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Designing Augmented Reality Based Interventions to Encourage Physical Activity During Virtual Classes

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Abstract

This project is an exploratory study of designing augmented reality (AR) based interventions to encourage physical activity among students attending virtual classes. We conducted a focus group study with four HCI students to understand the current behavior of students during breaks between classes. Based on these insights we designed two AR interventions: AR Exergame, an interactive game that requires the user to move their hands to grab virtual apples; AR micro-movements, a method that requires the user to switch to a different physical space when starting a new virtual class. These AR interventions were aimed at encouraging students to perform micro-activities in between virtual classes, i.e., small non-strenuous activities. The effectiveness of these methods to reduce video conferencing fatigue, a.k.a Zoom fatigue, and also to compare it with the students' current methods was tested through a user study with six participants.

Key Words: Augmented Reality, Zoom Fatigue, Interventions

1. Introduction

Since the beginning of the COVID-19 pandemic, the use of videoconferencing platforms has increased drastically, and they have become a necessary tool for conducting virtual classes and meetings remotely. Although these platforms have helped us to stay connected with our friends, family and colleagues, and have enabled educational institutions to continue classroom learning virtually, the effects of their increased usage and engagement are not all positive [10]. There are an increasing number of studies that have identified the negative effects of virtual classes and meetings known as "Zoom Fatigue" - the exhaustion felt due to prolonged usage of video-conferencing platforms (VCP) which exerts physical and mental toll on the users [1, 9, 26]. Moreover, attending virtual classes from home requires the students to engage with VCPs over extended periods of time which leads to an increase in Sedentary Behavior and a decrease in Physical Activity (PA) [25]. Numerous studies have shown that high levels of sedentary behavior are associated with diseases like type II diabetes, cardiovascular diseases, and breast cancer, which in-turn can have negative psychological effects and can become a cause of depression [6, 19].

Additionally, the virtual classroom environment has a limited support to emulate a physical classroom and there are fewer possibilities for physical activity [4]. For example, while attending school/college in-person, students have interim period of time between classes to physically move around in their environment – to switch classrooms or to participate in social activities, while the same behavior is not exhibited or sometimes not possible while attending virtual classes. One way to overcome this is through promoting Exergames (Exercise Games) as part of the students' routine which have shown substantial results in decreasing sedentary behavior among inactive children [16, 19]. However, physical activity and sedentary behavior are not mutually exclusive as the potential benefits of physical activity could be undone if the students spend the remaining hours of their day sitting in front of their computers [11]. Hence, there is a need to promote micro health interventions by integrating them into everyday tasks without disrupting ongoing routine [20]. These are health interventions which blend into the periphery of users' attention and can enable them to follow regular physical activity exercises.

Another concern arising among college students is that of smartphone overuse. with the increase in their use, smartphones pose a challenge of creating addictive habits among their users [31, 37]. These habits include smartphone addiction, where users mindlessly check their phones frequently and without any concrete intentions, which causes them to get distracted from the task at hand [29]. The overuse of social media apps and consuming a large amount of online content has also proved to be detrimental to the mental health of the users [37] and it affects their social interactions in real-life, causing them to feel disconnected from their friends and loved ones [38]. These challenges of overuse of smartphones have given rise to increasing HCI research into the field of intentional non-use of technology [39]. This concept was recently advanced by Google through "Digital Wellbeing" (Google LLC, 2020), where they announced new software tools that help users to monitor and gain awareness about their phone usage to limit overuse and attain a more conscious use of smartphones in their everyday lives.

Currently, there are many different applications available on the Google Play Store which enable users to track and self-monitor their phone usage [39]. Even though these applications provide features for restricting excessive phone use, few of them are effective in doing so [30]. This lack of effectiveness could be a result of their inherent requirement from the users to consciously decide to either accept or decline the restrictions imposed on them by the system. These apps focus on providing the usage data to the users and provide features like app blockers and app timers which help the users to deploy restrictive strategies, but they still rely heavily on users' willingness to deploy these strategies themselves. Other research has shown how users manipulate their work environment to reduce the interruptions that they face while working in an organizational setting [31]. This suggests that there is an opportunity to employ restrictive strategies on user's smartphone based on the contextual information derived from their current environment. Such a system can utilize computer vision algorithms applied using smartphone cameras along with inertial sensors present in almost every smartphone, to achieve indoor localization of the user's environment [28, 40].

