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Ergonomics of Office Work in a VR Environment: A State-of-the-art Literature Review

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Abstract: Virtual Reality (VR) holds promise as a potential professional work tool – one such potential is to support office work tasks. VR is a simulated environment accessed via head-mounted displays and hand-controlled devices for interacting with the virtual interface. This paper aims to provide a state-of-the-art review of empirical research on VR-based office work, focusing on ergonomics. A structured literature database search and criteria-based exclusion led to a total of 5 papers addressing office work in a VR environment. The research on VR-based office work identifies potentials and drawbacks relevant to consider for future research and developments. The identified studies examine technical solutions, task performance, user experience and comfort when using VR-based solutions. The fast pace of technology development, e.g lighter headsets, increased field of vision and screen resolution, new controls, and the emerging plethora of new software may resolve many identified challenges, while perhaps introducing new problems.

Keywords: Virtual reality, Office work, Ergonomics.

1. Introduction

Virtual Reality (VR) holds many promises, one of which is to support office workers' increasingly distributed work (Grubert et al 2018). It has received increased attention, particularly in the aftermath of COVID-19 and the widespread adoption of remote work among office workers. The increased interest in VR is also due to rapid technological breakthroughs, improved user comfort and affordable pricing.

VR is a simulated environment that is accessed by wearing Head-mounted displays (HMD), considered to provide visually immersive 3D experiences (in contrast to two-dimensional screen-based user interfaces). To interact with VR, users wear a head-mounted display (HMD), enter the simulated environment by turning on the device and starting an application, move and look around to browse the visual environment, and use hand-controlled devices for navigation and data entry. VR has been primarily used in the gaming industry. Other application areas include medical purposes such as management of pain and anxiety, industrial purposes like product simulation and visualisation, and training purposes.

The application of VR for office work has gained unprecedented attention in recent years as a result of increased remote work, primarily touted as a way for colleagues to meet virtually.

We define "office work" as a combination of knowledge work and/or administrative work that is traditionally carried out in an office environment that either functions as a stand-alone environment or is in proximity to other types of work environments like laboratories, health-care or manufacturing. However, the boundaries of where office work is conducted have been increasingly blurred following increased digitalisation, technological advancements and remote work policies (Kompast & Wagner 2002). Office workers have access to not only communication tools but also tools such as word processors and spreadsheets on mobile phones and tablets. These tools can be seen as infinite canvases that cannot be used to their full potential on smaller screens. VR technology can provide means to utilise the potential of such tools without any limitations of screen size and location of work (Grubert et al 2018).

This paper aims to provide a state-of-the-art review of research on VR-based office work, with a focus on ergonomics, and highlight areas in need of future research. This paper focuses on empirical studies that address VR-based office work, and excludes other domain applications.

2. Methodology

The structured literature review combined a search in Scopus and Web of Science (WoS) in order to find peer-reviewed materials about the combination of VR and office work. The keywords and operands used for database searches were: ("virtual reality" OR "VR") AND ("office work" OR "knowledge work"). Conference proceedings and journal articles from 2000-2021 were included in the search strategy. In total, 52 abstracts were found (n=40 in Scopus, and n=12 in WoS). After removal of duplicates (n=10) and abstracts that did not address aspects of office work with virtual reality technology (n=32), 9 publications were identified for full-text review. After a full-text review, five publications were found relevant for this review (removing 4 that were not empirical studies). The Prisma diagram in Figure 1 illustrates the literature review process.

