Virtual Reality as a Remote Workspace Platform: Opportunities and Challenges

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ABSTRACT
Millions of people all around the world are participating in an unprecedented experiment of working from home due the Covid-19 pandemic. There is no doubt that Working from Home (WFH) brings many benefits to the workers, including flexibility of hours and less commute. The problems associated with this working style include distractions, and lack of appropriate space and work-life separation. Through surveying the literature in this paper, we show that virtual reality (VR) has the capability to amplify benefits associated with WFH and assist workers in tackling its challenges. We then discuss some of the challenges that need to be considered and tackled to effectively work in virtual environments at home.

Author Keywords
Working From Home; Virtual Reality; Head-Mounted Displays; Notifications; Interruption

INTRODUCTION
Covid-19 has caused abrupt changes in the way we work and live. WFH is not only the new norm during nation-wide shelter-in-place, but some companies including Twitter and Nationwide are creating policies to give their employees the choice to work from home “forever” [2, 48]. WFH enables many workers to be more productive and have more job satisfaction [10, 29]. It also significantly reduces commute time, allowing workers to use their time more efficiently by sleeping, reading, spending time with family, or working. This commute reduction also has positive environmental effects.

Despite the positive outcomes of WFH, there are challenges associated with it that need to be considered as companies work towards more sustainable practices. First, WFH blurs the boundary between work and life since work is substantially interwoven with everyday life. Hence, detachment from work could be challenging to individuals at the end of workday. Another challenging aspect of WFH is the lack of access to an in-home office space to every worker. They have to work despite the distractions from family and roommates. Suggested solutions, like multitasking, to-do lists, and time management are only band aids to the underlying issue of mental distraction. Our suggested solution to the challenges faced with WFH is using virtual reality (VR) to create separate in-home workspaces. VR provides us with a unique opportunity to alleviates distractions and facilitates detachment from work in ways that no other technology can. Nevertheless, we suggest that the potential for the technology to assist workers in working efficiently in home is impeded by two significant challenges:

1) Situation awareness: VR blocks the physical work out, hence, preventing the user from gathering necessary information from the environment.

2) Interruption by others: those not wearing the VR device are not aware of the state of the wearer. Hence, they are not able to find the right time to interrupt the worker in the time of need and may negatively affect their workflow and productivity.

This is not to undermine some fundamental issues such as gender gap at workplaces, which is amplified at homes with the rise of WFH; women spend more time on household activities and childcare than men, even when both parents are working full-time [77]. However, these issues are beyond the scope of this paper. In this paper, we identify key prior research and industry advancements, and elaborate on the opportunities and challenges of using VR for WFH.

BACKGROUND
Only 7% of the US civilian workers, about 10 million people, were able to work remotely in 2019 [9]. Moreover, those who had this benefit tend to be paid higher; for instance, almost 50% of managers in the US, United Kingdom, and Germany, and 10-20% of managers in developing countries were provided were allowed to work from home in 2013 [11]. However, the current global pandemic is forcing workers to work from home and the companies to adapt. The question then rises as to if and to what extent will companies keep their WFH policies moderated for the pandemic once it is over. The answer to this question depends on the opportunities and costs of WFH for companies, workers, cities, and the general eco-system. To better understand this dynamic, Bloom et. al [10] conducted a study where a Chinese company allowed some of its call center employees to work remotely. They compared the WFH with those who continued to work on-

site and observed a 13% increase in remote workers' performance. Additionally, the firm saved $2000 per WFT employee, resulting in a 20-30% of overall productivity improvement for the firm. There are also studies suggesting work from home improves employee's work-life balance [19] and can reduce their role stress [26]. Bloom's study, however, also uncovered some of the challenges associated with WFT; for instance, promotion rate was lower for remote employees because of reduced interaction with their team leaders. Some of them also preferred to return to their offices because of the loneliness of working from home. In other words, lack of human contact was the major downside of WFH for the call center employees in this study. We hypothesize that this challenge can be mitigated by using virtual reality, through creating virtual working environments when working from home.

