Considering Colored Light for Identifying and Reflecting on Emotions

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Fig. 1. Real-time measured heart rate automatically adjusts the colored lights in a virtual environment.

Virtual Reality (VR) can be an affective medium supporting induction, expression and annotatation of emotions. However, the focus has not yet been placed on how VR can support identifying own emotions in real-time. In this paper, we present initial results of our research in this area. We automatically adjusted colored light according to the current heart rate of the user while watching emotional stimulating content. Heart rate was measured by a smartwatch. We present the effects of colored light as feedback modality and on perceived intensity of emotions. We discuss how this approach could support reflection and increase empathy and awareness in social contexts. Finally, we outline opportunities and challenges for future work regarding emotions in VR research.

CCS Concepts: • **Computer systems organization** → **Embedded systems**; *Redundancy*; Robotics; • **Networks** → Network reliability.

Additional Key Words and Phrases: Virtual Reality, Colored Light, Smartwatch, Emotion, Feedback Loop

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1 INTRODUCTION

Technologies such as Virtual Reality (VR) applications are increasingly often used to support mental well-being and health [3, 32]. To illustrate, searching for mental health and well-being VR apps in major app stores produces over 964 results [35]. Most of those apps place the focus on fostering relaxation and meditation, not on engaging with emotions [35]. However, identifying, understanding and accepting emotions is one of the key aspects of mental well-being (i.e. emotion regulation (ER)) [16]. ER is an intervention used in all major therapies such as CBT, DBT or depth psychology [7] and focuses on mentally regulating which emotions we experience and how we experience them [6].

Although HCI research has investigated emotion regulation in VR [24], a literature review by Montana et al. [24] highlighted that many focus on VR for mindfulness training (e.g. [20, 26]) and stress reduction (e.g. [29, 31, 38]), and researching setups of emotionally stimulating environments (e.g. [4, 5, 34]). It has been researched how entities of VR, such as colored light and weather, can successfully induce emotions [5, 19, 27, 28], and how emotions are annotated in real-time similar to self-reports [39]. Our own previous research has identified the need to integrate therapeutic practices with a focus on ER into VR [35], has identified research gaps considering specific design considerations [36], and evaluated a self-developed VR app called *Mood Worlds* which increases positive emotions, emotional engagement, and supports reflection and well-being by visualizing the emotion 'happiness' [37]. The consensus appears to be that VR is an affective medium. Its immersive VEs can evoke emotional states and responses similar to reality [8, 23, 28, 31]. Nonetheless, to date, few apps and little research on VR actually support identifying and reflecting upon own emotions.

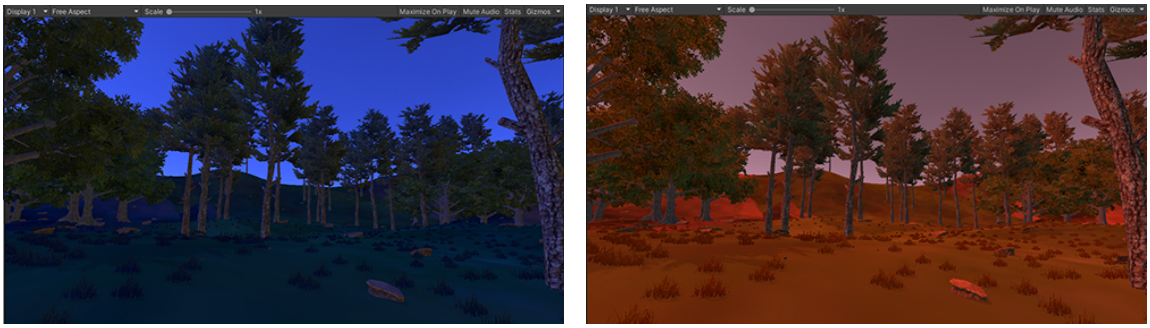
To address this gap, our research focuses on prompting users to identify what they feel by automatically adjusting entities in VR. As a starting point, we investigated the effects of colored light, which is gradually changed based on the user's current heart rate measured by a smartwatch, on perceived intensity of emotions. The next chapter will briefly introduce our study design and preliminary results. Then, we will identify possible use cases and discuss their applicability in supporting the users in identifying and reflecting on real-time emotions. We will define specific challenges that future HCI research should address and which will strengthen the relationship between emotion and technology in HCI research.

