefits of these methods, I minimised the possibility of bias in my results. The combination of user study and systematic literature review allowed me to cross-validate my results, gave me a more holistic view of students' requirements and experiences with social interaction via VC, and allowed me to answer my RQs from a variety of different perspectives. This ensured that the scores I attributed each VC tool during the hands-on review was as objective as possible, since the features I tested against were cross-checked with many different sources. It also ensured that the guidelines I drew for RQ5 were more likely to address the needs of all students, rather than a specific sample population.

Chapter 4

User Study

4.1 Objectives

As I found from my initial literature review, there is little existing research that focuses specifically on the research questions I was aiming to answer in this paper. Therefore, I thought the best way to find answers would be by asking my target group, students, directly about their experience with VC tools through a user study in the form of a questionnaire. With this user study I aimed to contribute towards answering RQ1, RQ2 and RQ3, which address students' opinion on what constitutes a successful online social interaction, the ways in which they used VC tools during the pandemic, as well as their experience with specific features of the tools. This user study has been approved by the School of Informatics (RT#7076).

4.2 Data Collection Method

I decided that the best way to conduct the study would be to distribute an online questionnaire[84]. The advantages of questionnaires, as opposed to interviews[56] or focus groups[91], is that it is easier to collect a much larger number of responses, since they take less time to complete than an interview or a focus group, and participants have the liberty to complete them in their own time. Furthermore, the analysis of the results is usually less complicated, since there is a specific set of questions that participants cannot deviate from - unlike a semi-structured interview for instance, where follow-up questions pursue the participants' views and can go onto completely new topics. Given my limited experience in conducting user studies, as well as the time constraints of the dissertation, these advantages convinced me to opt for questionnaires as my data collection method.

Of course, questionnaires also have the drawback that there is no guarantee for the quality of the collected data, especially qualitative. For example, participants may not understand the question and give an irrelevant answer, or they may even skip questions when they require a lot of writing. Had I more time to complete this project, I would have used a combination of data collection methods to take advantage of their

combined strengths, and thus mitigate any drawbacks. Specifically, I could have selected the participants who either gave the most interesting responses or those who did not elaborate enough on their ideas on the questionnaire and invited them for a follow-up one-on-one interview. This would have helped me gain more insight into those students' views on video conferencing tools and their features, and I would have been able to gather a lot more meaningful qualitative data. However, due to the time constraints this was not possible, so I tried to mitigate the impact of this limitation by designing the questionnaire so that it was as engaging as possible for the participants.

The questionnaire was created on Microsoft Forms[10], an online tool that provides a platform for easy creation and distribution of surveys, polls and quizzes. One of the advantages of Microsoft Forms is that it provides privacy and data security, as it provides data encryption 'in rest and in transit' [54]. This means that the participants' responses and personal information are safe from third parties, and that their identity remains protected. The University of Edinburgh also has a license for Microsoft, which means they trust Microsoft Forms for its security. Another advantage of Microsoft Forms is compatibility with the vast majority of browsers and devices, and an intuitive interface that almost everyone is familiar with.

4.3 Materials

At the start of the questionnaire participants were provided with a link to a participant information sheet. This sheet gave them any information they might want to have about the study, specifically the names and contact information of the researchers, the purpose of the study in more detail, as well as any information related to their data protection rights, including where the study results would be published.

After having read the information sheet, the participants were presented with a question asking for their consent, where they were required to confirm that they had read the participant information sheet, they understand that their participation was voluntary, they consent to their anonymised data being used in any academic publication, and that they consent to their data being used in any future ethically approved research. If someone selected that they do not consent to the above terms, they were automatically taken to the end of the questionnaire and were excluded from the study.

Once consent was obtained, participants were able to start the main part of the questionnaire. The questions were designed keeping in mind the guidelines in Ng Chirk Jenn's 'Designing a Questionnaire' [64], which helps researchers create questionnaires that keep their participants engaged throughout. For example:

- keeping the questionnaire as succinct as possible

- starting with the simpler questions and gradually progressing to the more complicated / time consuming ones

- providing exhaustive lists of answers to the multiple choice questions (as well as always including an 'other' option).

The first part collected some demographic information about the participants, particu-

larly their gender, age range, and the school that their degree fell under (e.g. school of informatics). This information was collected in order to explore any potential trends or correlations between their characteristics and their experiences with VC tools. None of the information collected in this section was sufficient to uniquely identify a single participant, which ensured the results remained anonymised.

The second section of the questionnaire contained questions related to RQ1, RQ2 and RQ3. Most of the questions were multiple choice in format and addressed RQ2. They asked about specific VC software that the participant had used, the purposes they used VC for, and to name specific social activities that they engaged in through VC software. Furthermore, I addressed RQ3 by asking participants to rate some of the most common features in VC tools depending on how much, in their opinion, they contributed to the quality of social video calls (see section 3.1). There were also some open-ended questions, where participants were asked to provide examples of what they like and don't like about VC compared to face-to-face social interaction, to give more details about what they like and don't like about the features of VC tools, as well as to describe what a fruitful online social interaction consists of, according to them (RQ1). The purpose of the open-ended questions was to give freedom to the participants to accurately describe their personal experience.

Copies of all the materials that participants were presented with in the user study can be found in Appendices A, B, and C.

4.4   Participant Recruitment

The students I recruited were all from the University of Edinburgh to ensure that their participation was in accordance with the guidelines of the ethics committee.

I promoted the study by email, which was sent to all students in the university from all years, with the help of my supervisor. I also reached out directly to as many students as I could, either by contacting them one-on-one, or by making announcements in online student groups (e.g. university society groups). In every case I explained the purpose of the study and invited them to fill out the questionnaire by clicking the link provided. When the number of participants remained low, I sent reminders to everyone and also contacted more student groups, urging them to share the announcement with as many people as they could.

Eventually, 64 students participated in my study. Half were between 18 and 21 years old (32/64), 25/64 were between 21 and 25, 6/64 were above 25, and only 1 was between 15 and 18. 36 out of the 59 that disclosed their gender were female and 3 were non-binary. 35/64 were from the College of Science and Engineering, and notably 24 of those were from the School of Informatics. 23/64 were from the College of Arts, Humanities and Social Sciences and the remaining 6 were from the College of Medicine and Veterinary Medicine.

4.5 Data Analysis Methods

As my questionnaire contained both multiple choice and open-ended questions, I used both quantitative and qualitative data analysis methods for the different types of results.

For my quantitative analysis, Microsoft Forms[10] was really helpful, as it provided very useful graphs that illustrated all the participants' responses. I tweaked these graphs where necessary and provided them in Appendix D. I used those graphs to draw conclusions by making observations on the majority and the minority responses. I also made observations by looking at the combination of participants' responses to pairs or group of questions, used information I got from my initial literature review, as well as my personal experience, to speculate on the reasons why certain pairs or groups appeared together. Finally, I used statistical analysis on certain questions, such as the ones asking participants to rate some common features of VC tools, where I calculated the mean, median, and standard deviation of the ratings.

For the analysis of the open-ended questions I used thematic analysis[49][80]. I used a combination of top-down and bottom-up thematic analysis. This means that I initially split each part of the participants' answers into pre-established themes that I came up with before looking at the answers, based on the target RQs of the user study, and then I split each quote further into sub-themes based on their content. This combination of techniques was useful, because the sub-themes constituted part of the answer to the RQ that the respective theme was driven by. To help me with my thematic analysis, I used Nvivo, a digital tool which supports thematic analysis [11].

The initial themes that I started off with were:

- 'Requirements', which was driven by RQ1. This refers to the participants' requirements for an online social interaction to be perceived as beneficial.

- 'Positive Experience' and 'Negative Experience', which were driven by RQ3. Here I coded any quotes that talked about aspects of social video chats during the pandemic that the students enjoyed or didn't enjoy respectively.

- 'Socialising during University Activities' and 'Extracurricular Socialising', which were driven by RQ2. These described the type of activities that students engaged in during university related and extracurricular video calls respectively, and hence the features that enhanced or deteriorated their experience with those activities in each context.

As mentioned above, the questionnaire questions had already been created based on the RQs, and since there were five open-ended questions in my questionnaire, each one automatically corresponded to one of the above themes. There were some cases where an answer contained parts that could be categorized under multiple themes, but those were less common.

4.6 Results

4.6.1 Quantitative Results

Almost all participants (61/64) used VC tools for a mixture of school-related and social purposes during the pandemic, with only 3/64 only using them for school related purposes, and 35/64 using them mostly for school-related and occasionally for purely social purposes. This relates to RQ2.

Half of the participants (32/64) said that opportunities for social interaction during online classes were important for them during the pandemic. However, 14 of those stated they did not have such opportunities. This relates to RQ3.

Only 45/64 participants said they turn on their camera during VC, 30/64 said they watch movies, 28/64 that they play games and 21/64 that they study together during social video chats. This relates to RQ2.

Participants were asked to rate how much they felt specific common attributes of VC systems contributed to the quality of their online social interactions, first in the context of extracurricular interactions, and then in the context of university related activities. The mean, median, and standard deviation of the ratings calculated for each feature are shown and discussed in Table 4.1 in section 4.6.5. This relates to RQ3.

Finally I extracted information about specific VC tools that the participants had used. This was useful for identifying popular tools that I could test in my hands-on review, which I used to answer RQ4 (see chapter 6). Almost all (63/64) participants had used Zoom[17] as a VC tool, while no participants had used Adobe Connect[1]. Discord[2] was not explicitly provided as one of the VC tools options, however it was mentioned by 6/64 participants, which ranks it the 12th most used tool out of the 21 that were mentioned in total.

4.6.2 Qualitative Results

The resulting themes and sub-themes are represented as nested nodes in Nvivo [11], and their resulting structure is presented in Figure 4.1 below. One sub-theme that

Name	Files
extracurricular socializing	47
features	0
helpful	25
unhelpful	27
negative experience	4
positive experience	2
Negative Experience	59
awkwardness	12
different timezones	1
difficult group interaction	8
features	7
feels unnatural	20
no change of surroundings	5
no emotional closeness	26
no non-verbal cues	8
no sponteneity	1
physical aspect	13
privacy	4
technology fatigue	39
understimulating	8

Name	Files
Requirements	56
different - innovative	10
easy access	14
cheap	2
face-to-face resemblance	18
emotional closeness	20
features	27
helpful	20
proper use of features	5
unhelpful	8
good internet connection	6
less stress	9
fun	13
productive	14
socializing during uni activities	44
features	0
helpful	24
unhelpful	25
negative experience	2
positive experience	1

Name	Files
Positive Experience	61
bringing people together	14
combined with face-to-face	2
easy access	40
features	17
less socially draining	17
choice of when to interact	9
multitasking	9
social activities	11

Figure 4.1: Resulting themes and sub-themes after thematic analysis of open-ended questions in user study

was common under all themes was 'features'. Since looking at specific features of VC tools was such a big part of my study, I separated any quotes that talked about particular features and their effect on socialisation. However, I still kept them under their respective themes so that it was easier to differentiate between the context in which these features were referenced each time. For example, it is easy to understand that features mentioned under 'Negative Experience' had a negative impact on students' socialisation via VC. [1]

4.6.3   RQ1: What defines beneficial online social interaction?

RQ1 asked how beneficial online social interaction is defined. This was mainly answered by the sub-themes that emerged from the Requirements theme of the thematic analysis, as seen in Figure 4.1. One of the sub-themes is 'different-innovative', which refers to the fact that a few students (10/64) required to achieve something from social VC that they could not achieve through face-to-face social interaction in order to consider VC beneficial. The main issues raised were first of all connecting with people living far away whom it is impossible to meet face-to-face with. Furthermore, half of those seemed to enjoy making use of features of VC tools, such as screen sharing or noise reduction, to enhance the interaction experience in artificial ways that wouldn't be possible with unmediated communication. For example, student 30 (25+,F,PhD Inf) mentioned 'I find the active talk indicator and the noise reduction really helpful, compared to talking in a noisy pub'.

Another popular sub-theme was face-to-face resemblance, which was further specified into emotional closeness. When asked to list what constitutes a successful online social interaction, 7/64 participants mentioned the word 'connected'. 10/64 mentioned that their need for emotional support should be met, specifically in relation to the struggles of quarantine. In particular, student 32(21-25,F,UG Med) described their requirements for the VC as 'Interactive, feeling part of a community, discussions about the pandemic and how it made us feel, and acknowledging the challenges of quarantine'. Finally, in contrast with what was observed before, a lot of students (16/64) mentioned features of VC tools, such as high video and audio quality as ways to simulate face-to-face interaction, which would increase the sense of fulfillment they felt after the interaction.

We notice here that we have two contrasting sub-themes: one where students seek

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[1]In the presentation of the thematic analysis results I often make reference to specific quotes from some participants' answers. In those cases, the participants are referenced by their unique number ID, followed by a short description of their demographic characteristics in the form 'age group, gender (F/M/NB/NA), type of degree (UG/PG/PhD) & school of study'. Here is a list of the abbreviations used:

- 'NA': Information not disclosed
- 'Inf': School of Informatics
- 'Med': Edinburgh Medical School
- 'SocPolSci': School of Social and Political Science
- 'Phys': School of Physics and Astronomy
- 'PhilPsychLang': School of Philosophy, Psychology and Language Sciences

resemblance to real life through video conferencing, and one where students seek a different form of communication that they couldn't have otherwise. One way to explain this would be that the students that talked about face-to-face resemblance were referring specifically to the quarantine period, whereas the rest were referring to video calls in general, without sticking to the context of the pandemic. This can further be supported by the fact that COVID-19 was mentioned in many of the quotes of the participants that seek resemblance(11/38), but in none of the participants that seek a different form of interaction. However, another observation is that all 10 of the participants whose requirements were coded under 'different-innovative' also had other requirements coded under 'face-to-face resemblance'. On top of that, many participants (25/64) recognized the innovative aspects of online meet-ups as an advantage, but still said that they missed in-person interactions. For instance, student 31 (18-21,F,UG SocPolSci) said: 'Even though meeting in person is an experience I have learned to cherish after the lockdown, being online with friends definitely had its perks'. This suggests that participants felt video conferencing is beneficial only if it is used to complement face-to-face socialisation, rather than as a substitute, which is in agreement with my findings from my initial literature review.

Regarding the rest of the sub-themes, easy access refers to the need for the user interface of VC tools to be intuitive and fast to grasp, as well as how restricted the specific software is by lag and bad internet connection (mentioned by 16/64). This sub-theme is related with 'good internet connection' (mentioned by 6/64). 'Less stress' refers to the participants' need to relax during their online social interactions and avoid the awkwardness and social draining that sometimes results from prolonged face-to-face interactions (mentioned by 22/64). For instance, student 51(21-25,F,PhD Inf) said they want to be able to turn their camera off when they start feeling shy. The sub-theme 'Productive' captures quotes by 14/64 students that contain terms like 'informative', 'useful' or 'engaging', as well as quotes that describe something that the participant has to gain out of the interaction, e.g. student 47(18-21,M,UG Phys) nicely summarized their requirements for successful interaction as 'they make me feel good'.

4.6.4 RQ2: How did students make use of VC tools during the pandemic?

RQ2 asks how students made use of VC tools during the pandemic, which can be split into two socialisation contexts, 'socialising during university activities' and 'extracurricular socialising'. 38/64 students said they used VC only or mostly for university related purposes, while the rest said they use it mostly for extracurricular purposes, or equally for extracurricular and university related purposes. Results showed that the types of activities that a participant engaged in were different depending on which of the two categories the participant fell under. Furthermore, since different activities take place in the two different socialisation contexts, the usefulness of each VC feature changed depending on the context, which was reflected in the feature rankings in Table 4.1.