2. Related Works

Previous research has focused on evaluating the effectiveness of the existing Digital Wellbeing applications in limiting the phone usage of their users [34] and to analyze the extent to which these apps promote behavior change [36] and habit formation [41]. These studies have shown the potential of using smartphones as an effective tool to aid in the breaking of old habits and even in the formation of new, healthy habits [41]. They have also demonstrated, by introducing new applications, that the behavior of users can be affected positively to increase their wellbeing [36].

The evaluative study done by Monge and De Russis [39] highlights the importance of providing solutions which limit the users' phone usage through introducing interventions like app timers and also concludes that users prefer these type of restrictive strategies over solutions that enable the users to self-monitor their progress. This preference was also found by Hiniker et al. [34], where they performed a thematic analysis of various features provided by the Digital Wellbeing applications to arrive at eight overarching themes found in all the apps – features to limit, stop, displace and increase smartphone activity; reduce total usage; and to limit context and dependency of use. Then through a user survey, they found that over 33% of users preferred features that limited or restricted their usage more than any other features [34].

Other studies have evaluated apps based on their effectiveness to promote behavior change and habit formation among their users. Klasnja et al. [36] posit that it is not feasible to indicate that a system supporting well-being has brought about its intended result, without demonstrating it through a large-scale study and they emphasize the importance of tailoring the evaluations specifically for the intervention strategies used by such systems. A large-scale study also enables the researchers to test different implementations of the same strategy. Similarly, Stawarz et al. [41] formulate an evaluation for apps that promote habit formation and present a design guideline which should be followed by these apps. They argue that the apps should support trigger events, use reminders to reinforce implementation intentions, and avoid features that teach users to rely on technology [41].

A study by Dabbish et al. [31] analyzed the self-interrupting nature of users who work in an organizational environment and explored the contextual elements in the users' environment which cause these interruptions. Their findings highlighted the behavior of users, where they self-interrupt to switch to a solitary work environment. Research by Al Delail et al. [28] and Morar et al. [40] present techniques that utilize the computer vision capabilities and the inertial sensors housed in commercially available smartphones to achieve indoor localization. These studies offer an insight into the effectiveness of using an AR-based system to practically deploy an indoor localization application to provide interventions in the user's work routine.

Bakker et al. suggest that for peripheral interactions to quickly and frequently shift between the users' center and periphery of attention, the interaction needs to be easy to initiate [2]. This is in accordance with the findings of Mueller et al. [18] and Mandryk et al. [17] who present that the design of casual exergames should also provide an "easy entry into play". Combining these two research areas, previous research has explored the possibility of Augmented Reality (AR) exergames that enable the users to move physically while gamifying their experience to provide incentives [24]. However, most of these systems require the use of gaming consoles like Xbox Kinect or Nintendo Wii, which are expensive and thus not feasible for every household environment [17]. In addition, Shin et al. implemented a webcam-based design using AI to recognize hand and body movements to interact with games like "Pop the Balloons" and "Name Body Parts" which were used as a part of a separate virtual physical education class [23]. Inspired by these works, we explore using AR to provide micro health interventions seamlessly (as activities in between virtual classes) and how effective they are to mitigate Zoom fatigue among students.

