A Non-Stationary Office Desk Substitution for Desk-Based and HMD-Projected Virtual Reality

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Abstract

The ongoing migration of HMDs to the consumer market also allows the integration of immersive environments into analysis workflows that are often bound to an (office) desk. However, a critical factor when considering VR solutions for professional applications is the prevention of cybersickness. In the given scenario the user is usually seated and the surrounding real world environment is very dominant, where the most dominant part is maybe the desk itself. Including this desk in the virtual environment could serve as a resting frame and thus reduce cybersickness next to a lot of further possibilities. In this work, we evaluate the feasibility of a substitution like this in the context of a visual data analysis task involving travel, and measure the impact on cybersickness as well as the general task performance and presence. In the conducted user study ($n = 52$), surprisingly, and partially in contradiction to existing work, we found no significant differences for those core measures between the control condition without a virtual table and the condition containing a virtual table. However, the results also support the inclusion of a virtual table in desk-based use cases.

Index Terms: Human-centered concepts [Human computer interaction (HCI)]: Interaction paradigms—Virtual reality; Human-centered concepts [Human computer interaction (HCI)]: Visualization—Empirical studies in visualization

1 Introduction

The analysis of abstract data has shown to benefit from an interactive and visual representation in an immersive virtual environment (IVE) [1, 16, 27]. The latter might be projected by a large immersive projection systems like a CAVE, or by a desktop-based system with a stereo display, usually including head-tracking and referred to as fish tank or desktop VR. Fish tank VR has the potential of being seamlessly integrated into the workplace of a data analyst, which often is an (office) desk. Compared to fully immersive systems (such as a CAVE), fish tank VR offers a lower degree of immersion [3, 16, 17]. However, the increasing relevance of HMDs in the consumer market that entails an increase of technical quality and robustness as well as price decrease makes a seamless integration of HMDs as fully immersive systems into desktop workplaces feasible [23, 26, 29, 32]. Such a scenario raises various requirements for the implementation of professional immersive data analysis applications, the most important one may be the prevention of cybersickness. Together with the fact that the user is usually sitting [32] this throws implications on the travel technique used to navigate the data set's three-dimensional visualization.

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When utilizing an IVE for interactive data analysis, the user may choose between two perspectives on the data, both maybe available in the same application: The user might look at the data from the outside or from the inside. Nevertheless, both have their application but raise different requirements for a suitable travel metaphor. In the first case, the reference frame is the user and their environment, thus the travel metaphor changes the position and orientation of the data. In this case, a suitable metaphor [14] might be to place the user in front of a virtual table while manipulating the data, as done in the work by Sousa et al. [23] in their application VRRRRoom or the work by Wagner Filho et al. [26]. However, for the scenario presented in this paper, we prefer to locate the user inside the data. This raises the need for a non-ground based travel technique (*flying*). While those techniques exist [30], the metaphor is usually not closed, i.e., it might feel strange to *fly* in the void while physically being seated. To address this mismatch, one may try to create the illusion that the user is a bird, or locating her on a flying carpet [24] or in a spaceship. None of these metaphors seem to be convincing if used for immersive analysis of abstract data. Nevertheless, if taking the physical environment into consideration, its dominant element is the physical desk the analyst is sitting in front of. This observation raises the question why not substitute [25] the real desk by a virtual one [19], which may compensate for the lack of a reference in the virtual environment and thus might even have a reducing effect on cybersickness and still keeps a certain semantic relation to the overall data analysis task. Furthermore, passive haptics such as provided by the desk have shown to increase presence [9, 10], which in turn has been shown to increase the task performance [13, 28]. In addition, such a substitution enables further interaction metaphors and concepts, such as augmenting the physical keyboard into the virtual environment [8] and using it for text input or system control, displaying and organizing additional meta data as virtual sheets, positioning menus on the desk [31] and thus making them tangible [26], to mention only a few [29, 32].