Students were asked to select the type of social activities that they engage in while on video call, as shown in Figure D.12 in Appendix D. Approximately half of the participants said they like to share content (34/64) and studying together (30/64), while

fewer said they like to watch movies together over video call (21/64) and to play games (28/64). All of these activities usually require the exchange of content between participants. For example, it is easier to converse over text while watching a movie, so that a discussion can be carried out in parallel without the need to pause. This explains why group and private chat and screen sharing were rated so highly in Table 4.1. Notably, out of the 21 students that said they watch movies together over VC, only 6 used VC mostly for university related purposes, which shows that watching movies is an activity mostly carried out in an extracurricular socialisation context.

Furthermore, a minority of students (19/64) said that they don't turn on their camera during video calls, and an even smaller minority (7/64) said that they don't talk live. A remarkable observation is that even though 12/19 of those who didn't turn on their camera used VC tools only or mostly for school-related purposes, that was the case for only 2/7 of those who didn't talk live, while 5/7 said they used them equally for extracurricular and school related purposes. What this may suggest related to RQ2 is that participants did not necessarily consider making conversation part of their extracurricular social interactions. Sometimes co-presence, i.e. the sense of togetherness that comes with just existing with others in the same space [66], is enough to satisfy people's social needs. In contrast, turning on the camera was essential for those who equally or mostly used VC tools for extracurricular social interaction, as confirmed by 19/26 participants that fell in that category.

4.6.5 RQ3: What was students' experience with online social interaction using VC tools and their different features?

Even though parts of RQ3 were already answered through the analysis conducted for RQ1 and RQ2, in particular the experience with specific features of VC tools, the overall experience of students using VC tools during the pandemic, i.e. if it was positive or negative in general and what are their general thoughts on VC tools for social interaction, remains to be discussed.

The sub-themes that emerged from the 'Positive Experience' and 'Negative Experience' themes are the aspects of VC tools that students liked or didn't like respectively about VC tools. Before even going into the specific sub-themes, it is remarkable to mention that the issues raised as 'Negative Experience' were many more compared with the aspects characterized as 'Positive Experience'. However, the total number of quotes under 'Positive Experience' was larger than 'Negative Experience'. This may sugggest that even though VC tools might lack in some aspects, such as feeling more unnatural and awkward than face-to-face conversation, there are some fundamental aspects that they do very well in, like providing flexibility to people to meet from the comfort and safety from their own home, no matter how much physical distance there is between them, and allowing people to engage in a variety of social activities that they wouldn't be able to otherwise. For example, the most popular activity that was mentioned was playing games with friends and family over video call, something that is much harder to do via any other form of online communication.

The main positive experience of VC was the flexibility that came with online interaction. Participants (57/64) said they enjoyed the fact that they didn't have to commute, dress

up, or spend money to meet with their friends, and also that they could exit the meeting as soon as they felt socially drained, something which is not as easy to do in real life. Overall, VC was the only form of interaction that came close to the face-to-face experience, while still maintaining many of the advantages of computer mediated communication.

Regarding negative experience, the majority of participants (39/64) mentioned technology fatigue as a detrimental factor to their experience with VC tools. This is definitely a consequence of the pandemic, as everything was moved online: students were in VC all the time for their courses, completed all their assignments on the computer, entertained themselves in front of the computer, since they were stuck at home because of the lockdown, and then still were in front of the computer to fulfill their social needs. A factor which may have contributed to the technology fatigue was the fact that students weren't able to change their surroundings (mentioned by 5/64), meaning that they associated their living space with both work and socialisation, which didn't help put them in the mood for social interaction. As student 61 (21-25,NB,PG PhilPsychLang) mentioned, there are 'no "hey look at that" moments' when socializing from the same space where you work and spend most of your day anyway. Many participants (28/64) thought social interaction via VC felt more unnatural due to the lack of non-verbal cues, the fact that they could see their live video feed during the call, as well as due to time lapses and technical issues. This led to awkwardness (mentioned by 12/64), lack of emotional closeness with the other person (mentioned by 26/64), as well as difficulty to hold a conversation, especially in group settings (mentioned by 8/64), since everyone kept interrupting and talking over each other and it was impossible to 'do multiple conversations / connections in parallel', as student 7 (25+,NA,PhD Inf) said.

RQ3 also asked about the students' experience with specific VC features. To answer this, it was useful to analyse the feature rankings shown in Table 4.1 below by combining them with students' justifications for these rankings, which were required in follow-up questions. These questions were optional, so only 47/64 participants completed them.

As far as extracurricular video calls go, the feature of video was rated very highly, since it allows for better communication through non-verbal cues, such as facial expressions and body language (mentioned by 9/47). Furthermore, features like screen sharing and group chat were also considered important, since they create a shared visual space and makes content sharing easier (mentioned by 9/47). This simulates real-life conditions, where people could just show content quickly to each other on their phones, or quickly search up something when it is difficult to explain from memory. On the other hand, features like filters, switching devices mid call and augmented reality games were rated low because participants didn't see how they would enhance the quality of the interaction (mentioned by 15/47). Student 57 (18-21,F,UG Inf) described filters as 'fun gimmicks [that] don't really affect the quality of the call'. Noise reduction was an interesting feature, since some students thought it was useful (mentioned by 3/47), some

Feature	Mode	Mean	Median	Standard Deviation
Video	5	4.39	5	0.721
Switching devices mid-call	2	1.91	2	1.3
Screen sharing	5	4.11	4	0.969
Screen interactivity	3	3.35	3	1.31
Meeting recording	5	3.04	3	1.56
Group chat	5	4.05	4	1.01
Private chat	5	3.89	4	1.21
Breakout rooms	4	2.94	3	1.3
User friendly UI	5	4.04	4	0.955
Active talk indicator	5	3.75	4	0.922
Noise Reduction	5	3.67	4	1.18
Filters	2, 3	2.52	2	1.22
Embedded augmented reality games	1	2.13	2	1.23
Shared whiteboard	3	3.1	3	1.27

Feature	Mode	Mean	Median	Standard Deviation
Video	5	4.11	4	0.97
Switching devices mid-call	2	2.76	3	2.13
Screen sharing	5	4.58	5	0.636
Screen interactivity	5	3.69	4	1.22
Meeting recording	5	4.32	5	1.13
Group chat	5	3.98	4	1.0
Private chat	5	3.47	4	1.85
Breakout rooms	5	3.43	4	1.44
User friendly UI	5	3.69	4	1.14
Active talk indicator	5	3.73	4	4.28
Noise Reduction	5	3.82	4	1.21
Filters	1	2.14	2	1.29
Embedded augmented reality games	1	1.68	1	0.889
Shared whiteboard	5	3.77	4	1.3

Table 4.1: Statistics derived from participant feature ratings in the context of extracurricular (left) and university related video calls (right), with 1 being minimum and 5 being maximum contribution to the quality of social interaction

thought it was distracting and unnecessary (2/47), and others thought it useful in theory and needless in practice, since they often found that it interfered with the audio quality of the call(mentioned by 5/47). Overall it seemed like, for the most part, participants didn't understand the need for features other than those that gave 'face-to-face' qualities to the interaction, like allowing people to see each other's body language or creating a shared visual space. Features like breakout rooms or shared whiteboards were deemed too formal and too structured for casual social interaction between friends (mentioned by 8/47).

Regarding socializing during course activities, many of the results were similar as extracurricular interaction. The main differences were that features like breakout rooms and shared whiteboards were deemed more important for socializing during course activities compared with extracurricular interaction. Many students (10/47) mentioned that such VC features encourage group work and gives the opportunity to socialise with your peers through collaborative activities, which wouldn't be possible without such features. However, other students had mixed feelings about these features, especially breakout rooms. For example, student 12 (21-25,F,UG Math) said 'Technology like breakout rooms is great but I imagine it was hard for teachers to use them effectively', while other students (8/47) talked about everyone being awkward and quiet in the breakout rooms. This points towards the fact that even though some features might be helpful in principle, their contribution to the quality of social interaction also depends on whether the students or teachers know how to use them effectively.

The conclusion we can draw is that, despite all of their disadvantages, VC tools provide the best solution for online social interaction when face-to-face is not an option, as was the case during the pandemic. The ideal situation would be to be able to use VC in combination with face-to-face whenever one or the other is more appropriate, and not be forced into exclusively online communication. Specifically, student 13 (18-21,F,UG Law) said that 'I think it's an amazing tool with incredible potential, especially when used by choice and not because there aren't any real life alternatives', and student 31(18-21,F,UG SocPolSci) said that even though they still missed face-to-face socialization, 'being online with friends definitely had its perks'.

4.6.6 General Observations

School where Studying versus VC Tools Used

Students from the School of Informatics seemed to have experience with a wider range of VC software, with each Informatics student having used approximately 6 (mean = 5.8) different VC tools. In contrast, non-informatics students used on average less than 5 (mean = 4.95) tools each. Furthermore, Informatics students tended to mention extra tools that were not included in the multiple choice options a lot more than non-informatics students. For example, Discord[2], Jitsi[9], Tencent[15] and Signal[12] were almost exclusively mentioned by Informatics students. This could potentially be explained by the fact that Informatics students are more comfortable with technology and find it easier, as well as more intriguing, to experiment with different software.

Importance of socialisation during online classes

38 participants said they only or mostly used VC tools for school related purposes, and 21 of those didn't find opportunities for socialisation during online classes significant. On the other hand, out of the 26 that said they use VC tools mostly for social or equally for school related and social purposes, 14 said that these opportunities were important to them. One explanation could be that the people that didn't socialize over video calls during the pandemic were either the ones that are more introverted or the ones whose face-to-face social interactions were not greatly affected by the lockdown. This would explain why they did not consider social interaction important during online classes, and vice versa why the people that socialized over video call needed the social interaction. Further research should be carried out to confirm this.

Impact of Age Range on Experience with VC

6/64 participants were in the above 25 years old age group. When we compare their answers to those of younger students (15-21 years old), we immediately notice that there are differences in what they perceive as VC limitations. Students over the age of 25 years generally focused more on the practical disadvantages, such as privacy concerns of online communication and difficulty in coordinating group discussions with more than 2 participants. On the other hand, younger students placed more emphasis on things related to lack of emotional closeness and face-to-face resemblance, such as lack of physical contact. One possible interpretation for this difference is that older students are more likely to be accustomed to living away from home, since they have likely been living on their own for a longer time, and thus being away from their friends and family did not have as great an effect as it did for younger students who are just now learning to live on their own. Another explanation could be that older students are more likely to be settled down and sometimes have a family of their own, therefore they have people in their household that they can socialise with face-to-face, and thus don't miss as much the intimacy that comes with it. On the other hand, younger students often live in student accommodation alone or with other students that they don't know beforehand, so it is more difficult to initiate a conversation. However, more research would be needed to confirm this hypothesis.

4.6.7 Limitations

One limitation of this user study was that the number of participants only constituted a small percentage of the student population. People are generally unwilling to participate in user studies unless there is some kind of external motivation, such as a monetary reward [88]. Furthermore, due to the time constraints of this project, I could only leave the questionnaire open for two weeks, before I had to stop collecting and start analysing responses. Lastly, I could only target participants from the University of Edinburgh due to the conditions of my ethics approval. Taking all this into account, 64 participants is a reasonable number, however when comparing it to all the students in the University of Edinburgh, in the UK, or even the world, it is still an extremely small percentage, and there is no guarantee that the participants' responses are representative of all students' opinions and experiences.

Moreover, as this project was time restricted, there was a trade-off, as I could either present a wide range of observations, or I could focus on few and analyse them in greater detail. I chose the first approach, which gave me a well-rounded understanding of how various factors affected students' experience with VC tools and their specific features. For example, I was able to observe how many demographic characteristics of the participants were related with a number of their responses. However, it would have also been interesting to formally quantify these observations, e.g. calculate correlation coefficients to understand the exact impact that a specific demographic characteristic had on each particular response. This possibility should be considered in future work.

Another limitation was that the quality of the responses, especially the qualitative ones, was sometimes sub-optimal. In particular, some students gave extremely short and non-descriptive answers to the open ended questions of the questionnaire, meaning there was very little useful information that could be drawn from them. For example, when asked to justify the feature ratings they gave in question 16 (see Figure C.8), student 39 (18-21,F,UG HistArch) said 'Didn't really contribute to productive and positive interactions', which doesn't really give any additional information other than the ratings themselves. This is a general limitation of the data collection method used, and as mentioned before, future work could complement this project by following up with one-on-one interviews to gain more insight on participants' responses when these are not sufficient.

Finally, related to the previous point, a few participants ended up giving unusable responses due to the fact that they did not properly understand the topic of the user study or what the specific questions were asking of them. The most common misunderstanding across participants was that a lot of them talked about VC tools in the context of virtual learning, rather than in the context of online social interaction. For instance, student 10 (18-21,M,UG SocPolSci) mentioned that they rated the meeting recording feature on VC tools highly because it is 'useful for going back and revising', which clearly isn't relevant for social video chats. In future research, this could be avoided by rephrasing the questions in a more comprehensible way, placing more emphasis on key words like 'social interaction'. Making the questions shorter and more succinct could also help, so that participants are more likely to not omit words in their attempt to skim through long questions.

Chapter 5

Systematic Literature Review

The aim of the systematic literature review was to answer RQ2, RQ3a and RQ3c, which address students' use and experience with using VC tools for social interaction during the pandemic, as well as the impacts of specific features of the VC tools.

From the PRISMA[77] checklist that was used to plan this review, I only used ECs, information sources, search strategy, selection process, data collection process, data items, and synthesis methods. I did not use effect measures, since a cross-comparison of the effect measures of different types of studies (e.g. user study versus systematic review) is not meaningful. I also did not use certainty assessment, reporting bias assessment or study risk of bias assessment, since these are only meaningful in meta-analyses.

5.1 Eligibility Criteria (ECs)

The papers that were included in the systematic review met the criteria displayed in Figure 5.1:

Content specific criteria:

1. The papers' scope must focus specifically on the experience of students of higher education with VC tools

2. The context in which this experience is discussed must be the COVID-19 pandemic.

3. The papers should be talking specifically about social interaction between students using VC tools, no matter if that is in reference to extracurricular social interaction or social interaction opportunities during their online courses.

4. The papers' content should address at least one of the RQs we are aiming to answer with this systematic review, i.e. RQ2, RQ3a and RQ3c.

5. The papers must be referring to VC tools that already existed during the pandemic. Any work talking about not-yet-released or experimental software will not be included.

6. The papers must be assessing VC tools respecting the definition we are following in this paper (see section 3.1)

Other eligibility criteria:

7. The papers must have been originally written in English, or an official English translation must be available.

8. The papers must have been written from March 2020 onward, since that's when the COVID-19 pandemic started and any paper written before that does not study VC tools in the context of the pandemic, therefore it's irrelevant.

9. Papers must be published in a reliable journal, database, e-book or website. Examples of what is considered reliable are any academic sources (scientific journals, university websites or databases, etc.), e-books written by academics, researchers, or experts in the field, and any well-established websites (e.g. global news websites like BBC or CNN, Forbes, etc.). Any research that is published on unreliable sources (e.g. blogging websites) will not be included, since its quality and accuracy have likely not been peer reviewed.