In this project, we aim to investigate the existing methods that college students use for overcoming Zoom fatigue and explore the design and effectiveness of an AR intervention system. We conducted a preliminary semi-structured focus group with HCI students to inform the design and methodology of a subsequent user study where we simulate a virtual classroom environment with micro-activities using an AR system. Here we define micro activities as short duration low-intensity movements (e.g. similar to moving from class to class in an in-person environment) which encourage physical activity among students, similar to micro-break activities suggested by Kim et al. to recover from daily work demands [15]. The user study involved three tasks where the participants watched short lecture videos and performed micro-activities in between two videos. A detailed description of the study is provided in the methodology section below. The system is evaluated through a mixedmethods study design where we collect and analyze quantitative data about the level of exhaustion the participants feel throughout the three tasks along with qualitative data about their overall experience of using the systems and their feedback for improving the preliminary design. Our results showcase the possibility of using AR to reduce sedentary behavior among college students during virtual classes and we further discuss the design implications and considerations in future prototypes of the system.

3. Methodology and Results

We conducted this research study in two parts. In the first part, we invited HCI students to take part in a semi-structured focus group study where we initially discussed our problem statement in brief and then guided an open-ended discussion between the participants. The ideas and insights gained from the focus group discussion became the basis for next part of the research and it informed the procedure design of the user study. In this section, we present the research process and results for both the studies in detail.

3.1 Focus Group Study

3.1.1 Participants and Research Setup

The participants for the focus group study were recruited through advertisements and word of mouth on campus. All of the participants were students who were pursuing Master's in HCI with prior experience in user research and study design process. In total, 4 participants (3 female 1 male, mean age 25) were present and the discussion was conducted virtually over Zoom video-conferencing platform which lasted for approximately 1 hr 15 min. The participants were requested to provide consent and were given $10 as compensation.

3.1.2 Procedure

The discussion started with the researcher giving a brief overview about the purpose of the study, followed by a semi-structured interview process to keep the conversation focused and open-ended. The main purpose of the discussion was to gain insights about the participants' current behaviors to mitigate. physical stress and exhaustion while engaged in prolonged virtual classes or meetings and thereafter brainstorm ideas to design intervention systems in the micro-activity design space. Half-way through the discussion, the participants were asked to take a short 5-min break which acted as a stimulus for them to discuss and reflect on their own behavior and the type of activities they did during the break. This discussion was recorded and then transcribed. We codified the quotes from the transcripts and performed a bottom-up (inductive) thematic analysis [3, 14] on these quotes.

3.1.3 Results and Discussion

Based on the results of thematic analysis on the participant responses and through prior understanding and literature review of the subject matter by the researchers, we identified three overarching themes in the behaviour of students during their breaks in between virtual classes – small non-strenuous activities (walking, stretching etc.); changing environments (e.g. moving to a different location); switch focus (e.g. browse social media during breaks).

Small non-strenuous activities: We found that participants often preferred small scale activities (e.g. micro activities) that are not physically exhausting. Two participants would usually "stand up and stretch" or "take a small walk". However, one participant also mentioned that "doing mundane tasks like drinking water or using the bathroom doesn’t feel relaxing".

Changing environments: When asked about how the environment they take their virtual class in would affect their experience, they said that "it is a huge factor". It even affects how they feel when taking a break, for example "moving to a different room to take a break feels significantly different than staying in the same room to take a break" and that "changing location might not be as beneficial than doing an activity".

Switching focus: All of the participants also like to switch focus away from the classroom during short breaks and they all agree that "switching focus might be better than completely detaching from work" and that "detachment from the system would be required for it to feel like a break". These were indicated in the participant comments where 1 participant would "keep sitting at [their] desk and play games on [their] smartphone" and another would sometimes "listen to a song". These findings showcase a need for a system which would help the students to shift their focus to a different task while still being present in the classroom environment.