However, in this work we want to initially evaluate the feasibility and impact of the described (office) desk substitution in a realistic scenario for immersive data analytics addressing abstract data. The major research question is in how far the desk substitution reduces cybersickness and if this simultaneously comes with a negative influences on the task performance or not. Thus, the virtual desk in this work is just shown and is tangible without giving it an explicit purpose, as a first step. This is the case by design as an additional utilization of the table, in whatever form, adds bias, as there is no such interface that can be regarded as general or standard, and we want to investigate the pure effects of the table to be able to judge the possible effects of more advanced scenarios. One reason for this is that already the pure visual existence of the table can add different and partially contrary effects. For example, a simple desk representation reduces the field of view (FoV), which on the one hand could reduce the task performance, depending on the given task, and could reduce cybersickness, i.e., due to less optical flow [6] or by serving as a resting frame [5]. On the other hand, a

Figure 1: The experimental setup for the user study.

visible and tangible virtual desk may give an anchor to reality, avoids hitting it by accident and increases presence [9, 10], which again may have implications for cybersickness and task performance. This makes it difficult to forecast the accumulated effects this substitution has. Furthermore, there is work done in the field of substitutional reality [18, 19, 25], but to the best of our knowledge the recent work of Cao et al. [5] is the only other one that involves virtual travel and/or a seated scenario and they found that an artificially included resting frame can have positive effects on the users' comfort. In this work, we want to extend the current findings in this field and conducted a user study to measure these accumulated effects, given an office desk substitution, on cybersickness, presence and the task performance in an HMD-based analysis task by comparing two groups performing the task with the desk visible and not visible respectively.

The rest of the paper is structured as follows. In Section 2 the conducted user study is described in detail. The results are listed in Section 3 and discussed, together with the limitations of the study, in Section 4. Furthermore, we mention some observations we made during the study in Section 5 and finally conclude the work in Section 6.

2 User Study

The environment and task of the user study were inspired by previous work [30], which evaluated different travel techniques in a similar desk-based scenario. Thus, the participants had to travel through the same large 3D graph (5214 vertices and 6913 edges) to find pairs of highlighted vertices and determine the shortest path between them (see section 2.2). We chose a between-subjects design with two groups where all participants sat in front of an office desk. Participants in the study group could see a substitution of this desk in the IVE, whereas participants in the control group did not have the virtual substitution (see Section 2.1). A *leaning* metaphor served as travel technique (see Section 2.3). The core measures were cybersickness, presence and task performance.

2.1 Apparatus

All participants sat on a rotatable and tiltable office chair at a regular office desk (see Figure 1). The study group's virtual table (see Figure 2) matched the real one in length and position, but not in color and model. Furthermore, the width of the virtual table was slightly reduced to alleviate its occlusion of the scene without making the change noticeable to the user. An Oculus Rift Consumer Version 1 served as projection and tracking system. All participants wore a chest strap and two electrodes on two fingers to collect biophysical measurements. This data is gathered as part of a long-term experiment and thus is not evaluated here.

2.2 Tasks

We chose a large graph displayed using a node-link visualization (see Figure 2) to make travel a mandatory prerequisite to solving the study task (see Section 2.3). The experimental part of the study consisted of a series of training and study tasks that basically were structured identically. The participant was asked in a dialog to find the shortest path between a pair of red vertices hidden somewhere in the graph and only slightly larger then the regular black vertices. First, the participant had to find this pair, followed by finding the shortest path between these two vertices. In some cases, the target path was additionally restricted by certain requirements, such as *only containing green edges* or *containing at least two edge colors*. For this purpose, all edges of the graph were randomly colored once for all participants using three colors: green, violet, and orange (to be colorblind safe). All participants received the same tasks in the same order. The tasks were preselected and had a loose tendency to get more difficult. After solving the task, the participant ended the task and gave the answer on a scale from 1 to 10 using a selection technique described in the next Section 2.3. Afterwards, the participant was asked to report their current well-being in an additional dialog from 1 (good) to 10 (bad). This was followed by a third dialog prompting the next task.