10. We are only looking at published work, so nothing in draft form or work that didn't make it to publication. This means that the publisher's or editor's name must be mentioned, along with the publication date.

11. Since the honours project is not funded, the papers must be either available for free on open-source academic journals or databases, or free access must be granted through the University of Edinburgh license.

Figure 5.1: Eligibility Criteria

5.2 Information Sources

The search engines I used were Google[6] and Google Scholar[8]. Google Scholar provides results only from academic sources, whereas Google provides a much wider range, such as news websites or authors' and organisations' websites, which can be equally reliable. However, Google is more likely to omit results from academic sources, since it has to filter through a much larger volume of data. It also displays a lot of unreliable results from discussion forums, social media pages, etc, where anyone can post anything and posts are often not fact-checked. That is why Google was used as a complementary search engine to Google Scholar to increase eligible results.

5.3 Search Strategy

Google [6] and Google Scholar [8] can yield a very large number of results, the majority of which are likely to be irrelevant to the topic of the systematic review. That is why it is important to pick an appropriate search key word, which will filter results that fully or partly cover the ECs.

The key word was derived from RQ2 and RQ3, by extracting the most meaningful words of these RQs and including synonyms. To come up with the synonyms I combined my own knowledge of the English language with the suggestions of well-established online dictionaries, such as thesaurus[14]. Out of all the results I picked out only those synonyms that made sense in the context of each RQ. The meaningful words derived from RQ2 and RQ3 were: 'university', 'students', 'online', 'social', 'interaction", 'video conferencing', 'tools', 'pandemic'.

Final search key word and Boolean Operators: "students" AND ("covid" OR "pandemic" OR "coronavirus") AND "university" AND ("social interaction" OR "socializing" OR "socialization") AND ("video conferencing" OR "video call" OR "video chat") AND -education

The way I used Boolean operators in my literature search followed the rules for using them in both Google[6] and Google Scholar[8] [83]. Notably, the '-' symbol is used to signify NOT, i.e. that the phrase must not be present in the generated results. The word 'education' has been excluded from the search, because otherwise most results talked about the role of VC tools as a remote learning tool, which is beyond the scope of this research. Also for the synonyms 'socializing' and 'socialization' I only used the American spelling rather than the British one, since it is globally the more commonly used. [73]

Steps for literature search on Google [6] and Google Scholar[8]:

1. Paste the search key word in the search bar exactly as above and press enter

2. For Google, click on tools (under the search bar on the right) and in the "from" section write March 2020. For Google Scholar, on the left, where there are the publication date options, write 2020 in the custom range box. This ensures I only get results published from the beginning of the pandemic (eligibility criterion 8).

3. For Google, go to the last page and click 'repeat search including omitted results', so that Google does not omit any results.

4. For Google Scholar, untick the box on the left that includes citations in the results (box for patents is unticked by default)

5. Go to the last page and record the number of results

This strategy produced 297 results on Google and 536 results on Google Scholar. The convention for this research project was that the maximum number of results we should generate is 1,000. That is purely due to the time constraints of the project.

5.4 Selection Process

Below are the steps taken to ensure each EC was met:

1. Criterion 7: ensure paper or article is in English (sufficient to read the first sentence of the main body of the paper). If it's not, check at the top and bottom of the web page for an option to change languages or a link to an English translation of the paper.

2. Criterion 9: Check the name and layout of the web page where the paper/article is found to ensure it is reliable (see definition of reliable in Eligibility Criterion 9 in 5.1). Also check the URL to ensure it is an official web page and not one aiming to deceive by imitating another well-known website (a phenomenon also known as URL spoofing). [82].

3. Criteria 8 and 10: Check for a publication date at the top and bottom of the web page. If there is no date, it could mean that the paper hasn't officially been published yet and it is in draft form, so we should reject it.

4. Criterion 11: Check that the full paper or article can be accessed for free or through the University of Edinburgh's license. In the case of an e-book, it could be the case that only part of it is available for free, which could also be useful.

5. Criteria 1-6: Read the title and abstract, where available, and tick off as many of the content specific criteria as are mentioned. If there is no abstract available, or if not all the content specific criteria have been ticked off, read the introduction and conclusion of the article/paper. In the case of an e-book, read the summary/description, and the first and last paragraphs of the extract that is available. Reject if not all 6 criteria have been ticked off.

Figure 5.2: Steps for checking ECs are met for a specific result

5.5 Data Collection Process / Data Items / Synthesis Methods

In each paper or article, I used CTRL+F to search for all the words from my search key word and their synonyms.

Once a word was found in the document, I read the paragraph around it, underlined relevant extracts and classified them in one or more of certain pre-established themes that were related to my RQs. The themes I was interested in were anything that

indicated: specific **VC software** used by students during the pandemic (useful for hands-on review); students had a **positive experience** with VC tools (RQ3), students had a **negative experience** with VC tools (RQ3); what **purposes** students mostly used VC tools for, for example social interaction during university activities versus social interaction outside of uni, as well as specific social activities they often participated in (e.g. games, watching movies, etc.) (RQ2); specific **helpful features** for social interaction (RQ3); specific **unhelpful features** for social interaction (RQ3); specific **usage or design guidelines** that the authors of the paper propose for VC tools (useful for eventually answering RQ5).

Thirdly, I copied and pasted all classified extracts in an excel sheet, in the column corresponding to the correct theme, including the title of the paper where I found them, the name of the journal/website/database where it was found.

Finally, I used a combination of top-down and bottom-up thematic analysis[111] to qualitatively evaluate my results. I first collected data items that fell under certain predetermined themes (e.g. positive/negative experience, helpful/unhelpful features, etc.). The themes 'positive experience' and 'negative experience' ended up being by far the most popular ones, so I then used bottom-up thematic analysis on those in order to break them down into sub-themes, so that it is easier to understand what made the experience with VC systems during the pandemic positive or negative for students. The extracted data items were organized and are presented in Appendix F.

5.6 Analysis and Evaluation of Systematic Literature Review Results

After evaluating the 833 identified sources against the ECs, I ended up with only 30 relevant papers, which are listed in Appendix E. Even though the vast majority of the search results met ECs 7-11 in section 5.1, it was very challenging to find papers that met all of the content specific ECs, and more specifically criteria 1 and 3. It was very often the case that all other criteria were met, however the scope of the paper did not focus specifically on students' experience, but rather on the general population. Equally frequent was the case that the papers examined students' experience with VC tools, but not in the context of social interaction, but rather of virtual learning or remote work - that is even after removing papers with the word 'education' from my results (see section 5.3).

The 30 papers were all publications in prestigious scientific journals and they described studies that usually involved a significant number of participants, clearly explaining the planning process and analysis methods, so they were deemed trustworthy enough to take into account for this review.

5.6.1 RQ2: How did university students make use of video conferencing tools during the pandemic?

One commonly mentioned social activity that students took part in while on video call was online gaming or watching movies (mentioned by 7/30). As Kelly et.al. mention, "Blending channels together appeared to help with homesickness by creating a situation that is more reminiscent of watching or playing together in the same physical space" [66]. However, the most commonly mentioned was students' attempt to satisfy their social needs through video call rather than their desire to do a specific activity together (mentioned by 10/30). The main priority was checking up on friends in order to preserve existing relationships and provide, as well as receive, emotional support [105]. Students tried to build social co-presence by video calling their family and friends without the explicit intention to interact with them, but rather to just create an open channel where each person could focus on their own activities, but still be able to engage in conversation when there was something interesting to point out or when they felt like sharing something with each other [66]. This creates the same natural flow of conversation that comes with sharing a physical space with others, since each person is aware of each other's surroundings (mentioned by 4/30). Finally, students also had to use VC for their university activities, such as lectures and tutorials. However, they still used that time to socialize with their peers and their professors whenever possible [63]. Social interaction is not limited to extracurricular, but can also be present in online courses that students participated in, for example with ice breakers conducted by the instructors, opportunities to directly converse with their peers in breakout rooms as part of course group activities, as well as the chance to send social messages during course sessions, either to the whole group or privately [95] (mentioned by 5/30).

5.6.2 RQ3: What was students' experience with online social interaction using VC tools and their different features?

The sub-themes that emerged from the thematic analysis on students' positive and negative experiences are shown in Figure 5.3 below.

Name	Files	Reference
emotional support	1	5
Intentionality in interaction	1	1
no difference in affiliation	1	1
no significant change for so	1	1
VC resembling face-to-face	1	5
co-presence	1	4
natural flow of conver	1	2
non-verbal cues	1	2
ways to increase sponteneit	1	1

Name	Files	Reference
difficult group interactions	1	2
difficult to meet new peopl	1	1
difficulties of long distance	1	1
dramatic shift from face-to-	1	1
lack of sponteneity	1	2
loneliness despite emotion	1	2
intensification of hom	1	3
privacy	1	2
technology fatigue	1	4
unnatural elements in onlin	1	5
lack of intimacy	1	1

Figure 5.3: Sub-themes derived from bottom-down thematic analysis on the quotes that fell under the topics of positive (left) and negative (right) experience of students with VC tools for social interaction

It is interesting to note that many of the sub-themes identified here were very similar to the ones identified during the analysis of the results in the user study, especially in the case of 'Negative Experience' (see Figure 4.1 for reference). Common themes in the two cases include awkwardness, privacy, technology fatigue, unnatural elements in VC interaction, difficult group interactions, difficulties of long distance interactions, lack of spontaneity. As for the sub-themes that emerged from 'Positive Experience', the ones in common are VC's resemblance to face-to-face interaction, emotional support, and intentionality in interaction. The fact that past research has identified so many of the same themes endorses the credibility of my own findings.

During COVID, feelings of loneliness, depression and anxiety were very common among people isolating, and especially among students (mentioned by 16/30). Stressful situations tend to increase the need for social interaction in people, since they use their interpersonal connections in order to self-regulate their emotions[26].

Socialising both inside and outside of the classroom was very important for students during the pandemic, especially those whose social lives were affected the most by the lockdown [95]. VC maintains a lot of the elements of face-to-face social interaction, such as non-verbal cues, facial expressions and a shared visual and audio space, which creates stronger feelings of co-presence and preserves the natural flow of conversation at a higher degree than other forms of online interaction[42] (mentioned by 13/30). Therefore, students felt that they were part of a group that was facing the same struggles as them and that they were not alone in feeling lonely, isolated and stressed. Hence, as Klindworth found, this intensification of their sense of belonging and the emotional support they experienced caused the negative emotions to be mitigated[68].

Furthermore, it is important to mention that a lot of students felt that quarantine did not affect their social life that much, and therefore were perfectly content using VC to socialize. As Scott mentions, 'young adults in the current study who previously interacted online or interacted flexibly with friends across contexts reported significantly less reduction in close friendship satisfaction during lockdown'[102].

The most prominent negative aspect of students' experience with VC tools was technology fatigue, which is the exhaustion people feel when frequently using VC software for prolonged periods of time[55] (mentioned by 8/30). The main factor that contributes to the fatigue is the unnatural elements that come with VC, such as excessive eye contact, seeing one's own video feed during the call, and reduction of mobility[45] (mentioned by 5/30). Our brains also have to put in more effort to process and send non-verbal cues, either because of poor video quality or because only a small part of participants' bodies is visible. As Boland hypothesises, 'electronic transmission delays disrupt neural oscillators that normally synchronize on syllable rate and enable interlocutors to effortlessly and precisely time the initiation of their turns'[34], which can be very draining and leads to VC participants not being fully present in the interaction.

Another issue with VC is that it can never fully replace face-to-face interaction, since, as Tanaka mentions, in VC there is no physical contact, and also there is a limit to the kind of experiences that participants can share together, since they do not have a fully shared sensory space [107]. A lot of students mentioned that even though they did feel emotionally supported when talking to their friends and family through VC, that still

did not alleviate their feelings of loneliness. Specifically, Kelly found that 'the inability to partake in events witnessed via technologies may intensify homesickness'[66].

Finally, the existing literature is a bit conflicting when it comes to the lack of spontaneity that comes with VC. Although video calls are useful for catching up with people you are already friends with, they take away from the spontaneous aspect of in-person social interaction and thus make it more difficult to build connections with new people[59]. Before all university activities became online, students ran into and socialised with their classmates on the way to class and mingled during society events. These opportunities are especially important for new students who have not made any friends yet and are looking to expand their social circle [38]. Many papers (12/30) that VC tools can only offer limited spontaneity, since participants have to find a pre-agreed time to interact. As Singh says, 'the lack of shared physical space has reduced the frequency of casual everyday exchanges between people, with the "disconnect" felt by most participants illustrating the inadequacies of computer-mediated communication'[105]. However, there are other papers that support that this is not such a big issue. For example, in the paper by Agnew et.al. [26] they found that there is no difference in the way people affiliate with strangers face-to-face versus on VC, so meeting new people is still possible through VC. The only problem is finding a way to co-exist online with acquaintances or strangers, which can prompt a spontaneous video call. There are specific tools that allow students to achieve that, such as Gather[5], which was found by Jacobs et.al to have a positive impact on the increase of frequency and spontaneity in social interaction among students[63]. More information about Gather can be found in subsection 6.3.2. It is remarkable that the research papers that talk about lack of spontaneity as a disadvantage generally do not involve a lot of participants in the research, while the ones that disagree usually have a lot more. For example, in Singh's research [105] only involved 5 participants, while Agnew's study[26] had 272. Therefore, there is more evidence to back this latter claim.

As far as specific features are concerned, the relevant papers do not examine in depth the impact of specific VC features on social interaction. Most of the time, papers address the advantages and disadvantages of VC tools as a whole, with the effect of specific features being either implied or not addressed at all. All papers that addressed the effect of specific features agreed that good video and audio quality are determining factors for preserving as many of the benefits of face-to-face interaction as possible (mentioned by 17/30), without however going into detail about what sub-characteristics of video and audio quality can make a VC tool stand out from the rest.

Helpful features that were mentioned were:

Good quality video and audio: help to experience a stronger sense of social presence, reassurance from seeing familiar faces and seeing what is happening at the remote site in real time [34].

Ability to easily turn on or off one's camera or microphone: related to the previous point. Sometimes it is important to take a break from socialization by turning off synchronous video and audio in order to avoid technology fatigue [31].

Chat functionality: useful to facilitate communication when VC participants are

engaged in a group activity, such as watching a movie [58].

Compatibility with all devices: important so that all participants have access to the same features, so that they can all benefit from online socialisation in the same way, no matter what kind of device or OS they use [36].

Unhelpful features that were mentioned were:

Network latency or jitter: can be a problem of the VC software itself if it doesn't offer settings for improved quality in non-ideal network conditions [55]. If there is jitter in the video or audio, then the interaction feels more unnatural and the technology fatigue increases, since it takes more effort to understand what the other person is saying or to read their facial expressions. Jitter is also the main factor that causes awkwardness in social video calls.

Seeing one's own video feed during the call: This was mentioned to be distracting for the VC participants, cause fatigue, or make participants feel insecure about their appearance [60].

5.7 Limitations

A limitation of my systematic review was that Google[6] only allows a 32-word maximum limit in the words one can include in their search, as stated at the top of the first results page when one inserts a query that exceeds that limit (see Figure 5.4 below).

> **"words"** (and any subsequent words) was ignored because we limit queries to 32 words.