When brainstorming ideas for implementing a micro-health intervention system, the participants propose that "it can suggest you things to do in 5 minutes based on your environment" and that the type of activities will "depend on what resources you have around you to take a break". Additionally, they want the system to provide "easy work mode to break mode switching" while having the "ability to delay or snooze the break alert" with "user defined level of control". Based on these recommendations from the participants, we came up with the idea for a system that can directly integrate into the students' workstations and work in the periphery to provide interventions for taking breaks. The system can suggest micro-activities to do during the breaks, like walking or changing locations, based on the students' environment and preferences. The need for contextual awareness of the student's environment can be realized through Augmented Reality [13] which not only enables us to detect the context but also can introduce interactive elements for them to engage with during their breaks. These interactive elements will act as the intervention to encourage physical activity and would change based on the students' environment. Additionally, as a part of our goal we wanted the system to have a low barrier to entry/easy to adopt and designed it to reduce the common hindrances in initiating physical activities like temporal, physical and psychological barriers [17]. Therefore, using AR based interventions could possibly integrate into the user's environment and work schedules, thus reducing the former two barriers, while the gamification aspect would help to overcome the latter.

3.1.4 AR Interventions

For the purpose of our research, we developed two interventions which utilise AR to suggest micro-activities to the students. First one is an AR exergame which promotes physical activity through moving and stretching the body, while the second one is about encouraging the students to switch their location or environment in-between virtual classes or during breaks. Below we present prototypes for implementing these interventions and test their effectiveness through a subsequent user study.

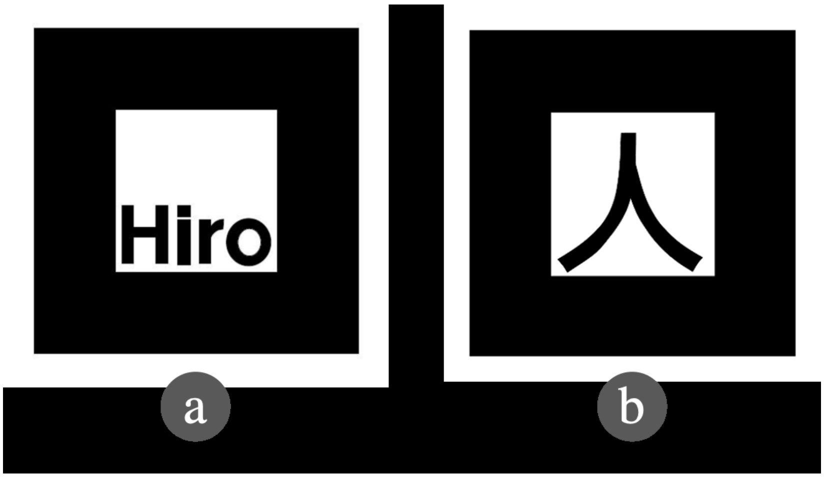

Figure 1. Markers used for the AR Exergame and the AR Micro-activities applications: (a) A Hiro AR Marker used to load 3D model of an apple for the exergame. (b) A Kanji AR Marker used as an additional marker to define a new space for AR micro-activities.

We built these interventions using the AR.js JavaScript library in which we detect AR markers (Figure 1) in the user's environment and display the corresponding interactions associated with the marker. For our preliminary investigations, we served the game over a web browser which can be accessed using any device that has a built-in camera. This setup enabled us to use a laptop with an integrated webcam to conduct the entire study and did not require the use of AR gaming consoles like Kinect or Wii. In addition, we expect that these methods can be integrated with existing VCPs such as Zoom (and using the device integrated cameras) so that routine interventions can be introduced seamlessly in user's schedule.

AR Exergame: We modelled this intervention based on the design of a popular game called "GrabApple" where the player has to catch the falling apples on the screen [12]. When the user scans the Hiro marker (Figure 1(a)), the system starts to display a 3D model of an apple at random points on the screen, changing the position at 2 second intervals. To play the game, players have to move their hands towards the position of the apple before it disappears from the screen, and they are encouraged to move and stretch their body to reach the extreme positions. The game was implemented as a Wizard-of-Oz prototype in which the users were given full freedom to interact with the system in any way they want and the gamification was enabled through manually recording the score for the number of apples they grabbed within the task duration. To make the game more engaging when playing over a period of time, we introduced a gamified feature where the camera feed from the webcam was laterally flipped (mirror image) to make the players' moves a bit obscure.