When speaking about VR, entertainment and gaming are the first applications that come to mind, and there has been significant progress in these areas; for instance, VR is implemented in roller coaster rides [76] and vehicles [35] to create more immersive and fun experiences. However, the use of VR for work purposes was envisioned since the early days of its development [50]. Today, we see many VR applications giving life to those predictions; One example is teleoperating machines and systems instead of performing tasks in unreachable or dangerous environments, such as nuclear reactors and depths of the ocean [71]. VR provides the remote human operators to gain situation awareness of the real environment and interact with it more naturally. VR can also assist in the education system by providing students with access to material that they may not usually have access to [61]. Hence, it improves students' educational experience and achievement [16]. The benefits of VR in education is not limited to schools and children. It has been widely used in workforce training [73]. Its adoption in medical training, such as training for cataract surgery [73] and minimal access surgery [65] has been widely studied. It is suggested that VR leads to improvement in physicians'' technical skills [3]. Here, we propose that VR can be leveraged for office work such that the work is done efficiently in the virtual environment.

CURRENT IMPLICATIONS

VR can overcome many of the problems that people face while working from home. It has the potential to modify and alter its user's perception of reality [17]. VR devices are unrivalled in immersing the user and creating a sense of being physically present in the virtual environment [20, 52]. VR has also been shown to be a successful mitigation of fear and physical pain during medical procedures and vaccinations, and can take patients' attention off the physical world [4, 15, 22]. The escape from reality proposed in health research has expanded to other fields, including fitness. For instance, being immersed in a virtual environment during exercise can reduce negative sensations associated with exercise such as pain and effort [49] and maintain motivation during high intensity trainings [7]. Hence, VR can change user's perception of fear, pain, and themselves. Slater and Sanchez-Vives [69] studied user's semantic knowledge about their body in VR, while manipulating their virtual body representations. They observed that as users' self-perception changed with their VR body form, their behavior and attitudes changed as well. This sense of presence and altered perception allows the user to detach from the physical world to some extent, making VR a suitable method to increase attention on the task at hand. Moreover, software constraints exceed the physical constraints in controlling the privacy of the VR user, resulting in a better control of distractions from the environment. Work-life balance is another possible outcome of this detachment, allowing the workers to create a clear boundary between their career and their personal life.

Improved performance, motivation and engagement (exergames) are other drives for performing tasks in virtual environments. Few studies have directly tested the effect of VR on task performance. Many of these studies were conducted with the idea of enhancing the experience of exercising, and show promise in improving athletes' performance with VR [53]. For instance, Barathi et al. [7] used VR as a medium for cyclists to compete against improved or moderated models of themselves. This platform improved the cyclists' performance while maintaining their intrinsic motivation. Exercise, however, is different from office work. One of key challenge in minimizing the performance gap between work done in conventional office and VR office is developing a suitable interaction metaphor [32]. For instance, typing, which is one of the most common tasks when interacting with computers, poses many challenges when performed in VR; the user does not see their hands or the keyboard, so typing on keyboards in VR is slow and imprecise, reducing user's productivity [43, 64]. Since the interaction metaphor on computers cannot be directly transferred to VR, current metaphors are being modified [31] or new ones are being developed [5]. In addition to interaction with the VR content, there have been attempts to increase VR work performance through increasing time spent in VR [33], and transitioning 2D windows to 3D virtual environments [25]. Ruvimora et al. [62] studied the performance of office knowledge work done in four combinations of traditional offices (open vs. closed) and virtual offices (VR office vs. beach). They found that virtual offices and physical closed office spaces had comparable usability scores and performance.

In the study of remote work in a Chinese company [10], some of the WFH employees decided to go back to their onsite office because of the loneliness of WFH. This problem can be addressed through modification of the virtual environment. Virtual reality allows for telecommuting, which is shown to be positively correlated with job satisfaction [29]. Moreover, creating a shared office space with coworkers allows for a more natural collaboration space, and higher levels of presence, closeness, and arousal, compared to video calls [14]. As pointed out by Bloom [72], in-person collaborations are necessary for establishing creativity and motivation among the employees in the work environment. The avatars used to represent each person allow for de-biasing against women and minorities [14], and contribute to developing trust[58] among coworkers. On the other hand, VR systems currently don't support collaborative experiences since they currently tend to focus more on individual experiences. However, design guidelines for collaborative VR spaces are being developed [59, 60] and industry is increasing its efforts in building in this feature in the VR devices [36, 55, 66].