Figure 5.4: Message at top of results page on Google when query exceeds 32 words

Similarly, Google Scholar[8] only allows 256 characters [67]. This meant that I had to carefully pick the key words from my RQs and only include those that were definitely present in any relevant paper. For example, the word 'students' would definitely have to exist in any relevant result, since a paper cannot be talking specifically about students' experience with the VC tools without ever mentioning the word 'students'. On the contrary, the word 'feature' was not included in the key words, since it was possible for an article to be referring to specific characteristics of the tools without ever mentioning the word 'feature' or its synonyms. Furthermore, 32 words or 256 characters was not enough for me to include all the key words' synonyms, thus I excluded the most unlikely ones to appear in this context. For instance, I could not include 'chatting' as a synonym for social interaction, since its presence did not guarantee that a paper referred to social interaction in the sense that it is used in RQ2 and RQ3.

Finally, another limitation was that I had to choose my key word so that the maximum number of results produced by the search engines was 1000 in total. That was purely because of the time constraints of the dissertation. However, it also meant that some papers that met the eligibility criteria might have been omitted. This is limiting because generally the more data is collected in a systematic literature review, the more easy it is to generalise its conclusions.

Chapter 6

Hands-On Review

The third part of my project was to perform a hands-on review of the VC tools that came up during my user study and systematic literature review. The goal was to assess them based on which beneficial features they provide and on how well they implement them. This addresses RQ4.

A table of all the tools that were identified versus those that were eventually tested is provided in Appendix H. Some of these tools are not purely VC tools, but rather have a VC functionality. In these cases I only looked at their other functionalities if they stood in place of certain VC features that otherwise the system did not provide, for example IM function standing in place of the chat feature for VC.

The high-level features that were found to be desirable by in the user study and which were tested in this review are: video, screen sharing, chat (group and private), noise reduction, talk indicator, breakout rooms, shared whiteboard, and user friendly UI. Even though noise reduction and breakout rooms were not rated as highly, I still included them because many students said that in theory these features are helpful, but usually they are not implemented correctly in the VC software. Hence, I want to see how they are implemented differently in the different tools.

6.1   Background Research

The beneficial features of VC tools that I extracted from the previous stages were very high level, therefore I decided to break them down into testable sub-features. To this end, I used the results from my user study and systematic review, but I also consulted other online sources. Below I give a justification for why particular sub-features were chosen for each high-level feature.

Video: Both my previous studies showed that video was the most useful VC feature. Hence, poor video quality had the most adverse consequences. The importance of good lighting was stressed by Buehler and High [36], and the importance of low latency for the avoidance of technology fatigue was mentioned by Garg et al.[55] Some sources talked about how virtual backgrounds can improve the quality of image transmission by

removing complexities from the background[109], as long as they do not cause artefacts that distort the person's image[34].

Screen sharing: A big part of what makes social interaction feel more natural and more beneficial is a shared sensory space, because that allows the creation of co-presence that helps participants solidify bonds[66]. Screen sharing is vital for the creation of common visual space during VC, so it is essential that it works seamlessly with other functionality of VC tools, as well as that it gives a high degree of freedom to participants, so that technical issues like bad layout do not take away from the interaction[37].

Chat: Just like with screen sharing, chat used in parallel with video calls is essential for developing a feeling of co-presence. Participants can share content that prompts conversation or allows them to engage in joint activities[66]. Being able to send emojis or reactions in the group chat can also make up for difficulty in including non-verbal cues in the interaction[47] (e.g. turning off camera due to slow connection). Being able to private message people during a group call is also important, because it makes up for VC's inability to support side conversations in group interactions[105].

Noise reduction: During the pandemic the places where people lived, worked and socialised became merged into one, the home[112]. In theory, noise reduction removes distracting background noises and creating a virtual 'third place' dedicated to socialisation. However, it was found that in practice noise reduction is sometimes not helpful, because it creates unwanted audio artefacts that make the conversation more unnatural and difficult to follow. I used this finding to come up with testable sub-features for noise reduction, such as consistency, customization options, and responsiveness to sudden changes.

Talk indicators identify the current speaker in a VC session, as in VC sometimes it is not obvious who is speaking. A talk indicator can also be useful if there is a distracting sound coming from somebody's background[20], so as to quickly identify where it is coming from. For these reasons, it is important for the talk indicator to be fast and accurate to correctly display the state of each participant. It must also be clearly visible on the screen, so that users can intuitively identify it. Finally, it must work seamlessly with other features, such as screen or whiteboard sharing, since in those cases participants' videos are pushed to the side of the screen and everyone's attention is on the shared content, so it is harder to distinguish the speaker.

Breakout rooms are a great solution to the problem of group interactions in VC. In the context of university related activities, breakout rooms are the only time that students can freely discuss among themselves without supervision, which allows for more informal conversation [44]. However, it was found that in practice breakout rooms can be awkward, especially when students are not free to choose which room to join, since they get stuck with people that are not willing to participate in the discussion. That is why it is important for students to be able to move around breakout rooms or return to the main meeting any time, so ultimately everyone gets the opportunity to socialise with people that they feel comfortable with and have a productive discussion. All the features that are available in the main meeting should also be available in the breakout rooms, so that participants are not restricted and can appreciate the additional benefits of breakout rooms.

Shared whiteboards can be used in video calls between student to assist in discussing and visualising ideas, group games and creative activities, but they can also be used in class to better coordinate ice breaker sessions and collaborative work [108]. That is why it is important for multiple participants to be able to use it simultaneously, for it to be responsive, and for it to provide a drawing, eraser, shape insertion, text box and image insertion tools that give sufficient freedom to use the board however best fits students' needs. It must also be flexible in its use and be able to be used in combination with other features, i.e. screen sharing and breakout rooms, since the simultaneous use of many media enhance the quality of the shared visual space, with all the benefits that entails.

User-friendly UI: The user interface contributes a lot to the user experience[74]. This is especially true for university students, since they are usually young people that have grown up with technology (for example, in the university of Edinburgh around 80% of them are below the age of 30 [103]). This means that they are accustomed to certain UI conventions and thus very sensitive to changes in those[81]. A common way to evaluate UI is to conduct heuristic evaluation[90] using Nielsen's 10 heuristics [89], which summarise all the aspects of the UI that have an impact on the usability of a system. Since this is an already established method, I decided to use these heuristics as my sub-features for the UI instead of attempting to come up with new ones.

6.2 Methodology

First, I identified all names of VC systems mentioned in my user study and systematic review.

Next, I attempted to download the app for each tool on my Windows 11 laptop. If there was no app available for Windows, then I checked if there is an online version. Sometimes I was required to first download the app and log in from my smartphone before I could use it on my laptop.

Then I went through each tool and started a video call. In each call I followed specific steps to ensure I do not forget any features and that the testing process is most efficient. These steps are detailed in Appendix I.

After testing, the scoring process occurred at a sub-feature level for each tool. Each sub-feature received a score of 1 if it was present and well implemented and a score of 0 if it was absent or it was implemented so poorly that it did not provide any benefits. A sub-feature received a score of 0.5 if its implementation issues were less major and still allowed the sub-feature to provide some beneficial functionality. Eventually I added up the individual sub-feature scores to calculate the total score for each high-level feature, as well as for each VC tool overall. Total scores were out of 48, since that was the total number of sub-features tested.

6.2.1 Making the video call

At first I wanted to create two separate accounts on each tool and connect my phone in one and my laptop in the other so I can start a video call with myself. However, for

some systems that was infeasible, since one can only log into an account with their laptop if the account is already active on a smartphone. Moreover, testing out some of the features in this way was very difficult, for example noise reduction, since I would not be able to test the feature's effect on the speaker's voice without another person talking on the other end. Therefore, I had help from a third party. This person is referred to as participant 2. Their role in the study was simply to download all VC tools that were to be tested and then join a video call with me on each one of them, where I occasionally asked them to perform specific actions that were necessary for me to evaluate a particular feature (see Appendix I). No data was collected about participant 2, since the video sessions were not recorded. The only actions participant 2 performed during the video sessions were strictly part of the testing scenario, and they did not help in the critical evaluation of each tool.

6.3 Results

The total scores attributed to each tool, as well as the scores for each of their high level features are shown in figure 6.1. A more detailed score breakdown is shown in Appendix G.

6.3.1 Best tools overall

Based on the total score that they achieved, the best tools overall were Zoom[17] with a score of 35/48, Webex[16] with 32/48, and Tencent Meeting (VooV) [15] with 30/48. One thing they had in common was they all scored above average for video (4, 2.5 and 3.5 respectively). As we can see in table 6.1, the majority of the tools scored between 1 and 2 on the video feature, so these three stand out as they were part of the few that scored above that. They also scored well above average on screen sharing and got some of the highest scores in UI user friendliness. Finally, even though the majority of the tools did not even have a talk indicator, breakout rooms or a shared whiteboard, these three mostly achieved a score of 50% or above for each of these features.

	Video (out of 4)	Screen sharing (out of 7)	Chat (out of 5)	Noise Reduction (out of 4)	Active Talk Indicator (out of 4)	Breakout Rooms (out of 8)	Shared Whiteboard (out of 6)	User friendly UI (out of 10)	Total (out of 48)
Zoom	4	6	5	4	0	4.5	3	8.5	35
Webex	2.5	5.5	2.5	3	2	5	2.5	9	32
Tencent Meeting (VooV)	3.5	6	4	1.5	2	6	0	7	30
Google Meet	2.5	4.5	1.5	3	4	0	5.5	8.5	29.5
BlueJeans	2	5	3.5	2.5	1	6	1.5	8	29.5
Gather	1	5	3	0	2.5	7	0	7	25.5
Jitsi Meet	1	5	3.5	0.5	3.5	0	6	6	25.5
Free Conference	1.5	5	2.5	0	2	3	3.5	7.5	25
Facebook Messenger	2.5	5.5	5	2	0	0	0	9.5	24.5
Skype	4	4.5	5	3	3	0	0	4.5	24
Discord	2	5	4.5	2	0	0	3	6	22.5
Slack	2	5.5	5	1.5	1	0	0	7	22
Microsoft Teams (for work or school)	1.5	6	4	4	0	0	0	6.5	22
Microsoft Teams	1.5	3	5	3	0	0	0	8.5	21
GoTo Meeting	2	5.5	3	0	2.5	0	0	7	20
Signal	1	2.5	4.5	0	3.5	0	0	6	17.5
Whatsapp	1.5	0	5	3	0	0	0	6.5	16
Telegram	1	4	4	0	0	0	0	6.5	15.5
Mean	2.06	4.64	3.92	1.76	1.5	1.75	1.39	7.19	24.3
Median	2	5	4	2	1.5	0	0	7	24.3
Mode	1,1.5,2	5	5	0	0	0	0	7	29.5, 22, 25.5
Standard Deviation	0.941	1.46	1.04	1.42	1.40	2.58	1.97	1.24	5.27

Figure 6.1: Total Score Attributed to each VC System during Hands-on Review

In practice, these results mean that, with their wide range of features and capabilities, the top three tools are suitable to be used by students for any type of social interaction. The students have a wide range of well implemented functionalities to choose from in order to make the experience as immersive as possible. Video and screen sharing were

particularly well implemented, and as we mentioned previously those are especially important to create beneficial online social interaction, since it is easier for the participants to create the feeling of co-presence that makes the socialisation feel more fulfilling.

Even though in the user study there were VC tools that appeared to be much more popular than VooV[15] and Webex[16] (see Figure D.9), those did not rank as highly. This could suggest that popularity and overall 'goodness' of VC tools are not correlated. Finally, it is remarkable that all of these tools are dedicated video conferencing systems, i.e. VC is their main purpose and it is not just an integrated additional functionality.

6.3.2   Best tools per feature

Even though the three tools above cover the top scores achieved across all tools for video, screen sharing, chat and noise reduction, there are other tools that scored higher when it comes to other features.

The top scoring tool for user friendly UI was Facebook Messenger[3] (9.5/10). It meets all of Nielsen's 10 heuristics and its characteristic property is that it is aesthetic and minimalistic, with a possibility for customization. Since this tool is used by 1.3 billion users as of 2023[30], it makes sense that the developers have the potential to perform regular large scale usability studies and make continuous improvements to the UI.

The top score for breakout rooms was achieved by Gather[5]. Regular VC systems make it difficult to meet new people or create new bonds with acquaintances that one is not particularly close with, since one must directly call or invite specific individuals to join a video call, something that requires an initial motivating factor to occur[105]. This becomes harder when there are many people in the same call, since there is no opportunity for side conversations and everybody is forced to speak together, which will cause less talkative people to be drowned out. However, Gather attempts to solve these problems by getting rid of the concept of a traditional video call and replacing that with a virtual space where people can use their digital avatars to navigate it and, just as in real life, use (virtual) physical proximity as a means of initiating spontaneous conversation[70]. In a sense, the whole virtual space can be seen as a 'breakout session', where participants can leave a 'breakout room' whenever they want and join another one by simply moving their avatar close to the people they want to converse with. In the virtual space there are different games and activities that people can join, which serve as great ice breakers and help the participants bond by creating shared experiences.

For the shared whiteboard, the tool with the highest score was Jitsi Meet[9] (6/6). The whiteboard functionality was very intuitive to locate and use, and it offered a wide variety of desired properties that facilitate group social activities (e.g. responsiveness, multiple simultaneous users). It also offered a sufficient variety of tools, enough for its intended use in social scenarios, such as games or ice breakers during a course activity.

Finally, the top score for talk indicator was achieved by Google Meet[7] (4/4). It was very clearly visible on the screen without being distracting, and it was very accurate and responsive. This was especially impressive since Google Meet is an online VC tool, and generally web applications are slower than desktop applications[96], especially for something transmitted in real time and constantly changing.

6.3.3 Most poorly implemented features overall

As we can see from the table in figure 6.1, the features breakout rooms, shared white-board, talk indicator and noise reduction received the 4 lowest average scores (from lowest to highest), all less than 50%. That was mostly because a lot of the tools did not implement these features at all.

The tools that were not dedicated VC systems (e.g. IM apps with VC functionality) were more likely to not offer those features. It is interesting to note that these kinds of apps tend to be used for casual, personal social interactions, whereas dedicated VC systems are viewed as more formal. One reason for this could be that dedicated VC systems usually allow a larger number of participants in one video call, allow one to schedule meetings, and provide a more secure process to ensure only authorised individuals enter a meeting, while non-dedicated apps do not. This agrees with the scores that students attributed to different VC tool features in table 4.1, which shows that these 4 features contributed more to the quality of the interaction during uni related rather than extracurricular social interaction.

However, even in the tools that provided these features, the sub-features that suffered the most were the **ability to customize settings** for noise reduction, **seamless function with other features** for whiteboard, **setting time limits and room managers** for breakout rooms, and **speed and accuracy** for talk indicator. These are significant omissions, since they affect the usefulness and user freedom that the features provide. Thus, it is clear that generally not enough attention goes into designing these features, or that flexibility of use is not properly considered.

6.3.4 Limitations

One limitation of the hands-on review was that all the tools were tested in the context of a one-on-one video call, and not in the context of a call with 3 or more participants. It was difficult to recruit more people because the time and effort they would need to devote would be substantial, and since this project is not funded, I could not provide compensation. Both my previous studies showed that VC presents problems with group interactions, so it would have been interesting to see that in practice.

Another limitation was that some of the popular tools that came up in the user study or systematic review could not be tested at this stage, since they had specific usage requirements which I could not meet. For example, FaceTime[4] is only available on MacOS, however I only own a Windows laptop, or Skype for Business[13] requires an organisational account to be already set up to allow a user to log in.

