The potential of head-mounted display virtual reality as an attention retention and anti-distraction tool: A study

by

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Abstract

The aim of this study was to evaluate the effectiveness of Head-Mounted Display(HMD) Virtual Reality(VR) as an attention retention anti-distraction tool. HMD VR is often used as an entertainment device, and more of its potential in the conventional workflow is yet to be explored. Two randomised trial carried out on 14 university students was conducted to investigate their performance on a memory-recall task using HMD VR, laptop alone, and laptop with peripheral blocking mask. Welch paired sample t-test was performed, showing a large effect size and significant statistically difference in mean map scores between the HMD VR and PC. The results suggest although participants have slower tested typing speed, they still have better performance at memory-recall writing tasks on HMD VR. Memory-recall tasks are known to be affected by individuals' attention to the task. Hence, it is suggested HMD VR can improve attention retention on certain tasks, and can help rehabilitation from distractions.

1. Introduction

Head-mounted display (HMD) virtual reality (VR) has been widely used in entertainment, for example, in gaming and video streaming, and as an innovative productivity tool, for example, in 3D design and modelling. There are limited numbers of built-in functions as well as software in VR that allow for conventional workflows such as typing and document editing, and it is important to understand the impact of using HMD VR when completing such tasks. Could VR be used as a productivity tool by enhancing people's attention? How does it influence cognitive behaviour? What are the key factors that should be focused on in the future development of productivity VR? This study aims to investigate the effectiveness of HMD VR on attention retention by asking university students to perform memory-recall writing tasks on a computer and on HMD VR.

2. Theoretical background

2.1. VR and attention:

In addition to VR providing spatial perception and a 3D workplace, research has suggested that there are opportunities for using VR in the rehabilitation of children with attention deficit hyperactivity disorder (ADHD) (Bashiri, A., Ghazisaeedi, M. and Shahmoradi, L., 2017). Studies have shown that VR would be a suitable tool for understanding and improving cognitive deficits. However, while studies have suggested that HMD VR has the potential to improve attention retention, it is unclear whether this capability would be of benefit to office workers and students who have more conventional workflows.

2.2. Distraction

2.2.1. Attention and distraction

Efficient information processing depends on the ability to focus on the task at hand (Pashler, 1997). Wickens' model of human information processing helps to understand an individual's capacity to process information when exposed to distractions (Figure 1) (Wickens et al., 2004). In essence, a distraction is something that is unexpected or undesired perception and can be divided into two types: continuous and conspicuous. Continuous distraction is continuously perceived, and if deemed irrelevant, an individual would choose not to react to the distraction. This continuous distraction would then be registered and stored in working memory (Sharit, J., 2012). However, this does not mean that perceptions are externally blocked. Sensory input still exists; the individual would still monitor outer environment, despite registered already. Moreover, background speech with high intelligibility (HI) would impair an individual's performance (Amprasi et al., 2012). This finding suggests that unwanted sound perception with HI is less likely to be registered, as it would otherwise be registered as a sound pattern that, unlike in an information-processing model of

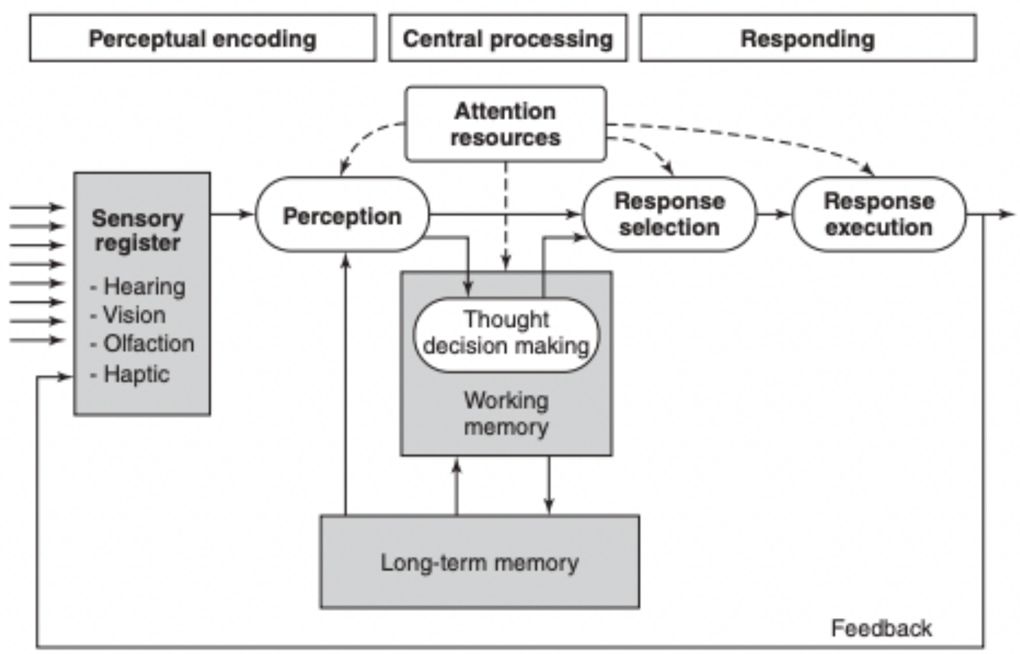


Figure 1 Generic model of human information processing. (Sharit, J., 2012. Adapted from Wickens et al., 2004.)

