Adaptive interfaces for personalized digital wellbeing

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Abstract
Especially since the start of the COVID-19 pandemic, the majority of humans spend most of their waking life using digital screen devices. The present paper explains how adaptive interfaces could improve digital well-being by customizing the output data and digital environments to each user.

Keywords
Virtual reality, biofeedback, UX, design, color psychology, machine learning, digital wellbeing, AI, adaptive interfaces, screen based interactions

1. Introduction

The impact of natural environments on human health to support subjective wellbeing has recently been studied [1, 2]. With an expanding variety of electronic media and digital environments, screen time has inevitably increased across all ages. Research suggests screen time is negatively associated with the development of cognitive abilities, and positively associated with sleep problems, depression, and anxiety [3].

Studies have explored self-regulated meditation techniques that relieve stress, reduce burnout, improve emotional awareness, and heighten attention [4]. In recent years, online applications have introduced elements directed to help users control breathing and aid in reducing stress and anxiety.

In natural environments, a dynamic exchange takes place between one's physiological state and one's response to and interaction with the surrounding space, for instance with oxygen intake and carbon dioxide output. In current digital environments, conversely, users can only respond by choosing static elements on the screen. Detecting the user's physiological state while using digital devices, and understanding how different output data impact the user can inform algorithmic processes of adaptive interfaces to customize the output data to the user's physiological state - and to adapt and personalize the digital experience to improve well-being during screen usage.

1.1. The Use of VR and Biofeedback Devices

The cross-disciplinary project "Mindful Technologies" [5] started in 2014 with neuroscientific research on visual stimuli and com-

Joint Proceedings of the ACM IUI 2021 Workshops, College Station, USA, April 13-17, 2021
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paring meditation techniques. The preliminary findings suggested different visuals impact neurophysiological states individually. It was also found that diverse meditation techniques led by the development of a virtual reality (VR) experience with heart rate biofeedback had individualized impacts. The VR experience would display a randomized guided meditation technique and personalized visuals to help guide the user to lower their heart rate. The subsequent digital health project "SEAing Breath" [6] initiated in 2016 used VR devices and breathing biofeedback prompting the user to learn diaphragmatic breathing in order to advance in a game-like educational experience about sea level rise. In past years, Affective Computing [7] has been used to elicit and automatically recognize different emotional states in immersive virtual environments for applications in architecture, health, education and videogames.

Augmented Reality (AR) devices were used for a project in collaboration with breathing expert Wim Hof in 2018 [8]. Hof's breathing technique was clinically studied [9] to voluntarily influence the sympathetic nervous system and immune system response. Using AR and a breathing sensor, the users would follow a virtually guided breathing technique and experience a visualization of their breathing patterns in AR and as audio.

The use of VR and AR devices paired with wearables to detect and display the physiological states to the users requires additional hardware, and demands more time spent on screens.

1.2. Physiological Computing Using Photoplethysmography

Physiological computing (PG) [10] uses physiological data as system inputs in real-time so software can be changed based on the user's physiological state, and Photoplethysmography (PPG) [11] is a measurement technique enabling remote vital sign monitoring by using only cameras integrated in laptops and phones.

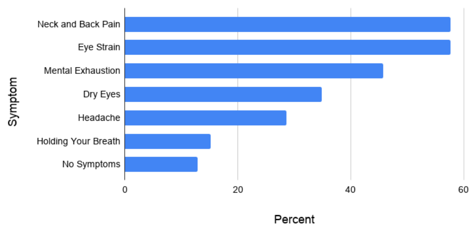

Figure 1: Symptoms of Screen Use

The project "NEHAN" [12] in 2018 at MIT (Massachusetts Institute of Technology) used PG and PPG to detect the user's heart rate using the laptop webcam and machine learning, and to display virtual and audio environments to the user. The interactions with the digital environments were analyzed and the visuals and audio with the lowest heart rate were displayed to the user.

2. 2020 Survey on Screen-time

Our ongoing research found that 55.7% of screen users (*n*=210) report they sometimes or often adjust screen settings like color, and, 87.1% of screen users experience symptoms like mental exhaustion and eye strain while using screens for a long time, whereas 12.9% don't experience any symptoms.

The majority (88.6%) of screen users adjust screen settings to improve symptoms during lengthy periods of screen use. Prototype testing of Adaptive Interfaces [13] using PPG and color displays in uncontrolled settings between 2018 and 2020 (*n*=80) indicated personalization of colors to each user can lead to an in-

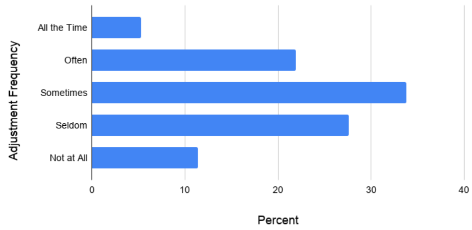

Figure 2: Frequency of Screen Adjustments

dividualized reduction in heart rate by up to 20% while experiencing the color display.

2.1. Adaptive Interfaces for Screen-based Interactions

Recent development of imaging photoplethysmography (iPPG) leverages subtle changes in light reflected from the skin to capture cardiac activity. These signals can be recovered from many types of commercially available and low-cost cameras (e.g., webcams and smartphones) [14].

Continuously detecting physiological data of the user during screen- or audio-based interactions is now becoming possible using (i) PPG to detect neurological or cardiac activity such as heart rate, heart rate variability or breathing rate without additional hardware.

Continuously customizing the output data to the users' physiological state is becoming possible with the ongoing research and development of Adaptive Interfaces.

2.2. Effect of Virtual Environments

Virtual environments have been optimized to aid neurobehavioral processes including attention and emotion regulation. Technology is gradually being adopted by organizations to train employees to be more productive. A pilot study showed that virtual stimulation improved education and reduced anxiety [15, 16].