Finally, I realise that the tools I tested are by no means an exhaustive list of the available VC tools for students to socialise online. There might be other VC tools which, although not as popular, may have features that the more popular ones don't, or they might implement these tested features at a higher standard. In order to confirm that the top rated tools in this study are indeed the top rated tools in general, a systematic review would need to be conducted to identify all of the existing VC tools, and repeat the study with all of them included. Nevertheless, this could not be accomplished for the scope of this project due to time restrictions.

Chapter 7

Usage and Design Guidelines

My final RQ draws guidelines which software developers and students can use to maximise the benefit of VC tools in social interactions.

Guidelines for Software Developers: VC software developers should draw inspiration from the tools that scored the highest overall in the hands-on review, i.e. Zoom[17], Webex[16] and VooV[15]. All of these provided almost all the beneficial features that were tested in the review, and generally scored at least 50% on all of them - even the features that were most poorly implemented overall. That is in contrast to other tools that implemented some features to a higher standard but completely omitted others. The three best tools scored particularly highly on the video, screen sharing and UI features. Their video provided customisation options to the user, i.e. light and image quality adjustments, or virtual backgrounds that did not distort the other person's image. Their UI followed Nielsen's 10 heuristics[89] and was intuitive even for beginners. Their screen sharing did not pose restrictions to the number of users that can screen share simultaneously, the layout of the shared screen and the videos of the other participants, or the other features that can be used simultaneously with screen share. Moreover, one tool that really stood out from the rest was Gather[5]. Its use of a virtual space and avatars that can connect with each other when in proximity took 'resembling in-person interaction' to the next level. Breakout rooms was a feature that suffered overall, but Gather gave it a new dimension that feels more natural to students than the traditional approach. Based on these observations, we can derive the following guidelines for VC software developers:

- Enhance video by adding light and image quality adjustment options, as well as perfecting virtual backgrounds. Make sure they keep the person's image intact.

- Enhance screen sharing and whiteboard sharing by providing customisable screen layout and by not limiting the number of participants that can share content.

- Ensure UI is consistent with standards used across platforms. Make sure to conduct usability tests or a heuristic evaluation.

- Use Gather's[5] approach to breakout rooms, which can alleviate VC's drawbacks related to awkwardness, lack of spontaneity, and unnatural flow of conversation.

- Prioritise implementing all beneficial features to a decent standard rather than omitting certain features only to perfect others.

Guidelines for Students as Users of VC Tools: No matter how good the VC software itself is, experience with social interaction over VC can be widely improved on the user's end. For example, student 23(21-25,NA,Inf) said in the user study that they 'drastically improved the quality of [their] video calls by investing in a better camera and microphone'. Also lighting conditions are very important for the transmission of a clear, more natural image (see 6.1), and a good connection maintains the natural flow of conversation and reduces technology fatigue (see 5.6.2). This can fix the technical issues, but to guarantee a fulfilling social interaction students should choose suitable activities that ensure they spend quality time together, create co-presence, and create shared experiences that they can bond over (see 4.6.3, 4.6.5, 5.6.2). Based on this, we can derive the following guidelines for students:

- Improve video quality by making sure the camera is intact, buying a higher resolution one, or experimenting with lighting and image quality settings, if those are provided by the VC tool.

- Adjust room lighting. The best strategy is to increase the lighting in the background, far from the camera, but decrease the lighting that is positioned near the camera. Correct lighting allows the camera to display colours more accurately and prevents a blanched or dark image projection, as well as graininess[87].

- Improve audio quality by buying a higher resolution microphone, adjusting noise reduction settings if provided by the VC tool, and using headphones to eliminate echo caused by the microphone picking up the sound of the speakers.

- Minimise background noise by going to a separate room, using headphones, or choosing a time for the call when nobody else is home.

- Reduce technology fatigue by remaining engaged and avoiding multitasking or going on other apps during a video call. If needed, there are app blocker programs, which remove distractions by blocking specific applications for a preset time duration[97]. If possible, you can also remove your own video from your view, which can be distracting from the social interaction and have negative impacts on psychology (see 5.6.2). It is also important to engage in offline activities in between video calls to reduce screen time.

- Reduce lag by moving closer to the router or using a wired connection[85]. Ensure that no other process is using up the bandwidth. This also helps reduce technology fatigue.

- Avoid video calls with many participants, since those can be hard to coordinate over VC. A breakout room feature that allows participants to freely move between rooms can be helpful (see 4.6.5, 5.6.2).

- Shared experiences is what strengthens the bonds between people. When face-to-face interaction is not an option, it is important to pick activities that you can do together over video call, such as play games, watch movies together, or have a virtual dinner.

Chapter 8

Conclusion

In conclusion, for this project I completed a user study, a systematic literature review and a hands-on review, and provided a list of recommendations. The user study answered RQ1, RQ2 and RQ3 from the perspective of students from UoE. It was conducted by having participants fill out an online questionnaire and analysing the responses with quantitative and qualitative methods. The systematic literature review was conducted according to the PRISMA[77] protocol and answered RQ2 and RQ3 from the perspective of past literature. Papers were chosen based on specific ECs, and data gathered from them was analysed using thematic analysis. The hands-on review was conducted to evaluate how much the most popular VC tools assist or hinder social interaction between students, based on the features of VC tools that were found to be beneficial for that purpose from the previous two reviews. Some background research was conducted in order to break down high level features into sub-features, and the tools were attributed a score based on which of these sub-features they provided. The final evaluation results were displayed in Figure 6.1. Finally, the results from all the above were used to draw usage guidelines for students wanting to make the most out of their online social interaction via VC, as well as design guidelines for software developers looking to optimise their VC platform for social interaction among students.

8.1 Discussion

Starting with my initial literature review, as shown in my methodology chapter, I mostly used the findings to formulate my RQs and to compose the background chapter. It was very difficult to find past research that had the exact same focus as my dissertation. Thus, I broke my topic down into smaller sub-topics, such as the importance of social interaction, social interaction during COVID-19, students using VC tools, etc. This way I still got an overview of all aspects of my topic, but from papers that were examining each one separately.

The biggest challenge with the user study was recruiting enough participants. The expectation was that at least 50 students would fill out the questionnaire when I shared it with all informatics students in the university with my supervisor's help. However, after a week only 22 students had filled it out, so I had to take immediate action to

promote my survey. After me and my supervisor sent a reminder email to all informatics students, I also directly messaged other students and various student groups that I was part of, asking them to complete the questionnaire and share it with other students in the university. I also started preparing for the possibility of conducting interviews with students to safeguard against issues with low participant numbers in the questionnaire. However, I did not need this, since I surpassed my goal of 50 participants. Eventually the user study took me longer to complete than expected, and that was mostly due to the difficulties I faced using nvivo[11]. The tool itself was quite slow and I found the UI confusing, which led to me needing more time to familiarise myself with it. In future projects I aim to look for and experiment with other similar tools, and perhaps I will find one that is a better fit for me.

The systematic literature was the most challenging step in my methodology. The number of papers I had to look through was very large, therefore I had to make a meticulous plan before carrying it out. The PRISMA [77] framework was really helpful in that regard, since it provided me with a guideline of everything I would have to consider before starting. However, conducting the review still took longer than the time that I had initially allocated for it. I also had difficulties comprehending what each section of PRISMA entailed, since often the explanations were not very descriptive, so that also delayed my planning process. I set a limit of 1000 results to look through in total to make the review more feasible given the time restrictions. This made it difficult to come up with an appropriate search key word, since now the results didn't only have to be relevant, but their number also had to be withing the limit. Filtering out results that contained the word 'education' was really helpful, since most papers talked about students using VC tools in the context of education and online classrooms. That significantly reduced the number of results and made them more relevant to the context of socialisation.

Finally, the initial plan was to conduct a second systematic review to identify all existing VC systems that can be used by students and evaluate all of them in my hands-on review. However, since my schedule was disrupted by the systematic literature review, I decided to rather focus on the most popular VC systems, which I had already gathered from the previous stages of the project, mostly the user study. This gave me more time to thoroughly plan the review and to do enough background research so that I could break down the high level beneficial features identified into testable sub-features - something which I initially thought would have already been accomplished by the user study, however the participants' responses did not touch upon that. I also quickly realised that it would be difficult to conduct the review completely by myself, since some features can only be effectively tested with a second participant in the call (see 6.2). Therefore, I got some help from a third party, so that I could see the effect that features such as noise reduction and video settings have on the video call.

8.1.1   Limitations

I have been analysing the limitations of my methods throughout this dissertation. In summary, the limitations of the user study mostly had to do with the limited number of recruited participants, as well as the quality of the responses. Specifically, the number

of participants is a very small percentage when placing it in the context of all university students. The quality of the participants' responses was also not good in some cases. For example, some participants gave unusable answers because they misunderstood the questions. The main limitation of the systematic literature review was that I could not use any search key word I wanted to search in Google[6] and in Google Scholar[8]. I had to limit the length of my search key word to match the requirements of each search engine, while it had to return up to 1000 results in total. This might have led to some relevant results being omitted. Finally, the main limitation of the hands-on review was that I could only test the features on one OS, since I only had access to one device, and I also could not test if the quality of the features was affected by more than 1 people joining the call. Thus, I cannot be certain if my results hold in every case. Another limitation is the fact that I only focused on the most popular tools instead of testing all the existing VC tools, as explained above.

8.2 Future Work

If I were to extend this project I would expand the hands-on review to all existing VC tools rather than just the most popular ones. I would first conduct a systematic review in order to identify the names of all VC software that are currently available. Ideally, I would remove factors that limit the tools I have access to. For instance, I would secure funding so that I am not limited to free systems, or I would gain access to devices with different operating systems. Ultimately, students could be redirected to a less popular tool, if one is found that can better fulfill their needs. The review could be further extended by testing each tool against harmful features apart from beneficial ones, or by including more researchers to assess how well each tool supports group calls.

Moreover, I could use the results from this project in order to create a prototype of a VC tool that meets all of students' requirements for online social interaction. This tool would follow the example of the highest rated tools from the hands-on review and would combine all of their benefits. After creating this prototype, I could recruit students to evaluate its functionality and usability, and if the results are promising, I could implement it. This would give university students a VC option tailored specifically to their needs, and it would greatly assist their selection process for VC software in case face-to-face interaction is infeasible again in the future. It could also be used by instructors and universities to better encourage interaction during course activities and make these activities more engaging.

Finally, it would be worth trying to disseminate the findings of this work in conferences and publications. The first step towards this goal has already been made, since me and my supervisor will be presenting this project in this year's UoE Learning and Teaching Conference.

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Appendix A

Participants' information sheet

Project title: Students' experience with using video conferencing systems for social interaction during the Covid-19 pandemic **Principal investigator:** Cristina Alexandru **Researcher collecting data:** Phoebe Mamalouka **Funder (if applicable):** N/A

This study was certified according to the Informatics Research Ethics Process, RT number rt#7076. Please take time to read the following information carefully. You should keep this page for your records.

Who are the researchers? Phoebe Mamalouka s1936575 Muminah Koleoso s1932280 Cristina Alexandru – supervisor

What is the purpose of the study? The goal of the study is understanding how students interacted with video conferencing tools during the COVID-19 pandemic and how they used them to remain socially active while social distancing. By collecting information about students' experiences with different aspects of the tools, the aim is to determine what are the features of such tools that help or hinder social interaction for students. Based on this information a list will be made of the most important features to test against in a following hands-on review, where these features will be evaluated in practice. These results can eventually be used for finding which are the best and worst tools overall for social interaction among students, as well as for drawing guidelines for how video conferencing tools should be used or designed in order to have the most benefits.

Why have I been asked to take part? Research target group is students

Do I have to take part? No – participation in this study is entirely up to you. You can withdraw from the study at any time, without giving a reason. Your rights will not be affected. If you wish to withdraw, contact the PI. We will stop using your data in any publications or presentations submitted after you have withdrawn consent. However, we will keep copies of your original consent, and of your withdrawal request.

What will happen if I decide to take part? You will be asked to complete an online questionnaire via Microsoft Forms regarding your experience with video conferencing tools during the COVID-19 pandemic. The questions will mostly focus on specific features of these tools and they kind of impact they had on your social interaction (did they help it or hinder it, and how). You will also be asked to disclose your age range,

year in university, and gender; this is all data that will be used to draw conclusions about the differences in online social interaction between different age groups and genders. There will also be an option for you to give your contact information in case you would like to be further contacted to participate in a face-to-face interview, this part however is completely optional. The time needed to complete the questionnaire will be approximately 10 minutes.

Are there any risks associated with taking part? There are no significant risks associated with participation.

Are there any benefits associated with taking part? You can benefit indirectly from helping us draw some guidelines on how to use video conferencing tools to achieve maximum benefits for online social interaction.

What will happen to the results of this study? The results of this study may be summarized in published articles, reports and presentations. Quotes or key findings will be anonymized: We will remove any information that could, in our assessment, allow anyone to identify you. With your consent, information can also be used for future research. Your data may be archived for a minimum of 2 years.

Data protection and confidentiality. Your data will be processed in accordance with Data Protection Law. All information collected about you will be kept strictly confidential. Your data will be referred to by a unique participant number rather than by name. Your data will only be viewed by the researchers named above. All electronic data will be stored on a password-protected encrypted computer, on the School of Informatics' secure file servers, or on the University's secure encrypted cloud storage services (DataShare, ownCloud, or Sharepoint) and all paper records will be stored in a locked filing cabinet in the PI's office. Your consent information will be kept separately from your responses in order to minimise risk.

What are my data protection rights? The University of Edinburgh is a Data Controller for the information you provide. You have the right to access information held about you. Your right of access can be exercised in accordance Data Protection Law. You also have other rights including rights of correction, erasure and objection. For more details, including the right to lodge a complaint with the Information Commissioner's Office, please visit www.ico.org.uk. Questions, comments and requests about your personal data can also be sent to the University Data Protection Officer at dpo@ed.ac.uk. For general information about how we use your data, go to: edin.ac/privacy-research

Who can I contact? If you have any further questions about the study, please contact the lead researcher, Phoebe Mamalouka, at s1936575@ed.ac.uk If you wish to make a complaint about the study, please contact inf-ethics@inf.ed.ac.uk. When you contact us, please provide the study title and detail the nature of your complaint.

Updated information. If the research project changes in any way, an updated Participant Information Sheet will be made available on http://web.inf.ed.ac.uk/infweb/research/study-updates.

Appendix B

Participants' consent form

Consent

By proceeding with the study, I agree to all of the following statements:

- I have read and understood the above information.

- I understand that my participation is voluntary, and I can withdraw at any time.

- I consent to my anonymised data being used in academic publications and presentations.

- I allow my data to be used in future ethically approved research

Appendix C

Questionnaire questions

Students' Experience with Video Conferencing Systems for Social Interaction during Covid-19

Before proceeding, read the following participant information sheet: https://docs.google.com/document/d/1aoAXlDP6USZU1WMzY0X-oDElLEmoglV9i_xG5C9lTP4/edit?usp=sharing

Section 1 ...