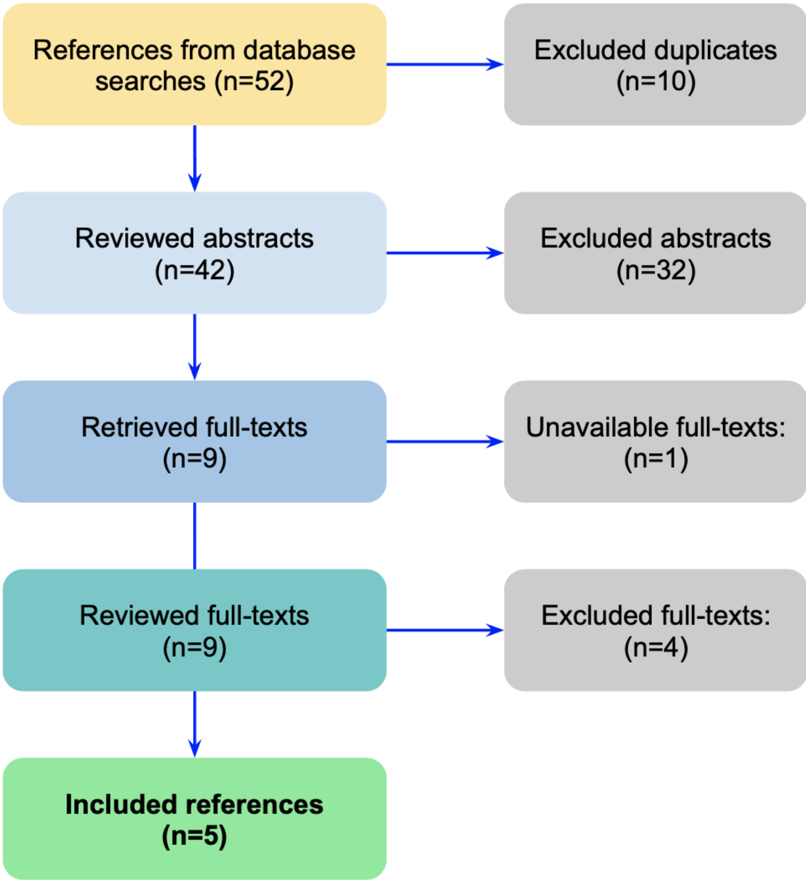

Figure 1: Prisma diagram of the literature search and inclusion/exclusion process

3. Results

The identified five publications presented empirical studies that either (i) presented and evaluated new prototypes or ways of using the VR-technology to conduct office work, or (ii) evaluated existing VR technology. The studies were published between 2018-2021. All studies were published as conference proceedings, except one in Ergonomics (Kim & Shin 2021).

All studies were conducted in laboratory settings. Four studies used the HTC Vive Pro (Biener et al 2020; Shen et al 2019; Gesslein et al 2020; Kim & Shin 2021), and one study used Oculus rift CV1 (Knierim et al 2018) for testing. The overall experiment duration in four studies was under two hours (Knierim et al 2018; Gesslein et al 2020; Biener et al 2020; Kim & Shin 2021), while one of the studies presented an experiment that took two full workdays (Shen et al 2019).

The experimental setting in four studies compared simulated tasks in a real environment with VR conditions, having participants test the different conditions (Knierim et al 2018; Shen et al 2019; Gesslein et al 2020; Kim & Shin 2021). The comparative set-up in Kim & Shin (2021) and Shen et al (2019) was carried out on two separate days to prevent fatigue. The comparative data in the studies by Gesslein et al (2020) and Knierim et al (2018) was collected in one day, with an overall shorter task duration. The tasks that were simulated in the identified studies were: typing tasks (Kim & Shin, 2021; Knierim et al 2018; Shen et al 2019), spreadsheet tasks (Gesslein et al 2020); content transfer and puzzle tasks (Biener et al 2020); and editing, content searching and image classification tasks (Shen et al 2019).

The number of participants across the studies varied between 5 to 32 with a majority of male participants (in total 95 participants; 26 Female and 74 male), with a mixed exposure to VR devices prior to the experiment.

The identified studies addressed several aspects of user experience and workload. Two studies evaluated simulator sickness based on subjective ratings (Biener et al 2020; Kim & Shin 2021) using a validated questionnaire (SSQ) developed for evaluating simulator sickness (Kennedy et al., 1993). Cognitive workload was assessed using NASA-Task Load Index (Hart & Staveland, 1988) in studies by Biener et al (2020) and Knierim et al (2018). One of the studies measured physical workload by subjective (dis-)comfort ratings, Electromyographic (EMG) measurements and observational data of posture neck movement (Kim & Shin 2021). Interviews and observations were conducted to cover more general aspects of the user experience (Biener et al 2020; Knierim et al 2018). Biener et al (2020) evaluated usability aspects with the System Usability Scale (SUS) questionnaire, a validated instrument for subjective ratings of usability (Lewis, 2018). Performance outcomes were assessed based on objective data such as typing speed, error rate, and reaction time (e.g. Shen et al 2019).

The insights from the identified studies are summarised in the following two sections: (1) technical enablers of office work in VR, and (2) potential benefits and challenges of using VR for office work.