2.3 Controls

For travel, we chose a *leaning* metaphor [15]. The decision for this technique and against a standard device like the gamepad was made as the *leaning* metaphor is easy to implement, easy to learn, needs no additional hardware and has been shown to perform better in a task like this in general and regarding cybersickness [30]. The *leaning* was configured to allow forward and backward movement as well as *strafing* to the left and to the right respectively, each related to the corresponding body direction. The resting position of every participant was once calibrated in the beginning. The implementation was very basic, i.e., the used deadzone had the form of a sphere ($r = 0.15m$) and the maximum speed was achieved after leaving a sphere with radius $r = 0.3m$. Outside of the deadzone, speed interpolated linearly between 0 m/s and 10 m/s. The reference frame for all translations is the direction of sight or rather the orientation of the HMD. In addition to looking around, the participants were also able to rotate around the yaw axis. This was triggered by looking to the left/right by more then $50°$ with respect to the tracking camera's reference frame. The participant's virtual translation and rotation was always also applied to the virtual desk in the study condition. However, looking around less then $50°$ did not affect the desk's pose.

Beside navigation, the participants had to perform certain system inputs, e.g., to answer survey and task questions in the VE (see Section 2.2), to confirm dialogs and to notify that they finished the task. The latter happened by looking for $2s$ at a white sphere, which initially was placed just out of the user's FoV to their left. While being focused by the user, the sphere turned blue and increased in size over time until the selection was confirmed. The sphere was placed in the same reference frame as the table. No actual eye tracking was involved but the pose of the HMD was used, together with raycasting. All dialogs contained lined up spheres that were triggered in the same way. In these dialogs only the x-Axis of the user's view-direction was considered for the raycasting, so that always one sphere is focused and thus highlighted, independent of the head's pitch. This showed to be very beneficial when selecting one of the options in the absence of a virtual pointer. In an actual interface we would have put the dialogs and triggers on the virtual table to be controlled by touch, but as there was no desk in the control group this was not reasonable for the study.

2.4 Procedure

The study procedure was structured as follows. First, every participant signed an informed consent outlining collection and usage of

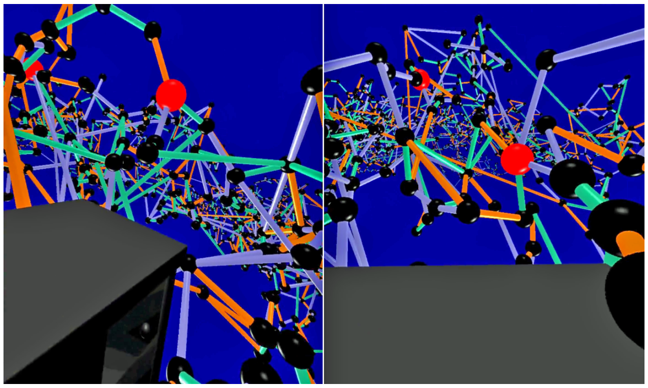

Figure 2: Two screenshots taken in the study condition. Both are showing the dark gray virtual table, a part of the surrounding graph and the slightly larger and red colored pair of spheres, which the participant has to find the shortest path between.

study data. Second, the participants received a small questionnaire that asked for their gender and experience with 3D video games and virtual reality. This information was non-anonymous, as it was used to evenly balance subjects regarding these parameters, because correlation properties between those groups and the core measures we want to investigate have been observed before [2, 7, 12]. The resulting distribution was at most off by one between the groups for both parameters. Afterwards, every participant got a detailed written description of the study, its procedure, tasks, interaction techniques and how these techniques will behave. Then, the participant was asked to pseudonymously fill out a demographic questionnaire, followed by an a priori simulator sickness questionnaire (SSQ) [11]. During the whole procedure, participants were invited to ask questions. This first part of the study took about 15 minutes.