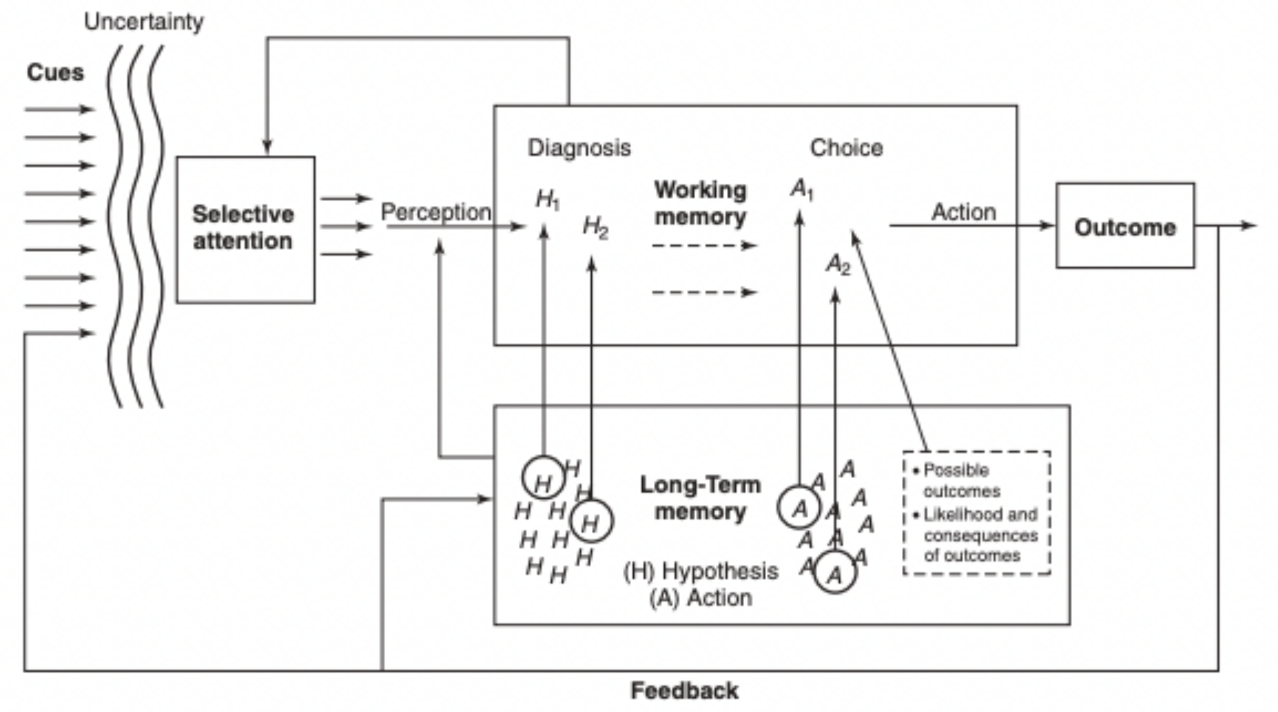


Figure 2 Information-processing model of decision making. (Sharit, J., 2012; Adapted from Wickens et al., 2004.)

decision-making, would not require any extra diagnosing (Figure 2) (Sharit, J., 2012; Wickens et al., 2004). Additionally, after certain environmental feedback has been registered, a portion of attention resources is occupied with monitoring sensory input. The result of a study on peripheral vision may support this assertion. Reynolds et al.(2010) suggested that the peripheral-vision space around the user is a valuable resource for awareness and communication systems and, hence, allows an opportunity for peripheral display. Nevertheless, the study also suggested that peripheral vision is unconsciously monitored and could, therefore, lead to unwanted distractions. If a portion of attention resources is required and is occupied with monitoring registered perceptions, this could then mean that if this occupation is removed, that could benefit attention retention when performing certain tasks.

HMD VR can be used to create a virtual environment where users have less visual perceptible elements and, consequently, less occupied attentional resources. When using HMD VR with minimised setups, there are fewer options in terms of attention resource distribution. Therefore, hypothetically, attention resources are less divided on different stimuli, which encourages selective attention on the task at hand, leading to better performance on certain tasks that require high levels of focus. If HMD VR does help with attention retention on certain tasks, it should be examined whether simple peripheral blocking would achieve the same result.

There are differences between simple peripheral blocking and HMD VR. Peripheral blocking still lets an individual turn their head, who will then perceive more visual input. Moreover, it is challenging to fully limit an individual's vision on the display uses a peripheral blocking mask. In contrast, if the environment is set to do so, VR creates a virtual space where the user is able to freely turn their head without perceiving anything conspicuous. Once the user learns the simplicity of the environment, they might subconsciously understand there is less to be monitored visually. Therefore, fewer attention recourses are occupied. This hypothesis will be tested by conducting two experiments.

The first experiment of this study aimed to investigate the impact of HMD VR on conventional writing tasks that require high levels of attention. The second experiment aimed to investigate an individual's performance on the same task using a peripheral blocking mask instead of HMD VR. Comparing the results would show both whether HMD VR may help retain attention and, therefore, increase performance on certain tasks and whether the same effect could be replicated using a simple peripheral blocking strategy.

2.2.2. Productivity and distraction:

The capacity to retain attention varies from person to person, but an office worker would be able to increase their performance through controlled processing that uses temporary goals as anti-distraction strategies (Engle et al., 1999). External distractions affect an individual's attention on specific tasks. However, the degree of distraction varies depending on the type of distraction and the task that is being performed.

2.2.3. Auditory and Visual distractions

Auditory and visual cortex activities are only triggered by auditory and visual distractors, respectively, which suggests that there is a cognitive difference when processing auditory and visual distractors (Salo et al., 2017). It is essential to investigate both auditory and visual distractions and their integration . If the computer task performed is considered simple and standardised, auditory and visual distractions are considered less impactful on productivity, and studies have suggested testing this using more complex tasks and more distracting factors (Korte et al., 2007). The impact of distractions could vary, both subjectively and objectively, on different individuals.

2.2.3.1. Visual Distraction

Avoiding being distracted by conspicuous but irrelevant stimuli is critical to accomplishing daily tasks (Cosman, J.D. et al., 2018.). This suggests that the visual distractor's level of conspicuousness is more determinative than its intelligibility. In a mock-up office study, both HI and LI continuous lighting visual distractions caused complaints but did not impair performance, which further supports this study's aforementioned hypothesis (Amprasi et al., 2012). Another study compared HI and LI visual distractions using face and non-face objects as distractors. In this study, no behavioural significance was found. However, face-specific processing did cause a high attentional load, and stronger suppression occurred for faces than for cars (Neumann et al., 2018). The results of this experiment are noteworthy, as they show that a strong suppression process might have happened and that attentional load was different, even when the individuals' performances were identical.