Provide Consent

1. Please select if you agree to ALL of the below statements:
   · I have read and understood the above information.
   · I understand that my participation is voluntary, and I can withdraw at any time.
   · I consent to my anonymised data being used in academic publications and presentations.
   · I allow my data to be used in future ethically approved research. *

   ○ Yes

   ○ No

Figure C.1: Question 1

Figure C.2: Questions 2-4

5. Which school are you in? *

    ◯ Business School

    ◯ School of Divinity

    ◯ School of Economics

    ◯ Edinburgh College of Art

    ◯ Moray House School of Education and Sport

    ◯ School of Health in Social Science

    ◯ School of History, Classics and Archaeology

    ◯ School of Law

    ◯ School of Literatures, Languages and Cultures

    ◯ School of Philosophy, Psychology and Language Sciences

    ◯ School of Social and Political Science

    ◯ Centre for Open Learning

6. Which school are you in? *

    ◯ Edinburgh Medical School

    ◯ Royal (Dick) School of Veterinary Studies

7. Which school are you in? *

    ◯ School of Biological Sciences

    ◯ School of Chemistry

    ◯ School of Engineering

    ◯ School of Geosciences

Figure C.3: Question 5 branches 1-3

7. Which school are you in? *

- ◯ School of Biological Sciences
- ◯ School of Chemistry
- ◯ School of Engineering
- ◯ School of Geosciences
- ◯ School of Informatics
- ◯ School of Mathematics
- ◯ School of Physics and Astronomy

8. Select all the years during which you were a student in university: *

- ☐ 2020
- ☐ 2021
- ☐ 2022

9. What is your gender? *

- ◯ Prefer not to say
- ◯ Female
- ◯ Male
- ◯ Non-binary
- ◯ Other

Figure C.4: Questions 6-7

Section 3 ...

Experience with video conferencing tools

This section includes questions about your experience and opinions about video conferencing tools and their specific features

10. Please state 1-3 things that come to mind when you think of a positive online social interaction? (For example, how they make you feel, what impact it has.)

Enter your answer

11. Select all video conferencing tools that you have used *

☐ Facebook Messenger

☐ Whatsapp

☐ Zoom

☐ Microsoft Teams

☐ FaceTime

☐ Google Hangouts

☐ Skype

☐ Slack

☐ Adobe Connect

☐ FreeConference

☐ GoToMeeting

☐ Other

Figure C.5: Questions 8-9

12. How often did you use video conferencing tools in general during the COVID-19 pandemic? *

    ○ Rarely

    ○ Once or twice a month

    ○ A few times a month

    ○ Once or twice a week

    ○ A few times a week

    ○ Once or twice a day

    ○ A few times a day

    ○ Multiple times a day

13. During the pandemic, how often did you use them for school related purposes (e.g. lectures, tutorials, meetings, etc.) versus non-school related purposes (e.g. casual chat with friends and family, online social gatherings, etc.)? *

    ○ Only used them for school related purposes

    ○ Mostly school related, occasionally non-school related purposes

    ○ Equally used them for school related and non-school related purposes

    ○ Mostly non-school related, occasionally school related purposes

    ○ Only used them for non-school related purposes

Figure C.6: Questions 10-11

14. During the lockdown, would you say there were opportunities for socialization during online course activities (e.g. group ice breakers, group activities, private chats)? How important were these opportunities for you? *

      ○   Yes, and they were important for me

      ○   Yes, but it didn't make any difference for me

      ○   No, but I wish there had been

      ○   No, and it didn't make any difference for me

      ○   Other

15. Which of the following activities do you usually do during social video chats? *

      ☐   Talk live

      ☐   Turn on my camera

      ☐   Share links, posts or other content

      ☐   Watch movies together (while sharing your screen)

      ☐   Play games (online or offline) (while sharing your screen)

      ☐   Work on assignments together (while sharing your screen)

      ☐   Other

16. List the first 3 things that come to your mind which you enjoy about social video chats more than in-person meetups: *

Enter your answer

17. List the first 3 things that come to your mind which you do not enjoy about social video chats compared to in-person meetups: *

Figure C.7: Questions 12-15

18. In the context of extracurricular social video chats, how would you rate the following features of video conferencing tools in terms of how much they contribute to the quality of the interaction (with 1 being minimum and 5 being maximum contribution)? *

	1(min. contr.)	2	3	4	5(max. contr.)	Never used feature
Video	○	○	○	○	○	○
Switching devices mid-call	○	○	○	○	○	○
Screen sharing	○	○	○	○	○	○
Screen interactivity	○	○	○	○	○	○
Meeting Recording	○	○	○	○	○	○
Group chat	○	○	○	○	○	○
Private chat	○	○	○	○	○	○
Breakout rooms	○	○	○	○	○	○
User friendly UI	○	○	○	○	○	○
Active talk indicator (square that lights up around person's image when talking)	○	○	○	○	○	○
Noise reduction	○	○	○	○	○	○
Filters	○	○	○	○	○	○
Embedded Augmented Reality Games	○	○	○	○	○	○
Shared Whiteboard	○	○	○	○	○	○

19. For the features that you rated with 3 or below above, give your reasoning *

Enter your answer

20. In the context of social interaction for school-related purposes via video calls, how would you rate the same features of video conferencing tools in terms of how much they contribute to the quality of the interaction (with 1 being minimum and 5 being maximum contribution)? *

	1(min. contr.)	2	3	4	5(max. contr.)	Never used feature
Video	○	○	○	○	○	○
Switching devices mid-call	○	○	○	○	○	○
Screen sharing	○	○	○	○	○	○
Screen interactivity	○	○	○	○	○	○
Meeting Recording	○	○	○	○	○	○
Group chat	○	○	○	○	○	○
Private chat	○	○	○	○	○	○
Breakout rooms	○	○	○	○	○	○
User friendly UI	○	○	○	○	○	○
Active talk indicator (square that lights up around person's image when talking)	○	○	○	○	○	○
Embedded Augmented Reality Games	○	○	○	○	○	○
Shared Whiteboard	○	○	○	○	○	○
Noise reduction	○	○	○	○	○	○
Filters	○	○	○	○	○	○

21. For the features that you rated with 3 or below above, give your reasoning *

Enter your answer

22. Do you have any additional comments?

Enter your answer

Section 4   •••

Contact information

23. If you would be willing to be contacted about participating in a follow-up interview, provide
    your email (or any other preferred means of communication) below (optional):

    Enter your answer

Figure C.10: Question 21

Appendix D

Graphs summarizing quantitative results of user study

2. What is your age group?

More Details   💡 Insights

🔵	Below 15	0
🟠	15 - 18	1
🟢	18 - 21	32
🔴	21 - 25	25
🟣	Above 25	6

Figure D.1: Answers to 'What is your age group?'

3. What kind of degree are you currently enrolled in?

More Details   💡 Insights

🔵	Undergraduate (Bachelor's)	50
🟠	Masters	5
🟢	PhD	9

Figure D.2: Answers to 'What kind of degree are you currently enrolled in?'

4. Which college are you in?

More Details   💡 Insights

🔵 College of Arts, Humanities and ... 23

🟠 College of Medicine and Veterin... 6

🟢 College of Science and Engineer... 35

Figure D.3: Answers to 'Which college are you in?'

5. Which school are you in?

More Details

🔵 Business School   2

🟠 School of Divinity   0

🟢 School of Economics   2

🔴 Edinburgh College of Art   4

🟣 Moray House School of Educati...   0

🟤 School of Health in Social Science   1

🟥 School of History, Classics and A...   1

⚫ School of Law   3

🟡 School of Literatures, Language...   2

🔵 School of Philosophy, Psycholog...   4

🔵 School of Social and Political Sci...   4

🟠 Centre for Open Learning   0
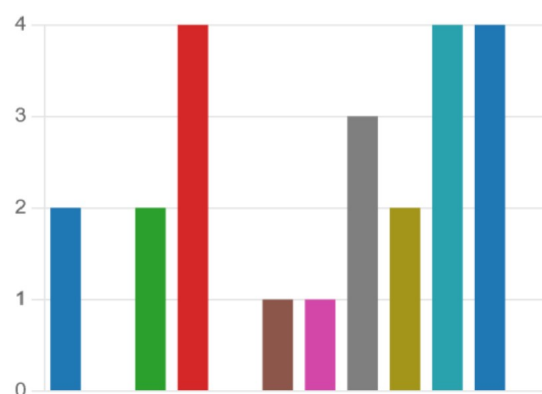
Figure D.4: Answers to 'Which school are you in?' - Humanities branch

6. Which school are you in?

More Details

🔵 Edinburgh Medical School	6
🟠 Royal (Dick) School of Veterinar...	0
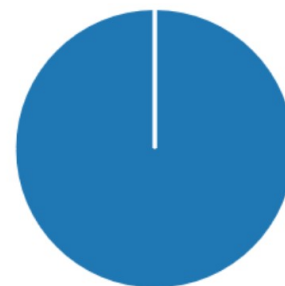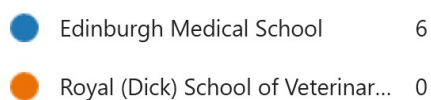
Figure D.5: Answers to 'Which school are you in?' - Medicine branch

7. Which school are you in?

More Details   💡 Insights

🔵 School of Biological Sciences	1
🟠 School of Chemistry	0
🟢 School of Engineering	5
🔴 School of Geosciences	0
🟣 School of Informatics	24
🟤 School of Mathematics	3
🟣 School of Physics and Astronomy	2
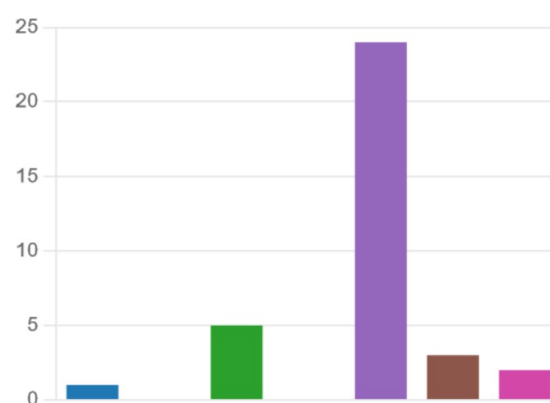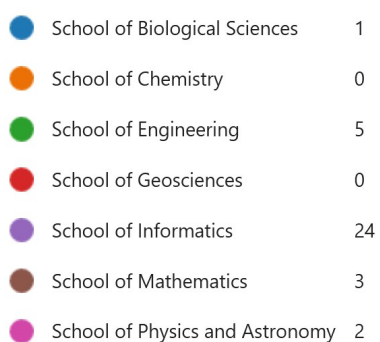
Figure D.6: Answers to 'Which school are you in?' - Science branch

8. Select all the years during which you were a student in university:

More Details

🔵 2020	50
🟠 2021	59
🟢 2022	61

Figure D.7: Answers to 'Select all the years during which you were a student in university'

9. What is your gender?

More Details   ☼ Insights

🔵	Prefer not to say	5
🟠	Female	36
🟢	Male	20
🔴	Non-binary	3
🟣	Other	0

Figure D.8: Answers to 'What is your gender?'

Facebook Messenger (43)
Whatsapp (42)
Zoom (63)
Microsoft Teams (57)
FaceTime (25)
Google Hangouts (29)
Skype (42)
Slack (17)
FreeConference (2)
GoToMeeting (3)
Discord (6)
Tencent Meeting (1)
Google Meet (2)
Jitsi (2)
Signal (2)
BlueJeans (1)
Telegram (1)

Select all video conferencing systems you have used
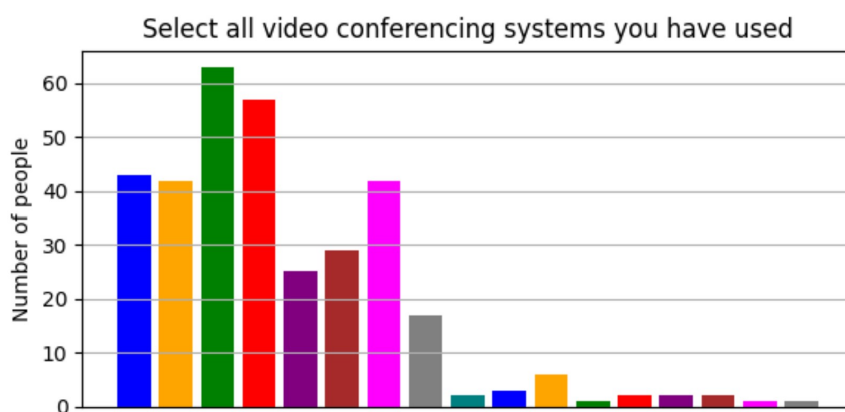
Figure D.9: Answers to 'Select all video conferencing tools that you have used'

12. How often did you use video conferencing tools in general during the COVID-19 pandemic?

● Rarely	1	
● Once or twice a month	1	
● A few times a month	3	
● Once or twice a week	1	
● A few times a week	19	
● Once or twice a day	13	
● A few times a day	14	
● Multiple times a day	12	
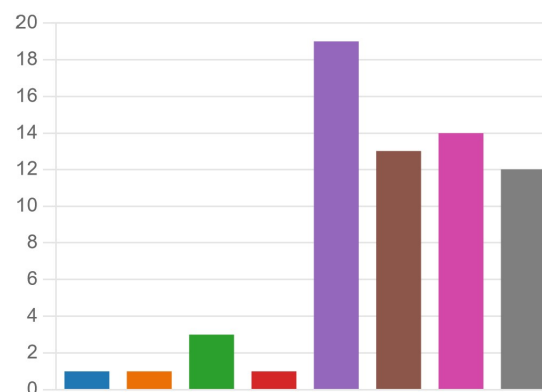
Figure D.10: Answers to 'How often did you use video conferencing tools in general during the COVID-19 pandemic?'

14. During the lockdown, would you say there were opportunities for socialization during online course activities (e.g. group ice breakers, group activities, private chats)? How important were these opportunities for you?

● Yes, and they were important fo...	16
● Yes, but it didn't make any differ...	21
● No, but I wish there had been	14
● No, and it didn't make any differ...	9
● Other	4
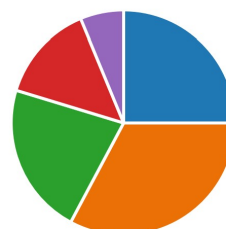
Figure D.11: Answers to 'During the lockdown, would you say there were opportunities for socialization during online course activities (e.g. group ice breakers, group activities, private chats)? How important were these opportunities for you?'

15. Which of the following activities do you usually do during social video chats?

More Details

🔵	Talk live	57
🟠	Turn on my camera	45
🟢	Share links, posts or other conte...	34
🔴	Watch movies together (while s...	21
🟣	Play games (online or offline) (w...	28
🟤	Work on assignments together (...	30
🟣	Other	0
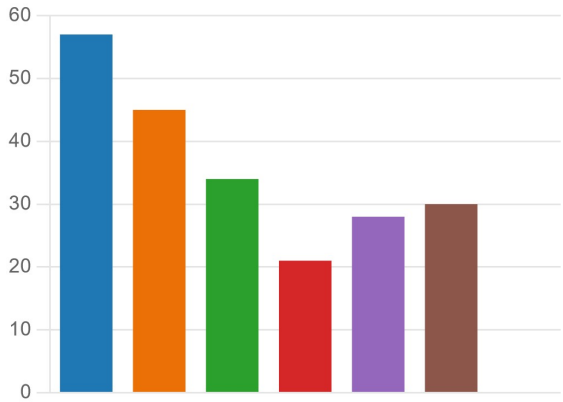
Figure D.12: Answers to 'Which of the following activities do you usually do during social video chats?'

18. In the context of extracurricular social video chats, how would you rate the following features of video conferencing tools in terms of how much they contribute to the quality of the interaction (with 1 being minimum and 5 being maximum contribution)?