In the second part, each participant was equipped with two sensors to acquire physiological data (not further discussed here, see Section 2.1), seated in front of the desk and helped to put on the HMD correctly and comfortably. Afterwards, they had 3 minutes time to get familiar with the interface by means of some training tasks, verbally guided by the experimenter. The training was relatively short and restricted in time, such that the overall time in the IVE was identical and exactly 15 minutes for every participant to keep SSQ results comparable. Thus, after training, the participants had exactly 12 minutes to solve as many tasks as possible (see Section 2.2). After the time ran out (either still working on a task or not), participants were asked a last time about their well-being and then left the IVE by taking off the HMD.

In the final part of the study, the participants were asked to fill out some concluding questionnaires including Likert-scale items, an a posteriori SSQ and a Witmer and Singer presence questionnaire [28]. The complete procedure took approximately 45 minutes. During the whole study, all textual content (on paper or in the IVE), was presented in English and German side by side.

2.5 Participants

52 subjects (12 female and 40 male, ages $M = 27.6$ years, $SD = 6.3$ years) participated in the study. One (female) participant (in the virtual desk condition) canceled the study because of nausea. Another (female) participant had to be excluded from the study as the laboratory's security alarm siren was triggered during the experiment. Finally, one (male) participant was excluded because he obviously did not follow the tasks. The data of all three were not considered for the analysis. Between all participants, 3×20€ Amazon coupons were raffled. Additionally, they were compensated with free candy and soft drinks. All participants reported normal or corrected-to-normal vision. 5 participants reported not having prior experience with virtual reality devices, 35 participants reported to play or have played 3D video games on a regular basis.

Table 1: Cybersickness parameters, *vt* marks the virtual table condition and *n* the control group. The health questions relate to the state of well-being the participants reported during the study, from 1 (good) to 10 (bad).

	Cond.	Mean	Std. Dev.	p-value
SSQ score *(a post.)*	n	23.19	26.53	
	vt	35.22	31.58	.155
Δ SSQ score	n	11.82	22.84	
	vt	16.51	38.18	.606
last health question	n	2.68	2.27	
	vt	3.38	2.02	.264
Δ health question	n	1.20	1.73	
	vt	1.92	2.22	.213
max. health question	n	3.16	2.41	
	vt	3.67	2.22	.448
avg. state of health	n	2.33	1.91	
	vt	2.62	1.59	.568

2.6 Hypotheses

As mentioned before, the effects of the virtual table on the chosen core parameters cybersickness, presence and task performance is hard to predict, especially because of expectable accumulating effects. Nevertheless, based on the preliminary considerations and related work [5], we have the following hypotheses, which consider just direct effects. Due to the realistic anchor to reality (resting frame), its passive haptics and our previous observations that it *just feels good*, we expect that...

H1 ...the group with the virtual desk suffers less cybersickness compared to the control group.

H2 ...the group with the virtual desk experiences more presence compared to the control group.

Because of the FoV being smaller, we expect that...

H3 ...the group with the virtual desk shows lower task performance compared to the control group.

3 Results

We analyzed the results with independent-samples t-tests at the .05 significance level, using Welch-Satterthwaite adjustments to the degrees of freedom instead where Levene's test indicated that the assumption of homogeneity of variances was violated.

3.1 Cybersickness

First, the SSQ questionnaire [11] was evaluated. The results are given in Table 1. The t-test revealed neither a statistically significant difference between the two groups in the SSQ score ($T(47) = -1.446, p = .155$), nor in the spread between *a priori* and *a posteriori* SSQ score ($T(37.298) = -.520, p = .606$).