Peripheral vision blocking has been widely used as a strategy to increase performance. For example, horses have a wide visual field and could easily be disturbed by an unfamiliar sound or visual stimuli. It has been empirically determined that horse blinkers both improve the performance of racehorses and help them focus. However, research has also shown that horses with blinkers become more sensitive to unfamiliar sounds (Dziezyc et al., 2011). Additionally, in the past, cubicles were used in offices in order to increase productivity. It was believed that using cubicles would be of benefit, as unrelated matters could more easily be ignored. A more modern office setting is the open office, which encourages communication and perhaps also mutual supervision. HMD VR naturally blocks a user's vision and replaces it with a virtual setup. While a VR environment is often used to immerse a user in an alternative world, using simple or blank backgrounds with the task interface would help eliminate any undesired sensory input.

2.2.3.2. Auditory Distraction

When testing in a mock office setting, the significance of sound distraction and temperature change on productivity was found in a study that was conducted in an office setting (Mak, C.M. and Lui, Y.P., 2012). When compared with visual distractions, auditory distractions such as noisy backgrounds, closing doors, and human activities were found to be more significant. Mak, C.M. and Lui, Y.P.(2012) showed that auditory distraction should be considered as having a significant impact on worker productivity.

Auditory distractions can be divided into four types: LI, HI, continuous and conspicuous(Figure3). However, unlike visual distractors, intelligibility is more of a determinate factor in terms of its capacity to impair an individual. It has been shown that background speech of HI affects performance (Liebl et al., 2012). Another study concluded that although both auditory and visual

	Low Intelligibility (LI)	High Intelligibility (HI)
Continuous	Indistinguishable background noice	Distinguishable discussion, news report, radio
Conspicuous	Item drops on the floor, door closing	Greetings, short conversation

Figure 3. Different types of auditory distraction.

reactions were affected, the auditory reaction time was the most affected by HI conversations (Makda, M.M., Gotmare, N. and Deshpande, M., 2017).

This study's experiments will test the impacts of both audio and visual distractions.

3. Methods

3.1. Two experiments

This study consists of two experiments. The second experiment was conducted to examine the effect of peripheral vision blocking.

3.2. Participants

3.2.1. Experiment One

The experimental group consisted of 10 participants (four females and six males) aged 22–38 (M = 25.5 years old). They were all university students or researchers, fluent English writers, had passed a university-level English qualification, and reported normal hearing and normal typing ability.

3.2.2. Experiment Two

The experimental group consisted of four participants (two females and two males) aged 24–26 (M = 24.6 years old). They were all university students, fluent English writers, and had passed a university-level English qualification. All four participants reported normal hearing and normal typing ability.

3.3. Equipment and preparation

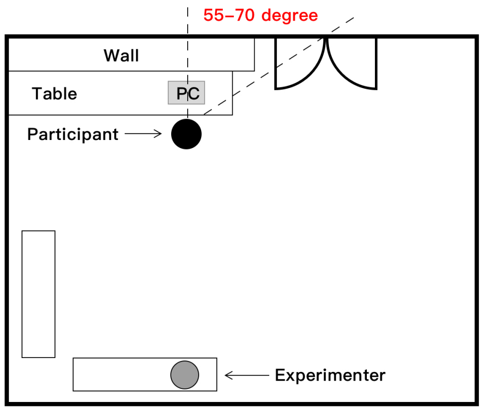
The two experiments were conducted in the "dark lab" of the Creative Computing Institute at the University of the Arts, London. The room was about 29m^2, and the desk used for the experiments was placed so that the participants could see the door in their peripheral vision (Figure 4). A chair was placed ~4 meters behind the participants, from where the researcher performed HI distractors. For experiment one, each participant was asked to perform a writing task in Oculus Quest 2 and a 13' MacBook Pro; for experiment 2, a peripheral vision blocking mask modified from a wielding mask was used, and each participant was asked to perform a writing task on a 13' MacBook Pro. The Quest 2 was equipped with an Apple Magic Keyboard with the same layout as the MacBook, which aimed to minimise the impact of typing differences (figure 5). All typing interfaces were monitored and recorded.

A Google document was used for each participant's writing task(figure 6). Participants were allowed to change the font size. All participants were given time before each section of the experiment to practice typing using standard typing speed test software. Their best typing speed records were also recorded as words per minute(WPM).

The participants were randomly assigned into two groups. The two groups used VR and the mask in a different order.

3.4. Memory recall writing task

All participants were given the same writing task. The task consisted of two 10-minute sections. The participants were asked to perform the task in VR and the mask. Before the first section, the writing task was explained in the document, and each



‘Darklab’ floor plan, demonstration purpose only.

Figure 4 Floor plan.

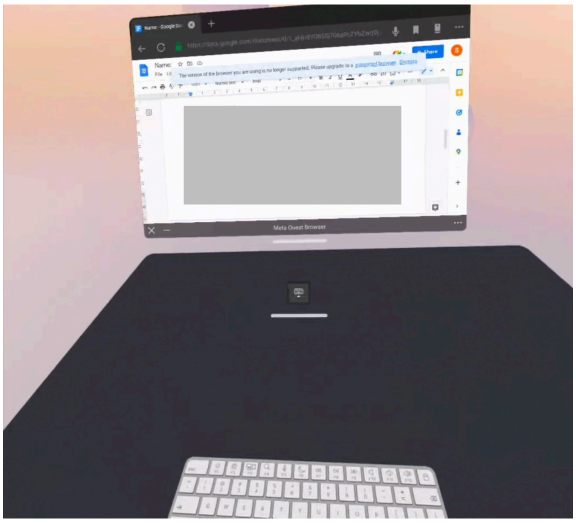


Figure 5 Interface of HMD VR, screenshot from recording. Content censored.