AR Micro-movements: The goal of this method was to explore encouraging the user to do a quick movement in between virtual classes or virtual meetings (similar to moving from one classroom to another or one meeting room to another in in-person settings). As such, when the user attempts to join the next virtual meeting or class, the user is required to have a different marker scanned or appear in their background. By design, the user will have to keep the markers in different physical locations of their space. For example, the user may have the markers set up on two different walls or on opposite ends of the same wall that requires a small physical movement (Figure 2(b)). In this intervention, when the user scans the second marker such as the Kanji marker (Figure 1(b)), the system displays an alert on the web browser which contains a URL that can link to any lecture, meeting or video, and the link would be unique to this particular marker only. By updating the new meeting links that are bound with the AR markers, we aimed to emulate switching of the classroom environments for the students.

Figure 2. AR Interventions for reducing zoom fatigue (a) AR Exergame: The system detects the AR marker in the background and uses it as a reference to display 'virtual apples' (shown inside the dotted circle) in random locations. The user is required to reach out and grab the apples as they appear (b) AR Micro-movements: (b-1) The user has several AR markers in the physical working space (encircled by white circles). To enter a virtual class, a new/different marker is required to be visible in the background. To enter the next virtual class, the user is required to move to a different location such as the other side of the table so that a different unique marker is visible. (b-2) The user has physically moved to different location to enter the next virtual class.

3.2 User Study

In this study we aimed to evaluate the effectiveness of the AR interventions against Zoom fatigue through a user study [1]. The ultimate goal of the study was to simulate a virtual classroom environment and introduce different micro-activities (from hereon referred as activities) in between lectures (or videos) to understand how these activities affect the students' sedentary behaviour and also to see how the context of their environment affects their attention and focus during classes.

3.2.1 Study Design

We designed a within-subject evaluation for conducting the user study which consisted of the following three activities as the main independent variable:

1) AR Exergame: Playing the AR exergame to encourage students to do some PA, like moving and stretching.
2) AR micro-movement: Switching to a different location and scan AR marker to access the next video.
3) Short break (baseline): Taking a short break to do any activity that the students usually perform during breaks in their virtual class routines.

The dependent variable was the perceived overall fatigue that was measured with the standard Zoom Exhaustion & Fatigue Scale (ZEF) (only using the General and Visual Fatigue questionnaires) [8] and the third activity served as the baseline treatment against which we compare the effects of the AR intervention activities. The three activities were randomized for each participant using the Latin Square method [22] and each activity was performed twice within each task. Each task consisted of watching two 10-minute instructional videos and performing one activity after each video. Therefore, each participant completed 3 tasks where they watched 6 videos and performed 6 activities in total. After each task the participants were asked to fill out the ZEF questionnaire to collect quantitative data about their perceived exhaustion level. The responses were recorded on a 5-point Likert scale with values ranging from "Not at all" to "Extremely". Finally, at the end of the study, each participant was interviewed to gather qualitative data about their overall experience and feedback.

3.2.2 Participants and Research Setup

We recruited 6 participants (3 female, 3 male, mean age 25) for the study through advertisements on campus. The study was conducted in a lab setting with a desk and chair to a simulate virtual classroom environment and an AR marker was pasted on the wall behind the chair which would be visible on the webcam. The same laptop device was used for every participant which had the necessary software (Node.js and Chrome Web Browser) installed to run the application.