3.1. Technical enablers of office work in VR

Three studies presented and evaluated new prototypes or ways of using the VR-technology that can enable and/or facilitate office work tasks. Biener et al (2020) developed ways to make use of a larger screen access in VR, both side-by-side and arranged in-depth (with a “show all” button which was not used by the users; instead they browsed to the depth and back to scan the screens). They demonstrated how to make use of multiple screens with micro-movements for input. This application seems relevant in limited spaces (such as passenger seats). Other studies used two side-by-side screens resembling desktop usage (e.g. Kim and Shin 2021). It appears that the possible interaction patterns for utilising the large screen potentials in VR have not been sufficiently mapped/explored.

Knierim et al (2018) developed a tool to facilitate effective typewriting in VR. The tool visually represents hands and keyboards to counteract the downside of immersion in VR, specifically the issue of not seeing hands and keyboards. Typewriting is the most common generic office work that can be challenging for users who are not fluent touch typists. Other solutions in the market are point and click solutions with tracked controllers, handwriting with a pen on a tablet, speech, an overlay of the virtual environment with a cropped video stream of the real world, and “real keyboards” developed to be used with VR-headsets.

Gesslein et al (2020) developed new functions and ways of interacting with spreadsheets in VR for utilising the screen both in-depth and vertically. They also demonstrated that using a pen as an input device enables accuracy, intuitive interaction, and also frees up one hand that can be useful in small spaces.

3.2. Potential benefits and challenges of using VR for office work

The identified benefits relate to the context of VR-usage, particularly the access to a large screen that can facilitate mobile office work, taking place on-the-go in small and possibly crowded spaces (Biener et al 2020, Kim and Shin 2021). The immersion in a VR-environment also allows for protecting sensitive information on the user’s screen (Kim and Shin 2021). It is relevant to note that these benefits are raised as *potential* benefits and were not empirically tested in real environments.

The identified challenges covered risks associated with wearing HMDs such as physical discomfort and fitting eyeglasses within the headsets (Kim and Shin 2021), visual discomfort (ibid.), simulator sickness (ibid.), fatigue (Shen et al 2019), loss of productivity and higher workload due to novelty of and usability issues with input devices (Knierim et al 2018). In particular, having simulated keyboards limited the haptic feedback for experienced typists and not seeing one's hands when typing was a challenge for inexperienced typists (ibid.). These limitations led to merely including experienced touch typists in one of the studies (Kim and Shin 2021), suggesting a potential loss of productivity for those office workers who are not necessarily touch-typists. The interface and its general compatibility (in terms of controls, windows and screens) with the real environment is another challenge raised in the literature. Table 1 provides an overview of the identified benefits and challenges.

Table 1. Potential benefits and challenges of using VR for office work according to sources A (Biener et al 2020), B (Gesslein et al 2020), C (Kim and Shin 2021), D (Knierim et al 2018) and E (Shen et al 2019).

Benefits related to context of use	● Access to large screens in small spaces for facilitating mobile work (A,C) ● Overcome privacy issues in public spaces (C)
General challenges	● Limited evidence exists on mental fatigue (slower reaction time and more lapses) when comparing long-term tasks in VR vs desktop situations (E). It remains unclear which aspects of VR caused the reported mental fatigue. ● Simulator sickness ratings are higher in VR conditions compared to desktop conditions, but not considered a major concern for users (C). The authors conclude that VR can be appropriate for office work for mobile workers provided enough breaks are taken.
Challenges related to wearing a HMD	● Increased neck rotation in combination with carrying the HMDs weight was observed in an experimental study, leading to more use of neck extensor muscles and higher ratings of shoulder and neck discomfort (C). ● A recent study recruited users who do not wear eyeglasses to avoid problems with fitting the HMD (C).
Challenges related to the display	● Shifting the line of sight in VR seems to require more head rotation than in desktop situations (C). ● Visual discomfort is reported to a higher extent when comparing VR with desktop use (C).
Challenges related to input devices	● Neither the keyboard nor the hands were seen in earlier versions of VR, leading to productivity loss in typing tasks, specifically for inexperienced typists (D). ● Having No Hands in VR causes a significantly higher workload than having hand visualisations, for both experienced as well as inexperienced typists (D).
Challenges related to the interface	● The compatibility of representations between the VR and non-VR workflows (E). ● Challenges for utilising the limitless screen capacity include finding a comfortable distance, readability of information presented in peripheries, identifying an active window, and achieving an overview of information that may be represented in-depth (A).