Despite the opportunities that VR provides for working from home, during and after the current pandemic, there are challenges that need to be addressed for its successful implementation. The challenges that we focus here on those stemming from users' seclusion from the real world as a result of their immersion in the virtual environment. Namely, we focus on users' situation awareness and others' ability to interrupt them.

Interruption by Others

Finding the right time to interrupt someone is challenging due to the interruption's negative influence on performance and productivity [37] and its association with anxiety and exhaustion [45]. When working from home, the VR user is surrounded by those they are familiar with, and interruption becomes less irritating. Nonetheless, there are negative effects accompanying interruptions that are even more costly in virtual environments; not only they disrupts the workflow, but also they break the VR wearer's sense of presence, the feeling of being located in the virtual environment [52]. On the other hand, successful interruptions in which the interruption content is delivered at the right time reduces the associated costs [30, 38]. Hence, there is a need to investigate methods to minimize the occurrence of inconvenient interruptions, and to assist the VR wearer in the successful resumption of their primary task after being interrupted.

Interruption minimization

We argue that external Human Machine Interfaces (eHMIs) can be leveraged to guide the bystanders in interrupting the VR wearer. George et. al [27] conducted a study in which they investigated the bystander's ability to identify optimum interruption moments only based on the VR wearer's posture and physical activity such as head movement and hand gestures. This study showed that the type of VR task performed was an important factor in interruption in addition to the time of interruption; in other words, the VR wearers preferred to be interrupted during task switches and while performing tasks with lower workloads. This study focuses on an interaction between the bystanders and VR wearer that is only based on human judgment and is not mediated by technology. We, however, argue that eHMIs can assist the bystander from unintended consequences of poor interruption. Use of eHMIs is heavily investigated in the field of automated vehicles as a substitution for driver-centric communication with pedestrians. In non-automated vehicles, driver-centric cues such as the driver's hand gesture and eye contact are one of the communication channels with pedestrians when crossing the roads [21]. However, due to the lack of driver in highly automated vehicles, there is a need for eHMIs to communicate relevant information such as vehicle's intentions to the pedestrians. The proposed interfaces have various forms, such as light bands in front of the vehicle [21], auditory cues [44], and text messages displayed on the vehicle [8]. We propose for the eHMI concept to be implemented on VR devices to provide the bystanders with enough contextual information about the VR wearer, so they can make their decision to interrupt more informed.

The eHMI can be designed as a social translucent system [23]; one with visibility, awareness, and accountability as its core building blocks. Erickson and Kellogg [23] contrast a social translucent system to a door that opens to a hallway; if opened quickly, it may hit somebody on the other side. The addition of a window to the door is an example of a socially translucent system. First, it provides visibility of the movements on other side of the door. Second, the awareness it provides brings in the social rules that govern our actions; slamming the door into others is not socially acceptable. Third, it brings accountability to the person opening the door; if they do slam the door, they are held responsible as they were aware of the presence of someone on the other side of the door. Similarly, eHMIs can bring visibility, awareness and accountability to the interrupter and provide a socially translucent interface between bystanders and VR wearers.

As discussed before, eHMIs can bring visibility and awareness to the bystanders and give them enough contextual information about the state of the VR wearer. As for the accountability of the interface between bystanders and the VR wearer, two common methods are investigated; receiver-oriented and communication-oriented. When calling someone over the phone, the caller cannot collect the necessary contextual information about the other person. Hence, the existing solutions to communication initiation through phone are receiver-oriented; the receiver has to leverage ring tones and caller IDs to decide if they want to respond to the call, and there is a high probability that the call is disruptive to their task or social situation. The communication-oriented mechanism, however, provides the caller with cues of the receiver's context to empower them to decide whether to interrupt or not, rather than putting the burden on the other person [34]. The existence of eHMIs is an implementation of the communication-oriented strategy, putting the interruption responsibility explicitly on the interrupter, and hence, creating a socially translucent system.