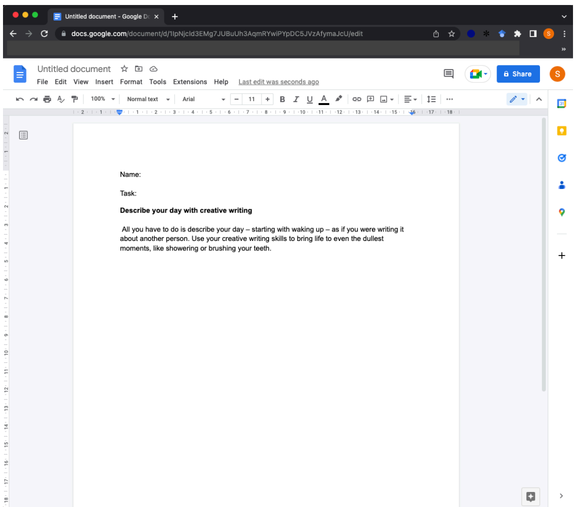


Figure 6 Pre-task screenshot of Google doc interface on laptop.

participant was given no more than five minutes to prepare for the question without typing anything.

The writing task was: 'Describe your day with creative writing'. A short guide was referenced from a creative writing guidance article by B.R. Pope (2019). "All you have to do is describe your day – starting with waking up – as if you were writing it about another person. Use your creative writing skills to bring life to even the dullest moments, like showering or brushing your teeth."

The participants were told to ignore incorrect grammar or typing errors. They were told to try to write as much as they could within 10 minutes. The same task was given to every participant in both experiments.

This writing task was carefully selected for the following reasons. First, the writing task was not intended to be knowledge based, as the participants could not be guaranteed to have the same level of subject knowledge. Second, it was intended to be an open topic that the participants could keep writing about within the given timeframe. Third, the task was intended to require a high level of concentration. A memory-recall task on everyday matters was considered suitable for this study because studies have shown that individuals perform better on memory-recall tasks when they are more focused (Baddeley et al., 1984; Perez-Mata et al., 2002).

3.5. Anti-distraction test

An audio-visual distraction with LI and an auditory distraction with HI were introduced during each section of both experiments.

During each 10 minutes section of the task, a researcher opened the door within the participant's peripheral vision at around the third minute and said, 'Hey, XXX (participant's name); oh, never mind,' as if they had walked in by accident. At around the seventh minute, a researcher sitting behind the participant read out made-up shocking news. The news in the first and second parts of the experiment was consecutive , while the name-calling behaviour remained the same. The fake news was clarified immediately after each experiment. The participants' behaviours were observed, and their writing behaviours on the devices were recorded and assessed.

3.6. Interview

An interview was conducted after the second section of each experiment. The interview started by clarifying that the shocking news was fake. Then, open questions were asked about the participants' feelings about writing in HMD VR and on a laptop. If not already mentioned, attention-related questions were then discussed. Each participant was asked to rate how much they felt distracted during the task on a scale of 1–10, with 1 meaning not distracted and 10 meaning fully distracted/ lost track of work(figure7). The participants were encouraged to discuss what they thought had affected them during the experiment.

METHOD	LOOK ASIDE(Y/N)	DISTRACTED LEVEL
VR1	No	1
VR2	No	2
R1	Yes	3
R2	No	5

Figure 7 Example chart for distraction rating

4. Result and analysis of results

In experiment one, all participants were able to type faster on the laptop than on HMD VR. However, all but one participant typed more in the writing task on VR than on the laptop. This result shows that HMD VR had a positive impact on the participants performing the memory-recall writing task. The first experiment had four invalid results due to multiple device glitches on VR during these four experiments. All participants felt that it had been easier to keep focused on the task with VR. However, the participants showed different reactions to the introduced distractions. Four participants mentioned that they noticed themselves glancing at their surroundings while typing on the laptop and were momentarily distracted by nothing in particular. None reported a similar situation in HMD VR. Most of the participants expressed discomfort about using HMD VR but also suggested that 10 minutes of usage was acceptable.

In experiment 2, the performance difference between wearing a peripheral mask and using a laptop alone was not significant. All four results were valid. It was shown that a simple peripheral-blocking strategy might not increase participants' performance on memory-recall writing tasks on a laptop.

4.1. Quantitative analysis

4.1.1. Experiment one

All 10 participants completed the study. Four participants experienced serious glitches while using the VR headset, and they were required to recentre the screen multiple times (average >6 times) and self-reported to have been severely distracted. Therefore, only six results are considered valid. All six participants with valid results typed faster on the laptop($M = 47.166$ WPM, $SD = 12.20$) than on VR($M = 40$ WPM, $SD = 11.47$). However, five out of the six participants wrote more on VR($M = 258.166$ words, $SD = 33.99$) than on the laptop($M = 240.833$ words, $SD = 67.19$). Five out of the six participants turned towards the researcher when first distracted while using the laptop. One out of the six participants turned their faces towards the researcher when first distracted while using VR. The LI distractors were considered to have minor to no impact on the participants when using HMD VR (M = 1.75; SD = 0.66) and minor to moderate impact on the participants when using the laptop (M = 3; SD = 1.5). The HI distractors' impact was considered moderate (M = 4; SD = 2.236) on the participants when using HMD VR and more distracting when using the laptop (M = 5.875, SD = 1.536). Although the two HI distractors weren't identical and the second fake news story was reported to be considered more shocking than the first one, the two groups of participants were given the same news while they were using different devices and making the quantitative results have its validity. No significant findings were determined between genders or age groups. No participant anticipated the actual purpose of the experiment.