2.3. Color Psychology

Color and its effects on psychological functioning have been long intertwined although research in this area is still at a nascent stage. Theory of Color draws associations between color categories and emotional response. Longer-wavelength colors were found to instigate a feeling of warmth whereas shorter wavelength colors feel relaxing and cool [17].

The right combination of colors can produce a higher level of contrast which in turn can influence memory retention [18]. Color is also seen to play a vital role in consumer psychology which is characterized by emotional attachment, attention, memory, attitudes, and behaviors [19].

Research has also indicated that different screen polarities and background colors can influence reading and comprehension of graphics on a screen [20] with results showing that participants performed well while looking at a light mode screen rather than a dark mode screen.

3. Conclusion

Recent improvements in webcam quality to record for more accurate (i)PPG, faster processing and cloud computing, along with users' higher comfort levels with webcams during the COVID-19 pandemic and the increased presence of stressful screen time, have enabled the potential for a more personalized human-computer interaction. We hypothesize the research and development of Adaptive Interfaces to customize output data to the users' physiological and neurological state can result in a stress-reducing interaction within digital environments. With the personalization of the user experience, screen settings and designs can support digital wellbeing as screen time becomes similar to a more dynamic interaction as experienced with natural environments.

References

[1] M. P. White, S. Pahl, B. W. Wheeler, M. H. Depledge, L. E. Fleming, Natural environments and subjective wellbeing: Different types of exposure are associated with different aspects of wellbeing, Health & Place 45 (2017) 77–84.

[2] M. H. Depledge, R. J. Stone, W. J. Bird, Can natural and virtual environments be used to promote improved human health and wellbeing?, Environmental Science & Technology 45 (2011) 4660–4665.

[3] S. Domingues-Montanari, Clinical and psychological effects of excessive screen time on children, Journal of paediatrics and child health 53 (2017) 333–338.

[4] C. Heeter, R. Lehto, M. Allbritton, T. Day, M. Wiseman, Effects of a technology-assisted meditation program on healthcare providers' interoceptive awareness, compassion fatigue, and burnout, Journal of Hospice & Palliative Nursing 19 (2017) 314–322.

[5] H. Bend, S. Slater, B. Knapp, N. Ma, R. Alexander, B. Shah, R. Jayne, Mindful technologies research and developments in science and art, AAAI Spring Symposium Series (2016).

[6] M.-D. County, the University of Miami, Project for the sea level rise public art program, 2018. Retrieved from www.seaingbreath.com.

[7] J. Marin-Morales, J. L. Higuera-Trujillo, A. Greco, J. Guixeres, C. Llinares, E. P. Scilingo, M. Alcañiz, G. Valenza, Affective computing in virtual reality: emotion recognition from brain and heartbeat dynamics using wearable sensors, Scientific reports 8 (2018) 1–15.

[8] H. Bend, Augmented reality (ar) wim hof + breath biofeedback and vr film (2018). URL: https://www.youtube.com/playlist?list=PLxkGuUxHzSsVdyJJ00gL_zawpQRJti.

[9] M. Kox, L. T. van Eijk, J. Zwaag, J. van den Wildenberg, F. C. Sweep, J. G. van der Hoeven, P. Pickkers, Voluntary activation of the sympathetic nervous system and attenuation of the innate immune response in humans, Proceedings of the National Academy of Sciences 111 (2014) 7379–7384.

[10] G. Jacucci, S. Fairclough, E. T. Solovey, Physiological computing, Computer 48 (2015) 12–16.

[11] V. Kessler, M. Kächele, S. Meudt, F. Schwenker, G. Palm, Machine learning driven heart rate detection with camera photoplethysmography in time domain, in: IAPR Workshop on Artificial Neural Networks in Pattern Recognition, Springer, 2016, pp. 324–334.

[12] N. Picard, H. Bend, Mit 2018. detecting heart rate via webcam, display of personalized visuals and audio (2018). URL: https://www.youtube.com/watch?v=TCUX0mNya5Q.

[13] H. Bend, breathing.ai prototype testing and interviews nov 9 and 10, 2018, 2018. URL: https://www.youtube.com/watch?v=mpbWQbkl8_g#t=20m15s.

[14] E. M. Nowara, D. McDuff, A. Veeraraghavan, Systematic analysis of video-based pulse measurement from compressed videos, Biomedical Optics Express 12 (2020) 494–508.

[15] M. Marquess, S. P. Johnston, N. L. Williams, C. Giordano, B. E. Leiby, M. D. Hurwitz, A. P. Dicker, R. B. Den, A pilot study to determine if the use of a virtual reality education module reduces anxi-

ety and increases comprehension in patients receiving radiation therapy, Journal of Radiation Oncology 6 (2017) 317–322.

[16] J. L. Maples-Keller, B. E. Bunnell, S.-J. Kim, B. O. Rothbaum, The use of virtual reality technology in the treatment of anxiety and other psychiatric disorders, Harvard review of psychiatry 25 (2017) 103.

[17] L. Wilms, D. Oberfeld, Color and emotion: effects of hue, saturation, and brightness, Psychological research 82 (2018) 896–914.

[18] E. Krahn, Decomposing the effect of color on memory: How red and blue affect memory differently, Pridi Banomyong International College, Thammasat University (2018).

[19] M. A. Dzulkifli, M. F. Mustafar, The influence of colour on memory performance: A review, The Malaysian journal of medical sciences: MJMS 20 (2013) 3.

[20] Y.-N. Shih, R.-H. Huang, S.-F. Lu, The influence of computer screen polarity and color on the accuracy of workers' reading of graphics, National Library of Medicine 45 (2013) 335–42.