2 UNDERSTANDING THE RELATIONSHIP OF COLORED LIGHT, HEART RATE AND EMOTIONS

Most research concentrates on subjective self-reports about felt emotions rather than on objective bio-feedback (e.g. [39]). However, emotions, e.g. being nervous or angry, and especially the intensity or arousal of emotions, influence the heart rate [11, 22]. Thus, our research question is: "How do changes in colored light in VR based on the heart rate influence the perceived intensity of emotions?"

2.1 Real-Time Emotion Measurement and Feedback

To answer the research question, a within-subjects pre-study with $n = 12$ participants was conducted. During the whole study, the heart rate was measured with a smartwatch every second and sent to the VR application. Participants engaged in a virtual environment (VE) by watching two videos displayed on a screen. Both videos were taken from a validated library with calculated arousal and valence levels [17], and induce positive affect with similarly high arousal values. While watching one of the videos, the colored light was gradually changed from blue (low heart rate) to red (high heart



(a) Virtual environment with blue colored light for low heart rate (b) Virtual environment with red colored light for high heart rate

Fig. 2. Virtual environments with colored light adjusted in real-time according to the users' heart rate.

rate) based on the users' real-time heart rate as can bee seen in Figure 2. Blue is not linked with strong emotions [21], but is associated with the activation of the parasympathetic nervous system, reducing the heart rate and increasing relaxation [14, 18]. Red is often associated with excitement and passion [15], and with being strong and active [1].

The other video was being watched without changes in the light. Colored light changes and the sequence of the videos were randomized and counterbalanced.

2.2 Colored Light as Indicator for Perceived Intensity of Emotions

We measured arousal and valence by integrating three validated and standardized questionnaires in VR: The self-assessment manikin (SAM) [2], the feeling scale for measuring valence (FS) [9] and the felt-arousal scale (FAS) [30]. Results were not significant. Additionally, heart rate was collected to measure for example the relaxation time after watching each video. The normalized mean heart rates can be seen in Figure 3.

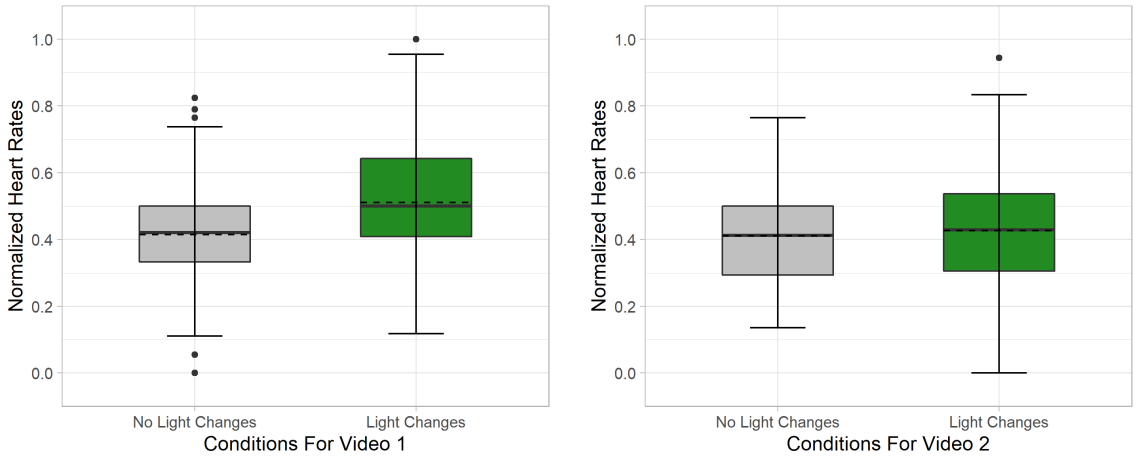
Again, results were not significant. That being said, the results showed an indication of a trend, namely heart rate and arousal increased in the condition with colored light changes.