4. Discussion

This review based on five articles may appear quite limited by virtue of sheer numbers. The exclusion strategies were intended to focus the knowledge space to empirical studies of combining VR technology and office work (as defined in the Introduction). The included papers nonetheless offer important insights regarding benefits and challenges of VR use for this purpose (as well as for carrying out studies of work-related VR use).

Some paradoxes of VR-usage become evident: for example, the VR environment offers the possibility of greater freedom of movement, since the user is in theory no longer restricted to placing work materials on a limited, designated desktop affected by gravity, or a limited screen size. However, conventional reliance on physical keyboards for text entry in office work require the users to sit or stand by a desk surface to support the input device. Recent studies point to the usability problems of interacting with physical keyboards in the VR environment (e.g. McGill et al 2015; Knierim et al 2018).

Further, VR offers a potentially “limitless” screen size on which to distribute information (including above the user’s head), but in practice, human eyes are limited by having a restricted field of vision where detailed viewing is only possible in the centre; also, having too-distant work surfaces greatly reduces their utility and may end up causing the user visual clutter. One of the studies (Biener et al 2020) tested side-by-side and layered windows for screen usage (resembling desk-tops); their results may be an untapped potential for user interface development.

Possibilities to extend the literature review have been considered, particularly employing a snowball-strategy search (where additional publications are identified from the reference lists of the papers that were included after the full-text review). A preliminary attempt to do so is currently being pursued, with approximately 40 additional papers (both journal articles and conference proceedings) being evaluated for possible inclusion. The drawback of this strategy is that the five original papers limit the search field to papers older than themselves. This may add some well-needed established knowledge published before the year 2000 (in particular a seminal article by Nichols (1999) that appears in most reference lists), as well as articles that were not captured by our original keywords. The year limitation cutting off the Nichols (1999) paper is particularly unfortunate, as the paper raised salient points like the risk for physical discomfort in the head/neck region when wearing a HMD; that the user experience of older HMD displays may be negatively affected by distortion, limited field of view, rendering problems, and low resolution; and learning problems associated with the usage of the equipment, e.g. remembering which buttons to press on the input devices.

A further enrichment strategy could be to also include grey literature (newspaper articles, white papers, product reviews, blog posts etc.), but the likelihood of these offering insights from empirical trials without an underlying marketing purpose is uncertain. However, their inclusion might mitigate the fact that the development pace of VR technology is very rapid, in contrast to the pace of academic publishing about the subject. Still, some of the included conference proceedings report on tinkering with VR tools, and present and evaluate working prototypes.

The issue of whether search keywords have been sufficiently inclusive, and at the same time sufficiently distinct, is worth discussing. While our keywords included the term “office work”, a preliminary observation regarding the snowball-searched papers is that most of the ones chosen for consideration do not use the term “office work”, but rather focus on office-related tools, like keyboards. This indicates that a more technology-focused search might have yielded additional relevant results, even if the context of office work were to be removed from the scope. This, however, would require a qualitative interpretation of whether any technology being described could have utility for office work, which could lead to some arbitrary inclusions. It is also worth considering that the use of terms in a practitioner or VR-technology-developer context may differ from the academic use of the same terms.

Finally, the literature review indicates knowledge gaps worthy of further investigation, evoking research questions such as;

- Is the current technology “mature enough” for implementation in office work? If not, what must be addressed?
- How does a person’s presence/immersion in VR relate to alertness/attentiveness when performing office tasks?
- What other cognitive ergonomics considerations might affect the performance and experience of the work?
- What other text entry devices could be considered as a productive alternative to touch type-keyboards, to enable freedom of movement?
- What are the implications of using speech-to-text solutions as a replacement for typing in a VR environment?
- What are the practical limitations of “limitless screen space”?
- What is a “healthy” or safe dose of VR usage for work, time-wise?
- How does work in VR influence the social and organisational work environment? How should work tasks be organised in VR environments?
- What musculoskeletal considerations should be taken into account when designing office work in VR?
- What are the accessibility considerations in a VR environment?

The answers to these questions appear to require further empirical studies of an interventional or experimental nature.

5. Conclusions

The research on use of VR technology for office work identifies potentials and drawbacks relevant to consider for future research and developments. While the VR-technology enables access to limitless screens that are not bound to desks and entail potentially new interaction patterns, the identified studies replicate and simulate traditional ways of working with office tasks, i.e. seated work with keyboards. The identified challenges include discomfort, fatigue, loss of productivity and problems with usability of the examined interfaces. The fast pace of technology development may resolve many identified challenges, while perhaps introducing new problems.

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