Pacific Graphics (2021)
M. Okabe, S. Lee, B. Wuensche and S. Zollmann (Editors)

Poster

Peripheral vision in simulated driving: comparing CAVE and head-mounted display

T. Tanoi and N. A. Dodgson

Victoria University of Wellington, New Zealand

Abstract

Peripheral vision is widely thought to be important but is not provided in the majority of head-mounted displays (HMD). We investigate whether peripheral vision is important in a simulated driving task. Our hypothesis is that subjects will be able to complete the task more quickly if they use their peripheral vision. We compared subject performance in a CAVE environment, with 270° field-of-view (so automatic peripheral vision) and in a HMD, with 110° field-of-view (so no peripheral vision but the ability to turn the head). Our results show almost no statistically significant differences between the two conditions. This contrasts with the opinions of our subjects: our expert users, in early tests, commented that peripheral vision helped in the task and the majority of our naïve subjects believed that the lack of peripheral vision in the HMD hindered them in the task.

CCS Concepts

• ***Computing methodologies*** → *Virtual reality;* • ***Software and its engineering*** → *Virtual worlds software;*

We compare a virtual reality head-mounted display (HMD) against a Cave Automatic Virtual Environment (CAVE) in a driving task to ascertain both the importance of peripheral vision in the task and the subjects' perception of the differences between the HMD and the CAVE. HMDs have limited or no peripheral vision and this has been thought to limit their attractiveness and usefulness sufficiently that researchers are developing wide field-of-view HMDs (e.g., StarVR's 210° FoV) or retro-fitting peripheral vision to existing HMDs [XB16]. The question is whether that extra peripheral vision helps in actual tasks or is simply there to provide context. While we do not attend to objects in our periphery, we are certainly aware of them [RCVD97]. We wished to investigate whether peripheral vision made any significant difference in a practical, simulated task. Our hypothesis is that the wider peripheral vision in the CAVE environment will produce better performance than the HMD. Our experimental results show almost no significant difference in performance of the task between the two conditions, despite the majority of the subjects believing that the lack of peripheral vision in the HMD had hindered their performance.

Virtual reality HMDs have been in use for decades, becoming popular and widely accessible in the last five years. However, they have drawbacks: the user is isolated from the real world, is disconnected from seeing their own body, and lacks peripheral vision. This work compares an HMD against a multi-screen CAVE, which suffers from none of these three drawbacks. We designed an experimental condition that could test our hypothesis in a task that had real-world application. We use a driving simulator task where we modify the visual display (between CAVE and HMD) but aim to keep as much of the rest of the environment as similar as possible to avoid confounding factors. For example, the user has a tactile interface (seat, steering wheel, pedals) that means that it can be used without the need for the user to see it, that is identical in both scenarios and that is familiar to anyone who has driven a car.

We used a driving simulator system (Figure 1) to provide a common, static interface that gives the user tactile feedback and in which it is not necessary for the user to turn their body. The latter constraint is because our CAVE installation has no rear wall and therefore it is not possible to allow the user to turn their body without losing the illusion.

We put considerable thought into finding a task that would work within a driving simulator and that would use peripheral vision. The task was to drive around a computer-rendered city, searching for and collecting objects: we implemented a cityscape version of Pacman, with the driver having to find and pick up forty pac-dots, which are located on all streets within the city. Pac-dots are collected simply by the driver driving past them. The buildings are sufficiently tall that the driver cannot see what is down a side-street until they are at a junction. The intention is that the driver will need to be aware of what is down the side streets and that this will require them either to glance down side streets as they drive past or use their peripheral vision to identify that there is a pac-dot down a side street that remains to be collected. Our hypothesis is that the subject can make better time in the task when they have peripheral vision (so do not have to turn their head explicitly to spot uncollected pac-dots) than when they have to remember to turn their head whenever they reach a junction.

DOI: 10.2312/pg.20211392

Figure 1: *Equipment setup. Left: HMD. Centre: CAVE. Right: A city layout with the path taken by one of our subjects (the colour shading indicates time taken).*

We ran early tests on members of our computer graphics research group, all of whom were aware of the aim of the experiment. These early tests helped us to tune the maximum speed of the car, the length and width of the roads, the behaviour as the user left the grid, the visual presentation of the pac-dots, and the level of discomfort in both conditions. Early tests were nauseating in both conditions but especially in the HMD. We corrected for this (slower car speed, better steering, increase the frame rate to 90fps) so that, in the actual experimental trials, none of our experimental subjects had to abort the experiment owing to discomfort and only one reported strong discomfort after their trial.