Previous studies shown users can type in HMD VR as good as they do in PC after a extended period of training(Grubert et al., 2018; Knierim et al., 2018). Beside direct data analysis of different condition, a weighted typing performance was considered as well. The weight is calculated as

$$\frac{Meanoftestedtypingspeedon VR}{Meanoftestedtypingspeedon PC} = \frac{40}{47.166} = 0.848$$

Weighted performance use all VR actual words typed divided by weight(0.848). Further data analysis is based on wighted performance.(Figure8, 9)

CONDITION	MEASURE	MEAN	SD	SE
PC	Tested typing speed (WPM)	47.166	12.205	4.9982
VR		40	11.471	4.683
PC	Actual word typed	240.833	67.196	27.432
VR		258.166	33.996	13.879
PC	Weighted Performance (W = 0.848)	240.833	67.196	27.432
VR		304.441	40.09	16.366

Figure 8 Data of Experiment One

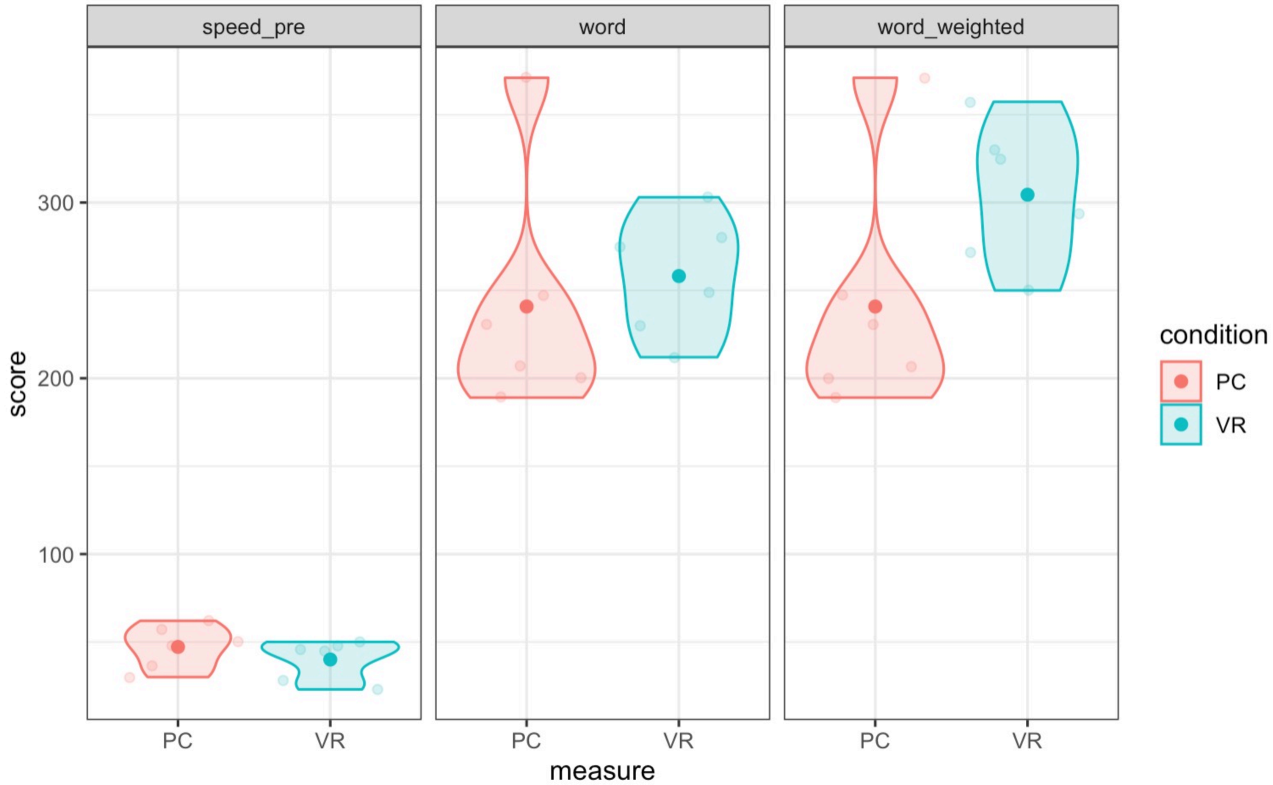


Figure 9 Experiment One data diagram

measure	estimate	statistic	p.value	conf.low	conf.high	method
Tested typing speed (WPM)	-7.16	-4.31	0.007	-11.43	-2.89	Paired t-test
Actual word typed	17.33	0.74	0.49	-43.17	77.84	
Weighted Performance	63.60	2.70	0.04	2.82	124.39	

Figure 10 Experiment One mean map score

Welch paired sample t-test was performed, t (63.61) = 2.69, p = 0.04, d= 1.10, 95% CI [2.82 124.39], showing a large effect size and significant statistically difference in mean map scores between the two conditions(Figure 10).

It is shown:

1. HMD VR had a positive impact on performance during the memory-recall writing task. The participants typed more when using HMD VR, even when their limit typing speeds were lower. The weighted performance is largely significant.
2. HMD VR may have some impact on an individual's ability to recover from LI and HI auditory distractions, but further investigation is required.

4.1.2. Experiment two

2 out of 4 participants wrote less while using peripheral blocking mask. On average, 4 participants had average typing speed 1.5% slower while wearing peripheral blocking masks(PC M = 31.75, SD = 2.21; MASK M = 30, SD = 2.94). They wrote slightly less on VR(M = 203.25, SD = 45.15) compare to writing in laptop (M = 209, SD = 34.31)(figure 11, 12).