Second, the state of well-being, which the participants were asked to track after solving each task (see section 2.2), ranging from 1 (good) to 10 (bad) was evaluated. Therefore, we picked the last value reported, the spread between the first and last, the maximum value selected by the participants, as well as the average state of health, which considered the time between the state updates. The results are also given in Table 1. The statistical analysis revealed no significant difference for any of the three measures, last value ($T(47) = -1.132, p = .264$), the delta ($T(47) = -1.261, p = .213$), the maximum health score ($T(47) = -.765, p = .448$) and the average score ($T(47) = -.575, p = .568$). Thus, **H1** cannot be confirmed. We found a strong significant correlation between the SSQ score and the last health question answered ($r = .666, p < \mathbf{.001}$).

Table 2: Results of the Presence Questionnaire [28], *vt* marks the virtual table condition and *n* the control group.

	Cond.	Mean	Std. Dev.	p-value
Presence	n	103.04	10.20	
	vt	102.04	14.68	.783
Realism	n	35.34	5.60	
	vt	35.52	7.01	.921
Possibility to act	n	23.00	2.55	
	vt	23.50	2.65	.504
Quality of interface	n	15.92	2.55	
	vt	15.58	2.86	.665
Possibility to examine	n	17.30	2.42	
	vt	16.52	3.40	.359
Self-evaluation of performance	n	11.48	1.85	
	vt	10.92	2.32	.354

Table 3: Performance Parameters, *vt* marks the virtual table condition and *n* the control group.

	Cond.	Mean	Std. Dev.	p-value
# Correct Tasks	n	6.96	2.13	
	vt	6.21	1.47	.159
Error in %	n	.18	.11	
	vt	.20	.12	.500
Total Distance Traveled in m	n	838.15	312.22	
	vt	813.22	230.47	.753
Total Head Rotation in °	n	12,113.67	3,159.60	
	vt	11,474.15	3,888.51	.530
Total Virtual Rotation in °	n	4,308.89	1,297.43	
	vt	4,319.35	2,150.17	.984

Similar results on correlations are found for all other pairs of simulator sickness measures. Finally, we found a strong significant and negative correlation between the last state of health given by the participant and the number of correctly answered tasks ($r = -.419, p = \mathbf{.003}$).

3.2 Presence

Regarding the final core parameter *presence*, we evaluated a Witmer and Singer presence questionnaire [28]. The optional items addressing acoustics and haptics were not included because the IVE did not provide any acoustics and the virtual desk did not allow direct manipulation, which the items in the questionnaire aim at. The presence score and its sub-scale scores are given in Table 2. The t-test revealed no significant differences between the two conditions in the presence score ($T(47) = .277, p = .783$) or in any sub-scale. Thus, **H2** cannot be confirmed. We found a significant and strong negative correlation between the presence score and the SSQ score ($r = -.436, p = \mathbf{.002}$), and a significant correlation between presence and the number of correct tasks ($r = .321, p = \mathbf{.025}$).

3.3 Task Performance

Regarding *task performance*, the number of correctly solved tasks and the number of not correctly solved tasks (errors) in relation to the total number of given answers were evaluated, because the number of finished tasks differs between the participants (see Section 2.4). All participants were told to prioritize precision (correctness) over speed. The results are given in Table 3. The t-test revealed neither statistically significant differences in the number of solved tasks ($T(47) = 1.430, p = .159$), nor in the error rate ($T(47) = -.680, p = .500$) for the two conditions. Furthermore, no significant difference was found in the secondary performance measures (see Table 3), such as traveled distance ($T(47) = .317, p = .753$), total physical head rotation (looking around) ($T(47) = .633, p = .530$) or virtual rotation ($T(47) = -.021, p = .984$). Thus, **H3** cannot be confirmed. We did not evaluate any of the measurements with regard to gender as the number of female participants was too small.