In the early tests, the expert members of the research group noticed that the peripheral vision afforded by the CAVE gave them an apparent advantage in completing the task. As they drove through a crossroads at full speed, they found it easier to spot uncollected pac-dots in peripheral vision in the CAVE than to whip the head from side to side to look down both side streets in the HMD. We took this to indicate that peripheral vision allows implicit memorisation of the location of uncollected pac-dots, leading to quicker completion times over the HMD, where you had instead to explicitly look down the side streets as you passed. These early informal observations indicate that the experimental task is a suitable test of our hypothesis.

We recruited 17 naïve subjects (8 female, 9 male; age 18–40, average 22, std. dev. 5.5). Eight had no VR experience, 7 some, and 2 frequent use. Seven had no experience in a driving simulator before, with 10 having some. Fifteen had real-world driving experience. One had no gaming experience, 9 some, and 7 frequent. Each subject was asked to complete five components to the experiment: a pre-test survey about their past experiences with driving, virtual reality, and gaming; an initial trial using only a single screen to familiarize them with the scenario; two recorded trials in first either the HMD or CAVE, followed by the alternate option; and finally a post-test interview about their perception of their performance as well as their perceived differences and discomfort.

We ran a repeated measures three-way ANOVA on this data to see whether any of our distance or time measures (Figure 2) was significantly influenced by context, run and layout or any interaction of these. We removed outliers before running the ANOVA. For five of the six measures the ANOVA showed that *none* of these results is significant. Only for 'Distance to 36', is there a significant influence of context ($F(1,21) = 5.253$, $p < 0.05$) though not of run ($F(1,21) = 0.358$, $p = 0.556$) or layout ($F(1,21) = 0.875$, $p = 0.360$). A post-hoc t-test for this one condition shows a significant difference at the 95% confidence level and that the HMD context has a shorter mean distance than the CAVE context.

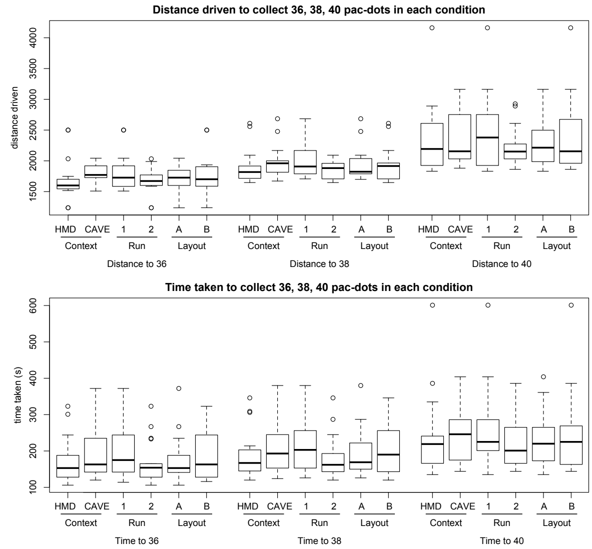

Figure 2: *Box plots of distance driven by subjects (top) and time taken by subjects (bottom). We recorded time and distance to collect 36, 38 and 40 (all) of the pac-dots.*

What can we conclude from this general lack of differences? There are several possibilities. (1) There is no significant effect *generally*. That is, peripheral vision does not significantly improve a human's ability to perform tasks. (2) There is no significant effect for this particular task. (3) There is an effect but this task's confounding factors overwhelm the effect. We have insufficient data to distinguish between these possibilities, though there is likely good enough other evidence to reject option (1) [SRJ11].

With regard to (3), we have subsequently developed two alternative tasks, using the same hardware, but we have again found it challenging to construct them to remove all confounding factors.

With regard to (2), it may be that peripheral vision makes little difference to this task. We constructed the task so that peripheral vision should have been useful. Indeed, our expert testers informally thought that peripheral vision was helping them and most of our naïve subjects thought that the lack of peripheral vision impaired their performance, once they were made aware of it. A new hypothesis, therefore, is that people can use their peripheral vision effectively in tasks if they are made aware that it is a useful thing to do (cf. training of the peripheral visual system [SRJ11]).

References

[RCVD97] ROBERTSON G., CZERWINSKI M., VAN DANTZICH M.: Immersion in desktop virtual reality. In *UIST* (1997), pp. 11–19. 1

[SRJ11] STRASBURGER H., RENTSCHLER I., JÜTTNER M.: Peripheral vision and pattern recognition: a review. *J. Vision 11*, 5 (2011), 13. 2

[XB16] XIAO R., BENKO H.: Augmenting the field-of-view of head-mounted displays with sparse peripheral displays. In *CHI* (2016), pp. 1221–1232. 1