3.2.3 Procedure

After a brief introduction to the purpose and design of the study, the participants were asked to provide their consent for participating in the study and give permission for collecting data through audio recording. Each participant was assigned a number which would be recorded with the data and no personally identifiable information was stored. The experimenter then did the preliminary setup which required calibration of the laptop screen to the AR marker position. This setup was required so that the 3D models appear within the screen limits and do not overflow out of the display. After the setup, participant was shown the first 10-minute instructional video for the first task, after which they were asked to perform the first randomly chosen activity. The duration for “AR Exergame” and “Short Break” activities was kept at 5-minutes, while the duration for “AR Micro-movements” activity was defined by the time it took for the participants to reach and scan the second AR Marker. After the activity, the participant watched a second 10-minute video and performed the same activity again, followed by filling out the ZEF questionnaire for the respective task. This process was repeated two more times for Task 2 and 3 and afterwards the experimenter conducted a post-study interview with the participant. In the post study interview, each participant was asked about their overall experience of doing the 3 activities and their recommendations for features they would like to have in both the AR interventions to improve the engagement and increase their motivation to interact with them in the future. Their answers are discussed in the discussions and future work section below. The full study took approximately 1 hr 30 min for each participant.

3.2.4 Data Analysis

The quantitative data was compiled and analyzed to identify the Overall fatigue experienced by each participant for each task. The tasks were assigned a number according to the activity that was performed in each task. Thus, Task 1 was identified by the AR exergame activity, Task 2 was short break activity and Task 3 corresponded to AR micro-movement activity. The Likert scale responses for the ZEF questionnaire were converted into numerical values of 0-4 from “Not at all” - “Extremely” respectively, and Mean and Standard Deviation was calculated for each task. The qualitative data was gathered from transcribing the interview responses and a deductive thematic analysis [3, 14] on the participants’ quotes was performed to identify specific themes relating to the AR interventions and overall study. The themes were reviewed by the second author and we identified 5 overarching themes: Preference on activities, Design recommendation for an AR application, Social gamification and acceptability, Effects of classroom environment, and Overall feedback.

3.2.5 Results

As the Figure 3 shows, the Overall Fatigue for all the tasks was close to or lower than 1 which corresponds to the feeling of "Slight" fatigue on the ZEF scale. Even though the overall fatigue was lowest for the baseline task where participants took a short break to perform any activity which they usually do in their routine, qualitative results show that the participants would prefer to interact with the AR interventions in their breaks, especially with the improvement of their features. While two participants did say "I would prefer to take 5 min break and doing some other activity", one of them mentioned that "depending on how AR/VR evolves, I would like to play that between classes". For one of the participants, the preference would “depend on [their] mood” and the availability of space in the environment. While another participant mentions that they “know playing the AR game would be better for [them] than just taking a break and doing nothing”. These results indicate the willingness of students to adopt AR based micro-health interventions into their virtual class routines and with the evolution of this technology, more students would be interested to take part. This being a preliminary study conducted over a short period of time, the quantitative data sample was not enough to effectively measure the exhaustion and fatigue levels for the 3 activities. Thus, it would require a much larger scale longitudinal study to achieve contrasting results between the different activities.

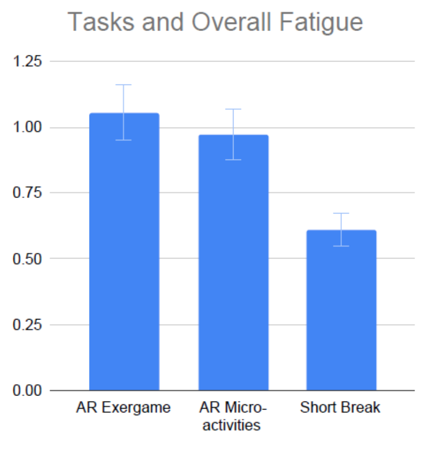

Figure 3. Bar graph showing the level of Overall Fatigue felt by participants after each task.

3.2.6 Discussion

The participants were intrigued by the AR exergame and were interested to share feedback on how the game can be improved and be made more engaging. All of the participants said that they would prefer to play AR exergames in the future if it allows them to detach from the virtual class to do a “fun” activity. They gave feedback on the existing design of the game, with one participant mentioning "[they] felt more involved because of the mirrored effect". However, many participants made design recommendations to improve the “GrabApple” game in an AR application as well, like “adding different interactions like [slashing gesture] in Fruit Ninja game”, “make apples harder to reach to perform better stretches”, and “adding different elements like kicking a ball to engage other body parts”. Many participants would also like to have a social gamification aspect to the game where they can “play group games with friends” or “share scores on social media” and “[Play] something that helps to engage the whole class as that is lacking in virtual classes”.