CONDITION	MEASURE	MEAN	SD	SE
PC	Tested typing speed (WPM)	31.75	2.22	1.10
MASK+PC		30	2.94	1.47
PC	Actual word typed	209	34.31	17.16
MASK+PC		203.25	45.15	22.57
PC	Weighted Performance (W = 0.945)	209	34.31	17.16
MASK+PC		215.12	47.78	23.89

Figure 11 Data of Experiment Two

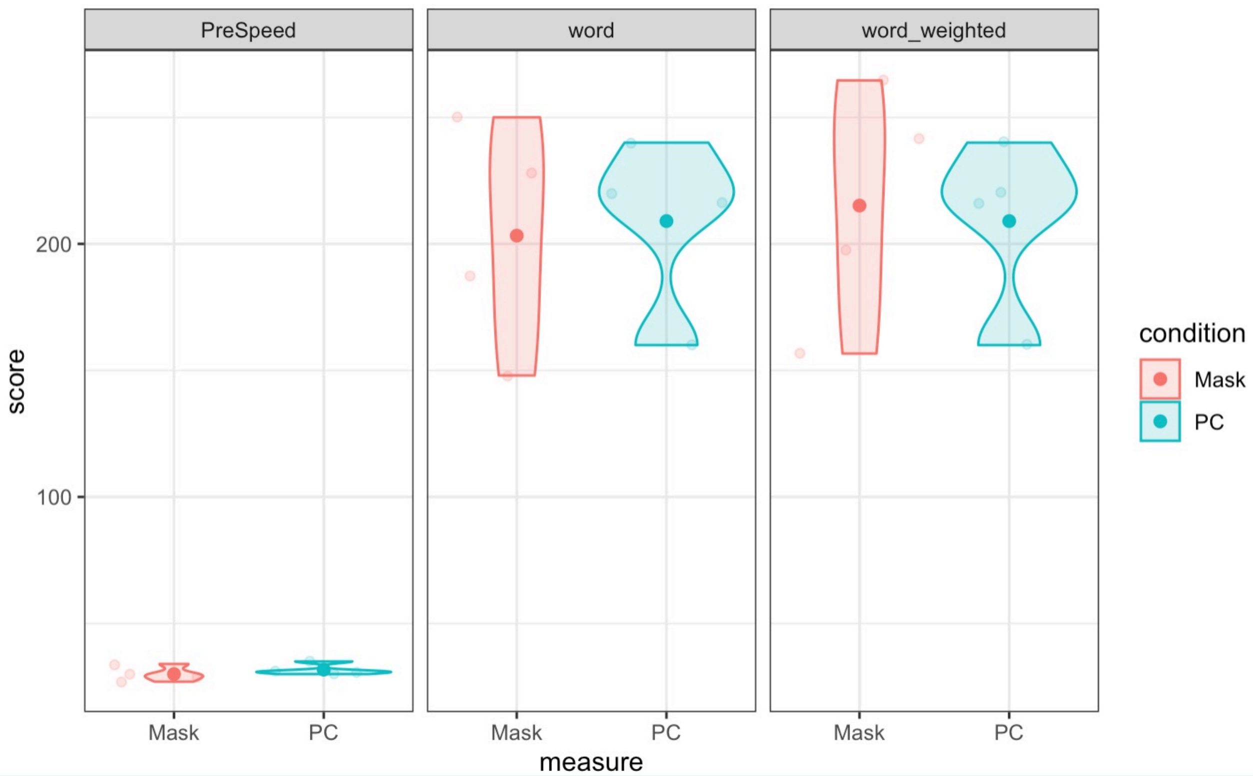


Figure 12 Experiment Two diagram

No participants turned their head towards experimenter at the first distraction while wearing the mask, compare to 2 people did without the mask on. The LI distractors were considered minor to no impact with peripheral mask(M=1.5, SD = 0.86), and minor impact to 3 out of 4 participants

(M=1.333, SD = 0.471). One participant looked at the experimenter during the LI distraction and reported he was severely distracted from his work(rate:6), which would lead the overall average to 2.5, SD to 2.061. The HI distractors impact were considered moderate (M = 4.75, SD = 3.65) when using peripheral mask, and were considered same distracting on laptop(M = 2.5, SD=0.5). However, 2 participants was greatly shocked by the news itself while using peripheral mask, gave the rate of 6 and 10. Larger sample space and a better choice of HI distractor might be proffered for further investigation. No significancy were found between different genders, nor age groups.

measure	estimate	statistic	p.value	conf.low	conf.high	method
Tested typing speed (WPM)	1.75	2.05	0.133	-0.96	4.47	Paired t-test
Actual word typed	5.75	0.54	0.62	-27.94	39.43	
Weighted Performance	-6.12	-0.53	0.63	-42.82	30.57	

Figure 13 Experiment two mean map score

Welch paired sample t-test was performed, t (-6.12) = -0.53, p = 0.63, d= 0,266, 95% CI [-42.82 30.57], showing a small effect size and no statistically significant difference in mean map scores between the two conditions(Figure 13).

It is shown:

1. The peripheral mask in itself did not have a significant impact on the participants' performance during the memory-recall typing task.
2. HMD VR has a positive attentional impact on users other than peripheral blocking.

4.2. Qualitative analysis

4.2.1. Experiment one

From the interview, all participants were more concentrated on the task when using HMD VR, subjectively. Some participants particularly mentioned they felt they were less distractible when using HMD VR because there were no objects for them to drift their central vision towards. However, half of the participants recalled they had glanced at the surroundings when thinking about what to write, and two of these participants reported that they had noticed that they were being momentarily distracted.

Only one participant turned their head to the researcher during the first distraction. Although the other participants knew from which direction the researcher was speaking, they did not turn their heads because they knew they would not be able to see the researcher even if they did turn around. The only person who turned their head towards the researcher did so in both sections and reported that he had turned his head towards the researcher as confirmation he had heard the message. Three participants mentioned that they felt they had entered a flow state faster and more easily when using HMD VR because there were no distractions.

Although it was commonly recognised that HMD VR helped the participants concentrate on the task, the participants had different reactions to the distractions. Two participants noted they were unable to concentrate, stopped typing for a few seconds, attempted to process the HI distractor and then resumed typing during the second distractions.