More Details
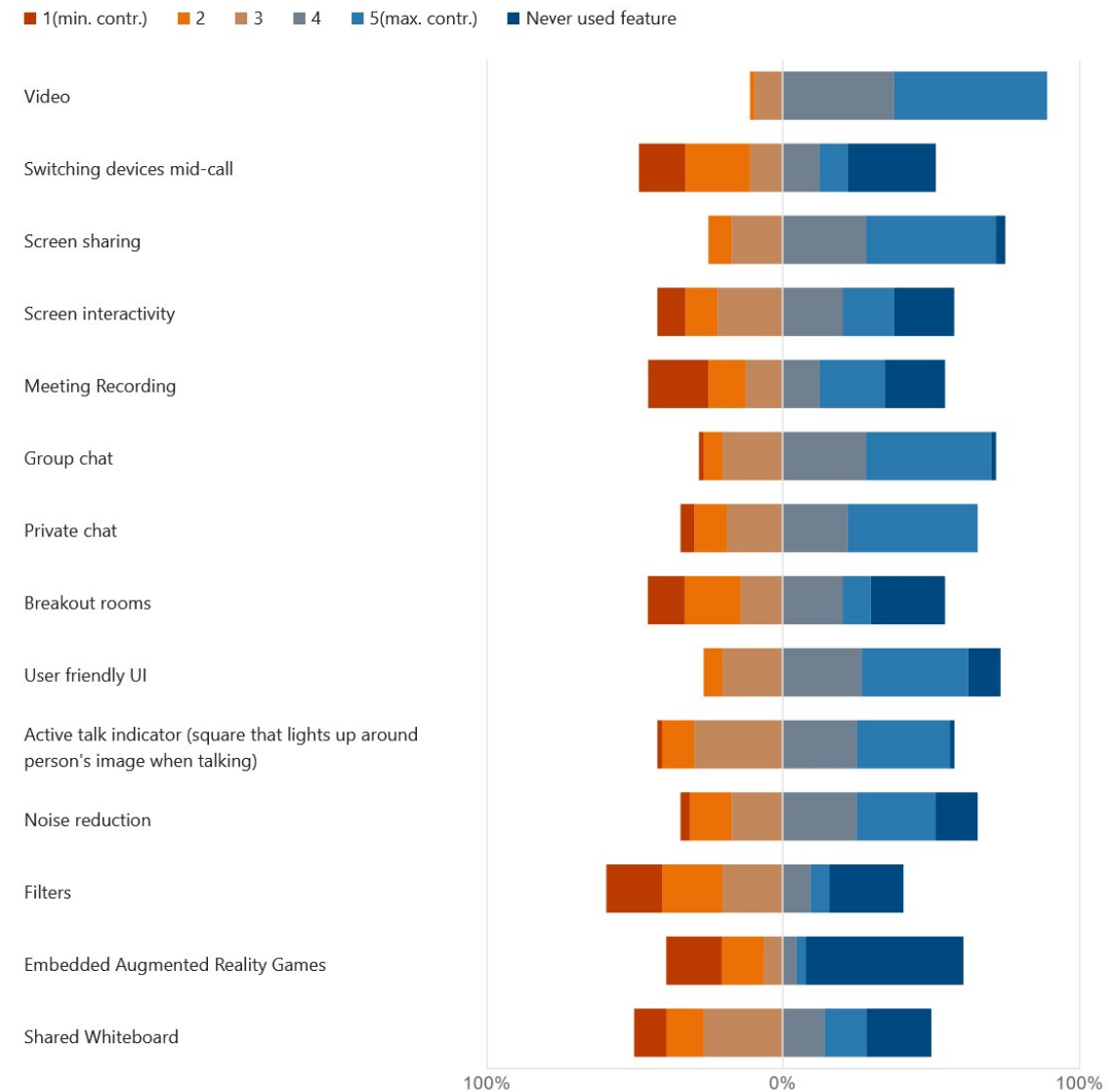
Figure D.13: Answers to 'In the context of extracurricular social video chats, how would you rate the following features of video conferencing tools in terms of how much they contribute to the quality of the interaction (with 1 being minimum and 5 being maximum contribution)?'

20. In the context of social interaction for school-related purposes via video calls, how would you rate the same features of video conferencing tools in terms of how much they contribute to the quality of the interaction (with 1 being minimum and 5 being maximum contribution)?

More Details
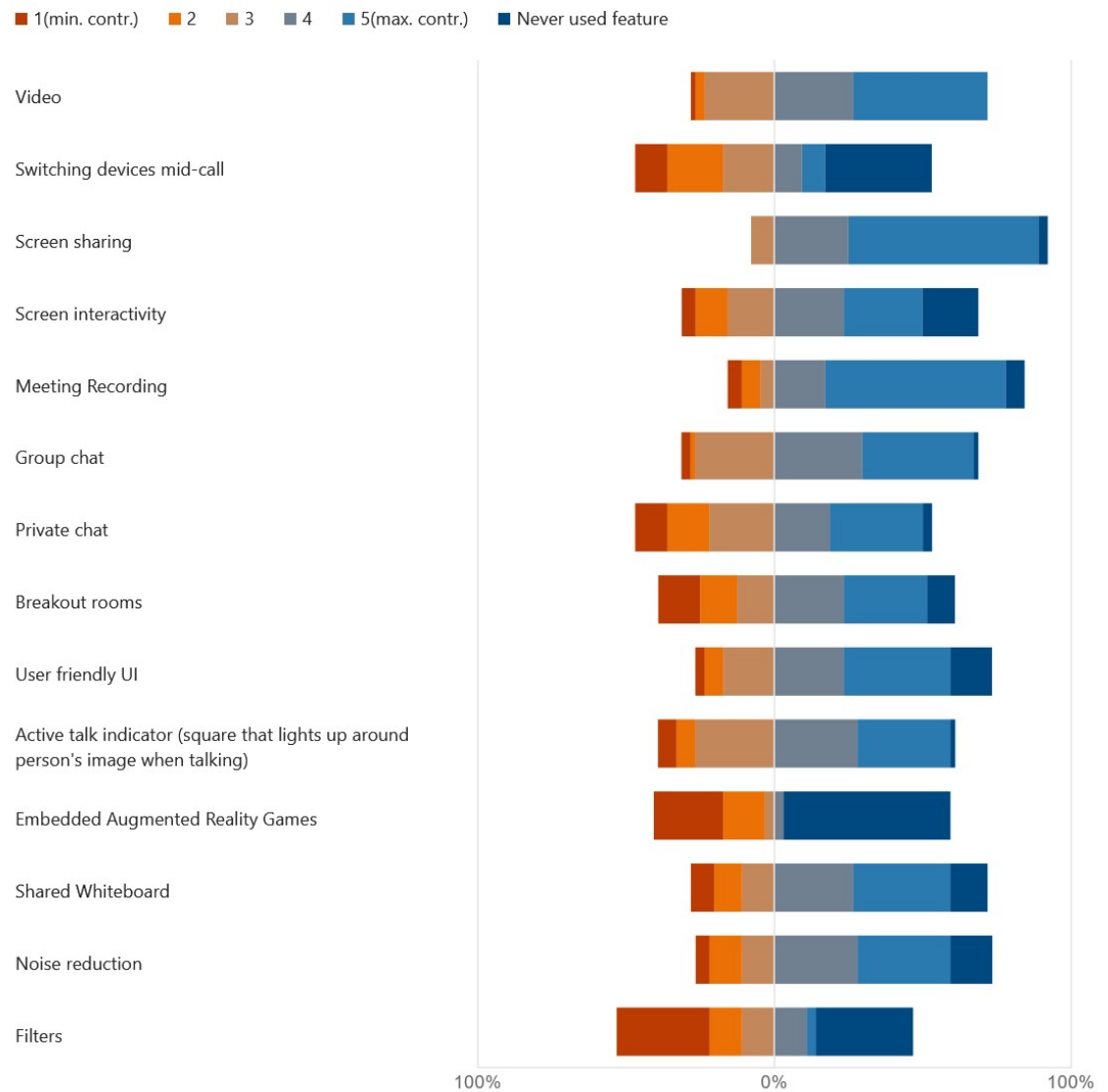
Figure D.14: Answers to 'In the context of social interaction for school-related purposes via video calls, how would you rate the same features of video conferencing tools in terms of how much they contribute to the quality of the interaction (with 1 being minimum and 5 being maximum contribution)?'

Appendix E

Relevant Papers from Systematic Literature Review

Singh, A. and Eden, G., 2021. Hanging Out Online: Social Life During the Pandemic. In Human-Computer Interaction–INTERACT 2021: 18th IFIP TC 13 International Conference, Bari, Italy, August 30–September 3, 2021, Proceedings, Part II 18 (pp. 25-33). Springer International Publishing.[105]

Boland, J.E., Fonseca, P., Mermelstein, I. and Williamson, M., 2022. Zoom disrupts the rhythm of conversation. Journal of Experimental Psychology: General, 151(6), p.1272.[34]

Scott, R.A., Stuart, J., Barber, B.L., O'Donnell, K.J. and O'Donnell, A.W., 2022. Social connections during physical isolation: how a shift to online interaction explains friendship satisfaction and social well-being. Cyberpsychology: Journal of Psychosocial Research on Cyberspace, 16(2). [102]

Kelly, R.M., Cheng, Y., McKay, D., Wadley, G. and Buchanan, G., 2021, May. "It's About Missing Much More Than the People": How Students use Digital Technologies to Alleviate Homesickness. In Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems (pp. 1-17).[66]

Hoefer, G., Massachi, T., Xu, N.G., Nugent, N. and Huang, J., 2022. Bridging the Social Distance: Offline to Online Social Support during the COVID-19 Pandemic. Proceedings of the ACM on Human-Computer Interaction, 6(CSCW2), pp.1-27.[61]

Christopher R. Agnew, Jonathan J. Carter, and Ledina Imami. Forming Meaningful Connections Between Strangers in Virtual Reality: Comparing Affiliative Outcomes by Interaction Modality. Technology, Mind, and Behavior, 3(3: Autumn), aug 1 2022.[26]

Almutairi, M.F., Alhassan, O.M., AbdElneam, A.I. and Alsenaid, A., 2022. An Analysis of Aesthetic Concerns Identified by Video Conferencing. Cureus, 14(11).[27]

Elmer, T., Mepham, K. and Stadtfeld, C., 2020. Students under lockdown: Comparisons of students' social networks and mental health before and during the COVID-19 crisis in Switzerland. Plos one, 15(7), p.e0236337.[52]

Lippke, S., Fischer, M.A. and Ratz, T., 2021. Physical activity, loneliness, and meaning of friendship in young individuals–a mixed-methods investigation prior to and during the COVID-19 pandemic with three cross-sectional studies. Frontiers in Psychology, 12, p.617267.[78]

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Buehler, E.M. and High, A.C., 2022. Indirect effects of video chat on outcomes of receiving support: Uniting theorizing about supportive communication and computer-mediated communication. Communication Monographs, pp.1-20.[36]

Hart, L.M., Mitchison, D., Fuller-Tyszkiewicz, M., Giles, S., Fardouly, J., Jarman, H.K., Damiano, S.R., McLean, S.A., Prichard, I., Yager, Z. and Krug, I., 2023. "Can you see me?" Videoconferencing and eating disorder risk during COVID-19: Anxiety, impairment, and mediators. International Journal of Eating Disorders, 56(1), pp.235-246.[60]

Vaux, D.E. and Langlais, M.R., 2023. Reframing Third Places: Environmental Changes of Merging Places During COVID-19. Journal of Interior Design, 48(1), pp.12-28.[112]

McKenna-Plumley, P.E., Graham-Wisener, L., Berry, E. and Groarke, J.M., 2021. Connection, constraint, and coping: A qualitative study of experiences of loneliness during the COVID-19 lockdown in the UK. PLoS One, 16(10), p.e0258344.[82]

Hall, J., Pennington, N. and Holmstrom, A., 2021. Connecting through technology during COVID-19. Human Communication Technology, 2(1).[58]

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Appendix F

Data Items of Systematic Literature Review

Title	Journal	Link	Software Mentioned	Helpful Features	Unhelpful Features	Positive Experience	Sub-themes	Negative Experience	Sub-themes	Use Purposes	Number of Participant	Suggestions for use / design of software
Hanging Out Online: So Human-Cc		https://lin	google duo, discord	synchronous video	N/A	Students would engag affords a high degree of social presence	intentionality	"challenges also include	privacy	watching movie	5	
				group chat -> chat	N/A	due to the richness of face-to-face re However, online social i technology fai emotional support						
						One result of this has l preserving relationships						
								they felt comfortable in difficult group interactions	different time checking up on friends / preserving relationships			
								the dissolution of the or not being able NA				
								(2021) suggests that there are nonverbal sources, such as	lack of sponte NA			
Zoom Disrupts the Rhyt Journal of		https://do	zoom	high quality video seeing oneself on the In contrast to other re face-to-face re Brady (1971) provided technology fai N/A				This replicated the ren natural flow b For example, Bailenson unnatural eler N/A			43	
								1.78% of trials were dropped because they	awkwardness			
Social Connections Duri CyberPsyc		https://do	N/A	N/A	N/A	Consideration of onlin face-to-face re loneliness and social co effect of dram NA					404	Research suggests that in order to alleviate loneliness and enhance con
						Relevant literature em emotional support						
						Specifically, in compar students who						
						This indicates that the preserving exi NA						
"It's About Missing Mu Proceedin		https://dl	whatsapp, facebook m	When asked about NA		For the problem of hou face-to-face re Several participants felt difficult group acquiring social					50	During the interviews, some of the participants expressed an interest in
						Twelve participants di co-presence	The most prominent co intensification seeking help and support					Emerging technologies that mediate the perception of taste, touch and
							However, interactions v less co-presen building social c NA					Those from rural areas described how poor internet connectivity meant
							Participants des NA					The frst related to maintaining relationships across timezones [6]. Three
Bridging the Social Dist Proceedin		https://dl.	N/A	N/A	N/A	Interestingly, all other emotional sup In particular, we note tt loneliness (de N/A					827	Specifically, students who only interacted in-person and never disclosec
								We would therefore exp privacy issues N/A				
Forming Meaningful Co Technolog		https://do	Skype	synchronous video	NA	As communication mo no difference NA					272	
Covid-19 And Movemer Internatio		http://dx.	NA					They realised the impor lack of sponte stimulation -> li			15	
								Where there is attachm intensification of homesickness				
Students under lockdow PLoS ONE		https://do	NA			Friendship and social s preserving exi students nominated fev loneliness (despite social suppr					212	
Physical Activity, Loneli Frontiers i		https://w	NA					Given the current crisis lack of intimar NA			367	
Indirect effects of video Taylor anc		https://do	zoom	good quality video	N/A	Social presence theory face-to-face re resemblance / non-verbal cues					139	video calls should be conducted in good lighting -> Perceiving a higher c
					compatibility with N/A							as long as image quality is good, screen size doesn't matter -> The findir
A Study of the Efects of Network Latency on	ACM	https://dl .acm.org/	Microsoft Teams, Zoom, Google meet		network latency and jitter			Users of video conferencing tools	technology fai	video game, socialization	18	
IMPROVEMENT IN THE ROOM FOR		https://m ail.google	Zoom, Teams, Gather, skype	Gather, Gather was used to recreate		Gather is a video-conferencing	increase of sponteneity	In-person seminars and workshops, for	awkwardness	socialization in the context of		replacing offices, seminars and conferences in a 'like-for-like'
Robot Mediated Handholding Com		https://m	NA		no physical aspect							Combining a device that mediates social touch between people in remc