This result is in line with the research findings of previous studies by Yu Chen and Pearl Pu![5] and Ren et al. [21], who show that players like to participate in cooperative fitness games and they feel more motivated in groups. However, one participant mentioned that not all games should be social as they prefer to play games "without scores and competition" and in these cases it would be beneficial to explore designs for puzzle or one-person arcade games. In the future, we can explore different AR games which integrate with the video-conferencing platforms and allows students to either play single-player exergames, like GrabApple [12], or compete against each other in collaborative exergames, like Play Volleyball [23].

Concerns of social acceptability of these AR exergames were also raised as not all students would be comfortable in performing the required tasks in public places or even at home with other roommates around. Two participants voiced these concerns, saying that "If someone sees me doing the activity it would be very weird" and "I will be shy or conscious to do these activities in public space like library". This shows that more research is needed to test the effects of exergames in public setting and to also explore the ethical aspects of sharing physical activity data among classmates.

We observed that most of the participants would like to move around after long periods of sitting down and mention that it helps them to pay more attention and focus on their lecture, which aligns with the meta-analysis research findings of de Greeff et al. where acute physical activity shows a positive effect on attention [7]. Identifying with AR Micro-movements, one participant mentioned "I prefer to move around in my environment to be active and I focus better", while another said, "I prefer standing for some time after a long session of sitting for lectures". While doing the task 3, some participants chose to switch to a more comfortable seating to watch the second video, stating that "it helps me to pay better attention".

Some participants also mentioned how the features already implemented in current VCPs help them to switch focus and move around, like "With camera off, I feel comfortable in moving around and switching places" and "Breakout rooms during virtual classes facilitate conversations, but they are again online". However, as the previous quote mentions, it is difficult to detach from the work entirely as these features are implemented in the system and sometimes not even utilized. Thus, we identify that AR micro-movements method could be further enhanced to encourage students to move around during virtual classes such as when moving to a break-out room or do micro activities in between classes when there is not enough time to take a longer break.

3.3 Conclusion and Future Work

With our design of AR intervention system, we have observed the possibility of serving AR interventions directly on web browser and using the in-built webcam of the device which is available in most commercially available laptop computers used by students to attend virtual classes. As such, we recognize that these methods can be directly integrated with VCPs and integrated directly to schedules, etc. Additionally, we identify that our AR micro-activity system can also be used to demarcate "working", "active" or "relaxing" zones in a user's environment, which can also be improved in the future using Indoor Localization techniques [27]. Future systems can even cease the reliance on AR markers and use image recognition and classification such as natural feature tracking to detect the context of the user's environment to serve different peripheral micro-health interventions.

Our study was a preliminary exploration and thus it presents several limitations which can be addressed in future research. First, it was conducted with a small set of participants in a lab setting and was focused on gathering initial insights. It lacks the detailed results and analysis that can be gained through a long-term in-situ experiment. Conducting a long-term study within students' natural working environment would also help us to better simulate the factors causing Zoom Fatigue, which we feel was lacking and not effectively emulated in our study. This will not only increase the accuracy of the collected data but will also give us a better insight into the effectiveness and social acceptability of the system. We can conduct this type of experiment by deploying a full-fledged software system on each student's working device, while making it robust enough to handle different types of living situations and environments. Data can be collected through active and passive means like giving periodic prompts to survey the participants and recording non-private device data, respectively.

Secondly, we do not utilize data collection devices like wearable health trackers or sedentary behavior sensing furniture, to track data about the participants' physical activity and exhaustion levels and rely primarily on their self-evaluation and qualitative feedback. Health tracking data can be utilized in future studies to quantitatively measure how different micro-activities affect the exhaustion and fatigue levels in students. Finally, in future explorations, we can design and build AR interventions that provide more engaging experiences and also incorporate social gaming features.

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