4.2.2. Experiment two

Two participants felt they were slightly more concentrated on the task. Two other participants felt there was no obvious anti-distraction. The only participant who looked at the researcher during the first distraction when using the laptop was the only one severely distracted by the name-calling event. He looked at the researcher and stopped typing. It also took ~4 seconds before he started typing again.

5. Discussion

5.1. Attention, distraction, and HMD VR

This study focused on the effectiveness of using HMD VR for attention retention in memory-recall writing tasks and for anti-distraction purposes. The results show that HMD VR has a positive impact on memory recall writing tasks; the participants were able to type more during the task while they had slower type speed in VR . Various factors might explain this result. However, the blocking of peripheral vision was the most likely factor. A further experiment using a peripheral blocking mask instead of HMD VR was conducted. The results showed that the impact of a peripheral blocking mask is minimum, which suggested that HMD VR affected participants in other ways as well.

Previous research has shown that attention on the task is known to be determinate for memory-recall-related tasks. While it is known that HMD VR can help improve performance during a memory-recall task, and it wasn't because of simple peripheral blocking, it could be suggested that HMD VR could help individuals retain attention on certain tasks. The range of applications needs further investigation, and different types of memory-recall tasks should be tested in the future.

This study suggested a hypothesis that when a user is using HMD VR, they are cognitively isolated from the outer environment, and the attentional resources used for monitoring the environment are now free to process the required task. This study has shown that simply blocking the peripheral vision does not positively influence performance. Because HMD VR offered less sensory input from the surrounding environment, the participants were able to both occupy fewer attentional resources on the sensory register and allow more attentional resources on the task itself.

This hypothesis could be further investigated through a longer-term experiment, during which participants spend more time in the surroundings in order to have the environment fully registered. Future studies could also conduct experiments in participants' already-familiar spaces. This study used a 'dark lab' and a VR workspace that were newly introduced to participants. Hence, it is possible that more attentional resources were used to register a more complex environment (dark lab) compared with a simpler environment (VR space) in a short period of time (20 minutes).
This study would like to add a theory from the current investigation. The cognitive cost to quit using HMD VR to observe distractors is significantly higher compared with using a laptop. This is because when an individual is distracted by any conspicuous distractor, the cost to look at the source of the distractor (e.g. a ringing phone or a speaking person) is very low (a glance). Glancing at various distractors may increase the chance of becoming severely distracted. However, the cost to quit using HMD VR is significantly higher (take off and put back on the HMD VR). It is possible that this 'cost to quit' effect can be used as a practical anti-distraction strategy in certain workflows. Individuals may wish to use this higher 'cost to quit' as a self-monitoring strategy. Such a strategy is commonly applied by students, who may study in a library instead of at home.

5.2. Real world application

Oculus Quest 2 is designed to fully block peripheral vision apart from a small section on top of the nose for comfort. This design feature enables the product's anti-distraction ability. However, numerous newer models of HMD VR glasses have open designs with far peripherals no longer being blocked (e.g. Oculus quest Pro and Lynx). This newer design could potentially lead to unwanted sensory input and cause conspicuous visual distraction.

The 'cost to quit' hypothesis, if further recognised, might guide the future design of HMD VR for conventional work users. While accessibility is critically important, specific functions could be introduced to maintain a high 'cost to quit' while also keeping accessibility high.

5.3. Limitation of the study

The limitation of the study is its small sample group. Participants' personalities and working habits were not investigated beforehand. The first hypothesis needs to investigate other factors of HMD VR. The 'cost to quit' hypothesis needs further investigation and brain activity monitoring for further study.

The result of this study was considered based on weighted performance. The weight was added because previous studies have shown participants should be able to type on VR as fast as on PC. For the soundness of evaluation of writing performance, weight was calculated by the mean of tested typing speed. However, it is possible participants’ ability to type on VR was keep elevating during the experiment. Future experiment should consider how to avoid this potential problem.

6. Conclusion

The results of this study indicate that HMD VR can positively impact the performance of memory-recall typing tasks. While the study participants were unfamiliar with VR and, therefore, had slower maximum typing speeds, most participants were able to type faster using HMD VR than on a laptop. Welch paired sample t-test was performed, $t(63.61) = 2.69$, $p = 0.04$, $d= 1.10$, 95% CI [2.82 124.39], showing a large effect size and significant statistically difference in mean map scores between the HMD VR and PC. The second experiment indicated that peripheral vision blocking had no significant positive impact on the performance of the task and was not the determinative factor of the effectiveness of HMD VR. HMD VR had a moderate positive impact on the rehabilitation from both HI and LI distractors. Experiment using larger varieties of distractors will be necessary.

The study results suggest that in memory-recall writing tasks, HMD VR has a positive impact on attention retention. It is suggested less attentional resources are occupied for sensory register and environment monitoring, and more attentional resources can be used for working memory and memory-recall.

This paper also proposes the 'cost to quit' hypothesis, which requires further investigation. It is suggested higher 'cost to quit' might function as an anti-distraction strategy for individuals who desire. Future design of HMD VR for specific use might need to consider keeping a certain level of 'cost to quit' when increasing accessibility.

7. Acknowledgements

I would like to thank my supervisor, Dr.Mick Grierson for his full support in my work. Special thanks to Miss Siyu Wang from UCL psychology department for her contribution to the data analysis of this study. I would also like to show my gratitude to all the participants of this study.