Based on these findings, we hypothesize that colored light can unconsciously impact perceived intensity of emotions. Future work can explore this aspect in an extended experimental study. In the next sections, we outline two use cases of automatic colored light adjustments in VR, and reflect on opportunities and challenges that future HCI research could address in this field.

3 SUPPORTING REFLECTION

As one use case, we envision an increased reflection on health data if participants are told about the connection of colored light adjustments to their current heart rate. Further, future research could import emotional stimuli with differing arousal and valence dimensions, switching from inducing happiness to anger, sadness etc. Thus, one of the benefits would be that colored light visualizes internal, former non-visible, body functions to the user. In other words, they get to meet their own physical reaction in a new way, and learn even small changes of affect feel like, thus effectively identifying emotions.

Based on these changes, another interesting inquiry would be to investigate psychic effects when seeing the own heart rate. If users become more aroused, the red colored light will become stronger, which in turn increases the heart rate again. Quetions that could be addressed are: Which strategies will users develop - will they try to relax more or will



(a) Values for video 1

(b) Values for video 2

Fig. 3. Mean Heart rates (dashed line), medians and standard deviations for the two videos, either experience without light changes (no light changes) or with light changes from blue to red.

they strive to be even more emotionally involved? Which strategies (if at all) will they choose to mentally influence the heart heart rate? Will they feel more happiness or will they become nervous, and will this knowledge of autonomously influencing the VE distract or support the perception of emotional stimuli?

Further, we aim to investigate and measure the achieved reflection level. Former research, having the application Mood Worlds [37] in mind, focused on reflecting on past experiencing by re-experiencing them in a VE. This ongoing research transfers reflection into the present, focusing on the felt intensity of emotions in that specific moment. We propose that future work could utilize the Technology-Mediated Reflection Model (TMRM) bentvelzen2021reflection to identify strengths and challenges of using colored light as visual feedback modality of health data. TMRM would fit as follows: (1a) temporal perspective - users are constantly prompted to reflect on their current heart rate due to colored light changes, (1b) temporal frequency - the reflection takes place as an reflection-in-action, meaning during the action [25], but for an intense and longer time of 5min while watching the emotional stimulating content, and (2) conceptual cycle - users link information from the VR system (colored light) to their lived experience (watching emotional stimulating videos).

4 INCREASING EMPATHY AND AWARENESS IN SOCIAL CONTEXTS

Research has shown that sharing the heart rate with others via technologies can increase intimacy [12] and empathy [13], facilitates sharing emotional video highlights with friends [33], and enhances awareness and empathy by helping to understand the context and emotional state when texting [10]. Thus, showing the heart rate through colored light to friends and family could be an unobtrusive possibility with the same benefits, so we assume. Future research should investigate the impact on perceived emotions in a multi-user setup of the VE. Further, self-created emotional stimuli, e.g. videos from a wedding of loved ones from that specific user, could be used to ameliorate social connectedness from a distance.

5 CONCLUSION

In this research paper, we use some of our previous work about emotions in HCI to reflect on the research gap of our current work and potential ways forward. We discuss potential use cases of using colored light automatically adjusted to the current heart rate of the user to visualize their emotional state while watching emotionally arousing videos. We show how this approach could support reflection as well as increase empathy and awareness. We thereby showcase possibilities for future research,. Our primary goal is to build an understanding of how we can use VR to facilitate identifying emotions, empowering self-reflection and increasing people's well-being.

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