Successful Continuation

Either when an interruption is posed at the right time or it was disruptive to the worker's primary task, it is important for the them to be able to continue the task. It takes time for the worker to recover from an interruption, and missing and repeating important parts of the task makes them more prone to making errors during this resumption lag [74]. One suggested mitigation for reducing the resumption errors and supporting the worker in continuing their task is imposing a lockout period after the interruption [13]. This proposed 10-second period allows the worker to slowly reengage with the task and think about how they would like to proceed with it. Another strategy is to provide the worker with some time before they engage with the interruption [18]. This time allows them to encode their primary task with retrieval cues [18] and to potentially finish their sub-task, so they can start a new subtask after the interruption as opposed to resuming the previous subtask [40].

In the context of working in virtual environments, it is also critical for the workers to get re-immersed and regain the feeling of being present in the virtual world. It is suggested that the perceptual formation of presence depends on the VR system's immersiveness which includes the system's objective properties such as its field of view and screen resolution. This is due to the fact that illusion of presence is perceptual and depends on sensory motor contingencies [12]. A study conducted by McGlynn [52] suggested that VR users reach a state of presence quickly; however, the amount of time necessary for presence formation it is not clear yet.

Situation Awareness

As mentioned before, blocking out the physical world and substituting it with a virtual environment has many potential benefits for someone working from home, including less distractions and more productivity. However, one shortcoming of this seclusion is losing situation awareness which is "knowing what's going on so you can figure out what to do" [1]. Gosh et. al [28] surveyed 61 VR users to identify which elements of reality they would like to be aware of. They found that users desired information about the physical space ("someone is about to tap your shoulder") and information about auditory cues ("someone in your room is calling your name"). Being aware of the physical environment is critical when using VR devices in vehicles [51] or walking [75] because of the physical risks posed to the VR wearer. Oculus Gaurdian [57] and Vive's play area are examples of initial attempts to ensure users stay within a safe area while performing VR tasks. Audio is also important in conveying information about the physical world when the user is visually impaired [46] or is visually engaged such as in a vehicle [67] or virtual environment [28].

O'Hagan and Williamson [56] identified four response levels when a VR device encounters and recognizes the presence of an element from reality; ignore, observe (waits for a trigger), communicate (communicates the presence of the element to the use), and react (reacts directly to the element on user's behalf, such as pausing the VR application. They also investigated different notification methods for the VR device; These prototypes used avatar, text notifications, audio notifications or a sonar radar to alert the wearer of the presence of a real-world element. Some participants expressed discomfort when the device notified the presence of another person without declaring their location. It is important to bear in mind that there is a fine line between having enough situation awareness and knowing too much about the physical world that it interferes with the VR experience and workflow [68]. Therefore, it is important to consider the context of working from home before implementing device notification systems using these results. One of the goals of getting immersed in a virtual environment is to avoid living space's distractions, and a system that constantly notifies the wearer of the unavoidable presence of others will not help them in achieving this goal.

Another notification approach for providing the VR wearer with situation awareness is the visual display of sounds. This method has a broad spectrum of applications for the Deaf and Hard of Hearing (DHH), including captioning on head-worn displays in a one-on-one conversation [63] and locating the speaker in the room[39] or in a group conversation [42]. One of the challenges of this method is split attention [41]. This effect happens when someone has to divide their attention between dependent sources of information that are separated spatially or temporally [6], which may result in cognitive overload [70]. Lu et. al [47]investigated subtle cueing to convey necessary information in the least distracting way possible, in an attempt to resolve the split attention problem. They achieved subtle cueing by increasing the transparency of the virtual cues such that they become almost invisible against the background image. Using auditory [24] and haptic [54] cues have also been investigated to assist users in context-triggered attention switches. Appropriate and timely mapping of the real world, through any of the mentioned modalities, assists the VR wearer in having enough situation awareness while not being distracted by them.

CONCLUSION

This paper investigates the opportunities and challenges associated with using virtual reality when working from home. VR shows promising prospects to increase workers' efficiency and reduce their distraction from physical world stimuli. We also propose that it assists them in better balancing their professional and personal life. The implementation of virtual environments as remote workspaces, however, introduces challenges that need to be resolved. These challenges stem from the real world being blocked out by the VR device. First, it inhibits the wearer from being aware of the physical world. Second, it impedes bystanders from perceiving their state since they cannot see their face or the environment they work in. we argue that both user's situation awareness and bystander's awareness are necessary to support healthy interruptions and propose mechanisms to fix them.

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