Analysed data and R script can be found at:

https://github.com/SimonS98/HMDVR_Attention_Research

8. Bibliography

1. *Cosman, J.D., Lowe, K.A., Zinke, W., Woodman, G.F. and Schall, J.D., 2018. Prefrontal control of visual distraction. Current biology, 28(3), pp.414-420.*
2. *Jahncke, H., Björkeholm, P., Marsh, J.E., Odelius, J. and Sörqvist, P., 2016. Office noise: Can headphones and masking sound attenuate distraction by background speech?. Work, 55(3), pp.505-513.*
3. *Al-Halabi, M.N., Bshara, N. and AlNerabieah, Z., 2018. Effectiveness of audio visual distraction using virtual reality eyeglasses versus tablet device in child behavioral management during inferior alveolar nerve block. Anaesthesia, Pain & Intensive Care, pp.55-61.*
4. *Kacker, S., Saboo, N., Sharma, M. and Nirvan, S., 2019. Effects of various distractions on audio and visual reaction time in 1st year MBBS students. National Journal of Physiology, Pharmacy and Pharmacology , 9 (1), pp.62-62.*
5. *Makda, M.M., Gotmare, N. and Deshpande, M., 2017. Influence of distractions on audio and visual reaction time in young healthy individual of 19-26 Years. International Journal of Clinical and Biomedical Research , pp.5-9.*
6. *Lan, Y.J., Lyu, B.N. and Chin, C.K., 2019. Does a 3D immersive experience enhance Mandarin writing by CSL students?. Language Learning & Technology, 23(2), pp.125-144.*
7. *Cosman, J.D., Lowe, K.A., Zinke, W., Woodman, G.F. and Schall, J.D., 2018. Prefrontal control of visual distraction. Current biology , 28 (3), pp.414-420.*
8. *Marsh, J.E., Campbell, T.A., Vachon, F., Taylor, P.J. and Hughes, R.W., 2020. How the deployment of visual attention modulates auditory distraction. Attention, Perception, & Psychophysics , 82 (1), pp.350-362.*
9. *Haynes, B.P., 2007. The impact of the behavioural environment on office productivity. Journal of facilities management .*
10. *Mak, C.M. and Lui, Y.P., 2012. The effect of sound on office productivity. Building Services Engineering Research and Technology , 33 (3), pp.339-345.*
11. *Korte, E.D., Kuijt-Evers, L. and Vink, P., 2007, July. Effects of the office environment on health and productivity 1: auditory and visual distraction. In International conference on ergonomics and health aspects of work with computers (pp. 26-33). Springer, Berlin, Heidelberg.*
12. *Oseland, N. and Hodsman, P., 2018. A psychoacoustical approach to resolving office noise distraction. Journal of Corporate Real Estate .*

13. *Liebl, A., Haller, J., Jödicke, B., Baumgartner, H., Schlittmeier, S. and Hellbrück, J., 2012. Combined effects of acoustic and visual distraction on cognitive performance and well-being. Applied ergonomics , 43 (2), pp.424-434.*
14. *Reynolds, L., Birnholtz, J., Luxenberg, E., Gutwin, C. and Mustafa, M., 2010. Comparing awareness and distraction between desktop and peripheral-vision displays. In CHI'10 Extended Abstracts on Human Factors in Computing Systems (pp. 3571-3576).*
15. *Bashiri, A., Ghazisaeedi, M. and Shahmoradi, L., 2017. The opportunities of virtual reality in the rehabilitation of children with attention deficit hyperactivity disorder: a literature review. Korean journal of pediatrics , 60 (11), p.337.*
16. *Engle, R.W., Kane, M.J. and Tuholski, S.W., 1999. Individual differences in working memory capacity and what they tell us about controlled attention, general fluid intelligence, and functions of the prefrontal cortex. Models of working memory: Mechanisms of active maintenance and executive control , 4 , pp.102-134.*
17. *Margetis, G., Ntoa, S., Antona, M. and Stephanidis, C., 2021. Human-centered design of artificial intelligence. Handbook of human factors and ergonomics , pp.1085-1106.*
18. *Sharit, J., 2012. Human error and human reliability analysis. Handbook of human factors and ergonomics , pp.734-800.*
19. *Sañudo, B., Abdi, E., Bernardo-Filho, M. and Taiar, R., 2020. Aerobic exercise with superimposed virtual reality improves cognitive flexibility and selective attention in young males. Applied Sciences , 10 (22), p.8029.*
20. *Amprasi, E., Vernadakis, N., Zetou, E. and Antoniou, P., 2022. Effect of a Full Immersive Virtual Reality Intervention on Selective Attention in Children. International Journal of Instruction , 15 (1), pp.565-582.*
21. *Salo, E., Salmela, V., Salmi, J., Numminen, J. and Alho, K., 2017.*
22. *Neumann, M.F., Viska, C.G., van Huis, S. and Palermo, R., 2018. Similar distraction, but differential suppression, for faces and non-face objects: evidence from behaviour and event-related potentials. Biological Psychology , 139 , pp.39-46.*
23. *Dziezyc, J., Taylor, L., Boggess, M.M. and Scott, H.M., 2011. The effect of ocular blinkers on the horses' reactions to four different visual and audible stimuli: results of a crossover trial. Veterinary ophthalmology , 14 (5), pp.327-332.*
24. *Pope, B.R. (2019). Creative Writing: How to Get Started with Creative Writing [+ 9 Exercises] . [online] Self Publishing School. Available at: https://self-publishingschool.com/creative-writing/.*

25. *Baddeley, A., Lewis, V., Eldridge, M. and Thomson, N., 1984. Attention and retrieval from long-term memory. Journal of Experimental Psychology: General , 113 (4), p.518.*
26. *Perez-Mata, M.N., Read, J.D. and Diges, M., 2002. Effects of divided attention and word concreteness on correct recall and false memory reports. Memory , 10 (3), pp.161-177.*
27. *Grubert, J., Witzani, L., Ofek, E., Pahud, M., Kranz, M. and Kristensson, P.O., 2018, March. Effects of hand representations for typing in virtual reality. In 2018 IEEE Conference on Virtual Reality and 3D User Interfaces (VR) (pp. 151-158). IEEE.*
28. *Knierim, P., Schwind, V., Feit, A.M., Nieuwenhuizen, F. and Henze, N., 2018, April. Physical keyboards in virtual reality: Analysis of typing performance and effects of avatar hands. In Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems (pp. 1-9).*