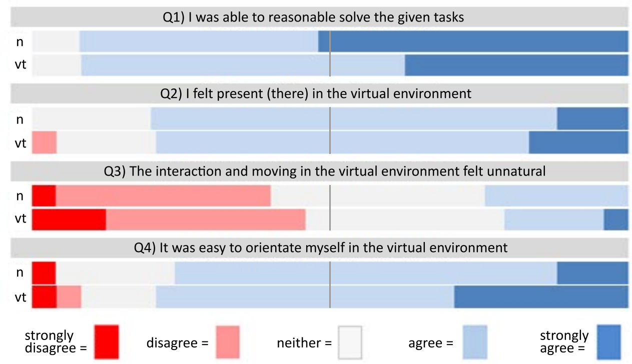

Figure 3: Answers to the subjective questionnaire, *vt* marks the virtual table condition and *n* the control group.

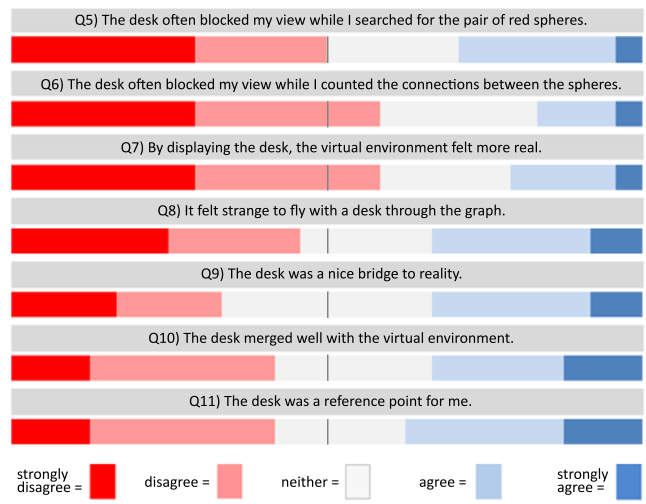

Figure 4: Answers to the subjective questionnaire regarding the virtual desk. The questions were only answered by the subjects that saw the virtual table.

3.4 Subjective Measures

Figure 3 presents the results for all items asking for subjective measures on a 5-point Likert scale. The t-test revealed no statistically significant difference for any of the four questions, Q1 ($T(47) = .814, p = .420$), Q2 ($T(47) = .018, p = .986$), Q3 ($T(47) = .486, p = .629$) and Q4 ($T(47) = -.609, p = .546$). An additional correlation analysis revealed that all four questions significantly correlated with presence, Q1 ($r = .408, p = \mathbf{.004}$), Q2 ($r = .327$, **p = .022**), Q3 ($r = -.466, p = \mathbf{.001}$), and Q4 ($r = .612, p < \mathbf{.001}$). Furthermore, the post SSQ score negatively correlates with Q1 ($r = -.337, p = \mathbf{.018}$) and Q4 ($r = -.364, p = \mathbf{.010}$). Figure 4 shows the items and results of a 5-point Likert scale questionnaire that was only answered by the participants of the study group. The correlation analysis revealed no statistically significant correlation between any question and any core parameter (task performance, presence and cybersickness).

4 Discussion

Given the presented results, we surprisingly could not confirm any of our three hypotheses. Cybersickness and presence were addressed by **H1** and **H2**. Regarding the comparison of the two conditions, no differences for presence and cybersickness were found in this study.

In another experiment, Coa et al. [5] found that the pure existence of a resting frame without any physically embedding seems to have a positive impact on the user's comfort, even when this effect also did not show in their SSQ scores. Thus, even though the tasks of our study did not assign a specific function to the virtual table, we were surprised not to be able to confirm these preliminary results and by the low overall relevance the virtual table had on presence and cybersickness. At least two people in the control condition hit the real desk by accident, which is less likely to happen in the virtual table condition. Given the results of similar studies, such as [30], we usually consider about 15 minutes of exposure to the virtual environment when using an HMD, which is mainly motivated by arising cybersickness. In this study though, there was only one participant who had to abort because of nausea and we think that this number would not have been much larger with a longer time of exposure (about 20-30 minutes), possibly due to the increased quality of consumer HMDs. Thus, we plan to extend the time of exposure for future studies.