Figure F.1: Relevant papers from systematic review (1-13)

Title	Source	URL	Tool	Notes	Findings	N	Additional
Impact of Video-Mediated Online Social	Tecnolog y, mind	https://t mb.apao	zoom	A similar social influence linear	co-presence/soc	70	
Videoconference Fatigu	Journal of	https://mail.google.com/mail/u/ ability to easily tur	NA		videoconference fatigue technology fatigue	69	Muting oneself, turning off one's webcam, or not looking at one's own
					Testing the interaction of these two characteristics suggested that even		
					However, the relationship with lower fatigue at the midday time point (		
"Can you see me?"	Vide Internatio	DOI: 10.11 zoom, microsoft teams	NA	seeing yourself during the meeting		640	Our findings suggest that videoconferencing taps into mechanisms asso
Places: Environmental Changes of Merging	Journal of	https://on NA		During the COVID-19 pa fusion of spac	NA	229	
Connection, constraint,	PLoS ONE	https://do NA					
Social anxiety is related	Anxiety, St	https://do NA		unnatural gaze	In line with our third hy awkwardness	85	
and Face-to-Face Communication: Relationship with Life	Journal of	https://do	zoom	It appears DM/texting co-presence / social support / preserving existing friendships		1869	
				Video chat and voice c less loneliness Compared to FtF contac lack of spontaneity / less frequent communication			
Relationships between:	Psycholog	https://wv	zoom	Although we did not t less loneliness / easy access		127	
HOW COVID-19 HAS AL	The Owl-F	https://jou	zoom, facetime, google hangouts	Indeed, when asked wh fusion of spaces / VC not enou		48	
Connecting Through Te	HALL, PEN	https://jou	zoom, skype, google hangouts	According to MRT, like face-to-face re FtF communication. The VC inferior to face-to-face / les		1947	
				Hall's (2020) study usin intensification of homesickness			
An Analysis of Aesthetic Concerns	Cureus	https://w ww.cureu	Microsoft Teams, Zoom, Google meet	seeing yourself during the call	During and after the coronavirus disease Aesthetic concerns work, school, telemedicine,	432	shorter VC, control of camera distance, camera off, focus on screen activities
Team Management and collaborative distance working	internatio nal hellenic	https://re positony.i hu.edu.gr	Skype, Zoom and MS Teams	teleworking makes people feel more organized and	remote working interferes with family life and makes it hard less stress fusion of spaces	60	
It's a touchy subject:	Hc University	https://pil discord, zoom		For this particular stuc face-to-face re However, for some it w VC not enough		915	For this particular stuc face-to-face re However, for some it w VC not enough
				Even video calls, which intensification of homesickness			
Visual attention patterr	Journal of	https://wv zoom		seeing yourself durin NA	The present study exam equally stressful for socially an	60	
The Psychological and S	Frontiers i	https://wv NA		Also, human communi emotional and social support			
Web-based Conferencir	Journal of	https://jou zoom, google meet, we	NA	Lectures that have bee lectures can si Flipped classroom web- VC replaced by audio calls in classrooms			

Figure F.2: Relevant papers from systematic review (14-30)

Appendix G

Data Items of Hands-on Review

	Facebook Messenger	Zoom	Skype	Google Meet	Microsoft Teams	Whatsapp	Discord	Slack	FreeConference	Tencent Meeting (VooV)	GoTo Meeting	Jitsi	Signal	BlueJeans	Telegram	Gather	Webex	Microsoft Teams (for work or school)
video																		
low light adjustment option	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
virtual background	0.5	1	1	0.5	0.5	0.5	0	0	0	0.5	0	0	0	0	0	0	0.5	0.5
locate on/off button	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
adjust image quality	0	1	1	1	0	0	0	0	0.5	1	0	0	0	0	0	0	0.5	0
screen sharing						0												
easy to find	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
include audio	1	0.5	0.5	0	0	0	0	0	0	1	0.5	0.5	0	0	0	0	0.5	0.5
share only part of screen	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
can everyone share	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1	1	1
share at the same time	0.5	0.5	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0
zoom into shared screen	0	1	1	1	0	0	1	0	1	1	1	1	0	1	0	0	0	1
rearrange windows to put screen at forefront	1	1	0	0.5	0	0	1	0.5	1	1	1	1	1	0	0	0	1	1
group chat																		
private messages	1	1	1	0	1	1	1	1	1	1	1	1	0.5	1	1	1	1	0
can they use in parallel with call	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
share a minimum of text and files, with some additional fun	1	1	1	0.5	1	1	0.5	1	0.5	0.5	0.5	0.5	1	0.5	1	0.5	0.5	0.5
emojis	1	1	1	0	1	1	1	1	0	0	0	1	1	0.5	1	1	1	1
reactions	1	1	1	0	1	1	1	1	0	0.5	0.5	0	1	0.5	0	0	0	1
noise reduction																		
how effective in reducing background 0ise	1	1	1	1	1	1	0.5	1	0	0.5	0.5	0.5	0	0.5	0	0.5	0.5	1
customize settings	0	1	1	0	0	0	1	0		1			0	0			1	
responsive to changes in environment	0	1	1	1	1	1	0.5	0.5		0			0	1			0.5	
consistency	1	1	1	1	1	1	0	0		0			1	1			1	
shared whiteboard	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ease of access and use																		
multiple participants		1		1					1	1		1		0			1	
clear who is making changes		0		1					1	0		1		0			0	
has at least drawing, eraser, shapes, text box, colour change		1		1					1	1		1		0			1	
responsiveness		0.5		0.5					0.5	0.5		1		0.5			0.5	
does it work seamlessly with other collaboration tools		0		1					0	0		1		0			0	
breakout rooms	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
can choose which room to join																		
can return to main meeting whenever they want		1		1					1	1		1		1			1	
can move between breakout rooms		0		1					1	1		1		1			1	
time limit		1		1					0	0		0		0			0	
ability to broadcast a message to all breakout rooms	0.5	0.5		1					0	0		1		1			1	
appoint breakout room manager		0		0					0	0		0		0			0	
all features present in breakout rooms		1		1					1	1		1		1			1	
ease of use		0		1					1	1		1		1			1	
active talk indicator	0	0	1	1	0	0	0.5	0	0	0	0.5	1	1	1	0	0.5	1	0
0delays or inaccuracies																		
distinguish between talking and 0ise	0	1	0	1	1	1	0	1	0	0.5	0	0.5	1	0	0	0.5	0	0
clearly visible on screen	1	1	1	1	1	1	1	1	1	1	1	0.5	0.5	1	1	1	1	1
does it work seamlessly with other elements	1	1	1	1	1	0.5	0	0	1	1	1	1	1	0	1	1	1	1
user friendly UI																		
visibility of system status	1	1	1	1	0.5	0.5	0.5	1	0.5	0.5	0.5	1	1	1	0	0.5	1	1
match between system and real world	1	1	1	1	1	1	1	1	1	1	1	1	0.5	1	1	1	1	1
user control and freedom	1	0.5	0	0	0.5	0	1	1	0	0	0	1	0	0.5	1	0.5	0.5	1
consistency and standards	0.5	1	1	0.5	1	1	0	0	0.5	0.5	1	1	0.5	1	1	0.5	1	1
error prevention	1	1	0	1	1	1	0	1	1	1	1	0	1	1	0	0	1	0
recognition rather than recall	1	1	1	1	1	1	1	1	1	1	1	0.5	1	1	1	1	1	1
flexibility and efficiency of use	1	0.5	0.5	1	1	0	1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1	0.5	0.5
aesthetic and minimalist design	1	1	0	1	1	1	0	0.5	0.5	0.5	0.5	1	1	0	1	1	1	0.5
help users recognize, diag0se and recover from errors	1	0.5	0.5	0.5	0.5	0.5	0.5	0	1	1	0	0	0	0	0.5	0	1	0
help and documentation	1	1	0	1	1	1	1	1	0	1	1	0.5	0.5	1	1	1	1	0.5

Figure G.1: Detailed Breakdown of Score Distribution among Sub-features for Hands-on Review

Appendix H

VC tools identified for Hands-On Review

Name of System	Type of System	Was it Tested	Reason if not
Facebook Messenger	Instant Messaging (IM) app with VC functionality	Yes	
Whatsapp	IM app with VC functionality	Yes	
Zoom	Dedicated VC app	Yes	
Microsoft Teams	Collaboration tool with VC functionality	Yes	
Microsoft Teams for Work or School	Collaboration tool with VC functionality (specific to organizations)	Yes	
Google Hangouts	Online collaboration tool with VC functionality	No	Implements Google Meet for VC functionality (see below)
FaceTime	Dedicated VC app	No	Not available on Windows
Skype	Dedicated VC app	Yes	
Skype for Business	Dedicated VC app (specific to organizations)	No	Need an organizational email with access to an account
Slack	Collaboration tool with VC functionality	Yes	
FreeConference	Dedicated VC app	Yes	
GoTo Meeting	Dedicated VC app	Yes	
Discord	Collaboration tool with VC functionality	Yes	
Tencent Meeting (VooV)	Dedicated VC app	Yes	
Google Meet	Online dedicated VC app	Yes	
Jitsi Meet	Online dedicated VC app	Yes	
Signal	IM app with VC functionality	Yes	
BlueJeans	Dedicated VC app	Yes	
Telegram	IM app with VC functionality	Yes	
Google Duo	Online dedicated one-on-one VC app	No	No longer exists – has been merged into Google Meet
Line	IM app with VC functionality	No	Technical difficulties
WeChat	IM / social media app with VC functionality	No	New users must be verified by an existing user
HouseParty	Dedicated VC app	No	No longer exists
Gather	VC app / collaboration tool	Yes	
Webex	Dedicated VC app	Yes	
Adobe Connect	Webinar app	No	Did not fall under the definition of VC systems

Figure H.1: Tools identified during user study and systematic literature, and a report of which of them were tested in the final hands-on review

Appendix I

Steps for Testing Features in Hands-on Review

Figures I.1, I.2, and I.3 show the steps taken in order to evaluate each sub-feature. This falls under step 3 as described in the methodology section of the hands-on review.

Sub-feature	Way of testing
Video	
Good location of on/off button for camera	Checked if button visible on main screen
Low light adjustment option	Checked if option existed in video settings and evaluated quality improvement while dimming the lights in my space
Image quality adjustment	Checked if option existed in video settings and evaluated difference in quality
Virtual backgrounds	Applied background on myself and visually tested how well my image is preserved. I also made sudden movements to test how they affected how well the image was captured.
Screen Sharing	
Good location of share button	Checked if button visible on main screen
Option between sharing specific tabs and entire screen	Checked available options when initializing a screen sharing session
Can all participants share their screen	Asked participant 2 to share their screen while I was still sharing
Can participants share their screen simultaneously	
Can other participants zoom into video of shared screen	Attempted to zoom into participant 2's screen by using the most intuitive methods, i.e. by scrolling up with my mouse or by pressing CTRL and the "+" sign. If that didn't work I checked if there was a dedicated option on the screen sharing window
Can other participants rearrange meeting layout to switch between other participants and screen share video at the forefront	Attempted to drag participant 2's image to the centre of the screen while they were screen sharing. If that didn't work, I checked if there was an option to change the meeting layout in any way
Include computer audio while sharing	Asked participant 2 to enable the "include audio" option when that was available and asked them to play a youtube video on their screen while I evaluated the sound quality. I also asked them to speak simultaneously with the video to test if it would affect the quality.
Chat	
Embedded in video call	Looked for chat button on the main screen
Can be used in parallel with video call	Attempted to send a text message while in the video call
Can participants send private messages to specific participants while in a group call	Looked for a "Send to:" drop down menu in the chat. If that didn't exist, I tried to click on participant 2's name in the call to see if there was an option to message them directly

Figure I.1

Can participants send emojis or reactions	Looked for emoji button in chat and hovered over participant 2's texts to see if I can react to them
Can participants send files, gifs and stickers	Looked for corresponding buttons in chat
Can participants create polls	Looked for corresponding button in chat
Noise Reduction	
How effective is it	Asked participant 2 to play music in the background and occasionally increase or decrease the volume
Can participants customize its settings	Looked for option in audio settings and tested each setting using the same process as above
Is it responsive to sudden audio changes in the environment	Asked participant 2 to suddenly play loud music while speaking at a constant volume
Is it consistent	Made sure each experiment lasted for at least 20 seconds
Active Talk Indicator	
Does it have delays or inaccuracies	Observed how it responded to my voice
Does it distinguish between voice and background noise	Checked if activated by music
Is it clearly visible	Observed its location on the screen
Does it work seamlessly with other elements	Observed its behaviour while screen sharing
Shared Whiteboard	
Good location of initialization button	Looked for initialization button on main screen or on main options menu
Can multiple participants use the whiteboard simultaneously	Asked participant 2 to use the board at the same time as me
Is it clear to other participants who is making each edit	Observed if name of participant making changes is visible on the board while changes are made
Is there a drawing tool, a shapes tool and a textbox tool	Checked for options on whiteboard options menu
Are there any extra tools, like sticky notes, laser pointer, or image insertion	
Good speed and responsiveness	Observed whether participant 2's drawing movement appears seamless and whether I can see changes in real time or whether there are delays
Does it work seamlessly with other collaboration tools	Attempted to screen share while keeping the whiteboard open
Breakout Rooms	
Good location of initialization button	Looked for initialization button on main screen or main options menu
Can participants choose which rooms to be assigned to	Attempted to start breakout session without assigning participants to specific rooms
Option for time limit	Checked for option while creating the breakout room

Figure I.2

Can participants return to the main meeting at any time	
Can participants move between rooms	Looked for breakout room options while in a breakout room myself and checked if option was there
Ability to broadcast message to all rooms	
All features present in main meeting also present in breakout rooms	Checked if options menu looked the same in breakout room as in main meeting
User friendly UI	UI was evaluated throughout the entire hands-on testing process
Visibility of system status	Checked if mic and camera status are visible, checked if it was clear when I was sharing my screen and which part of the screen I was sharing
Match between system and real world	Checked if the icons on menu options resembled corresponding real-world objects, checked if virtual tools available could be used in a way that resembles their real world counterparts (e.g. whiteboard)
User control and freedom	Checked if user had full freedom of navigating the tool and its functionalities or if there were restrictions in what they were allowed to do (e.g. if they could use the screen sharing and whiteboard functionalities simultaneously)
Consistency and standards	Checked if navigating the different functionalities of the tool was intuitive and similar to what a user would expect
Error prevention	Checked if the system prompted me to confirm certain major actions that could have been clicked by accident, e.g. screen share, invite new participant, leave meeting
Recognition rather than Recall	Checked whether it was easy to navigate through the tool simply going by my intuition, without reading documentation
Flexibility and efficiency of use	Looked for keyboard shortcuts, checked whether there were customization options for experienced users (e.g. option to skip introductory tutorials, save individual preferences across meetings)
Aesthetic and Minimalist Design	Checked if the options menu was cluttered and if it was difficult / overwhelming to find the option you're looking for
Help users recognize, diagnose and recover from errors	In order to provoke an error, I disconnected from the internet mid-call and checked if the error messages were informative of what the problem was, or whether they gave suggestions on how to fix it
Help and documentation	Checked if there was a help button in the menu options and or hover documentation

Figure I.3