One reason that made us expect less sick participants in the virtual table condition was that the table serves as a point of reference, which was confirmed by some of the comments. However, there was no difference in Q4, which directly addressed this, and no tendency in Q11 either. A possible explanation might be that all participants had and could re-orientate to the control dialogs, which always appeared behind the physical table.

A first reason for also not finding any effect on presence goes back to our observation that the participants did not interact much with the table independent of the condition. Given this the place illusion as described by Slater [22] would have foreseen no effect on the perceived presence of the user. However, we were surprised by the overall high scores (see Table 2 and Figure 3, Q2), as it might be unclear what it means to feel present in a 3D visualization of a graph. Various items of the standard questionnaire are hard to transfer to immersive data analysis scenarios, which was confirmed by participants as king how they should answer them. In this case one possible explanation for the observed results might be the *benefit of the doubt* that is given to questionnaires by participants, as discussed by Slater [21] and Skarbez et al. [20]. Additionally, we observed in various experiments that the *ceiling effect* has often a large impact on presence questionnaires, which is generated in the participants being enthusiastic about the VR experience, which leads them to give high ratings in general, which then might be not longer statistically differentiable. Nevertheless, we do not see any better option to measure presence in this case. We thought about the option to *restart* the tasks after some time and tell the participants so, which maybe measures how good their mental model of the graph is and if they were able to build up a cognitive map. But this requires the study to be longer and does not directly measure presence, but only a possible positive side effect [4].

In **H3**, we hypothesized that the task performance in the virtual desk condition will be lower than in the control group, but none of the recorded parameters showed any significant difference. In the following we want to discuss possible reasons. The only direct but big influence of the virtual desk on the performance that we expected was the limiting FoV (see Figure 2). The tasks basically were two-fold. In the first part, participants had to travel through the whole graph to find a pair of vertices. The extension of the graph is three-dimensional but mostly extended along the horizontal plane. Thus, the FoV limitation is partially avoidable when the user flies and searches from *below* the graph. However, despite the fact that some participants did so, most flew through or even over the graph, which decreased their FoV significantly. That this expected effect was less relevant is additionally confirmed by the participants' subjective assessment (see Figure 4, Q5), which revealed that the desk was on average only slightly blocking. Also, a closer look on the task performance and our observations during task executions reveals similar results. After finding the two target vertices in the graph, the participants had to determine the shortest path between these vertices. For the easiest cases, any close and static position to the vertices allowed for an easy counting, whereas in the cases of higher difficulty, participants had to inspect the path from various perspectives or even travel alongside it. We observed that almost all participants followed the instruction to rate precision over speed. However, the task difficulty was so high (see Table 3) that the error rate still was .20 and .18, respectively. Thus, the tasks were not too easy and the paths included all three axes, which is therefore not the reason for no significant differences in the performance. In summary, we expected and sometimes observed that the virtual table blocks the user's view in this part of the task, especially when the participants altered their position between the point of interest and overview. However, the participants' impression regarding this effect (see Figure 4, Q6) was not significantly different to the searching part of the task. Anyways, there was no correlation between the subjective scale addressing the virtual table and the core parameters. When the participants in the virtual table condition had become less sick and/or felt more present, this would have been another good explanation for the task performance not being worse, and is one of the possible side effects named in the beginning. These relationships were confirmed by the correlations we found, but as mentioned before no direct effect on cybersickness or presence were found. Finally, we think that the task and environmental design was representative. In summary, we do not have a good explanation for this outcome other than that the limited FoV was compensated by something else, which we were not able to measure. However, these results are promising as there seems to be no negative influence of a virtual/substitutional table. Contrariwise, the use of a virtual and substitutional table offers seamless integration of extensions such as menus [26] or a keyboard [8] placed on the physical table and thereby an increase of its utility in real analysis tasks. In our opinion, this will have a benefit even if the desk alone had no positive, nor negative influence on presence and cybersickness.

The original idea of the office desk substitution was to create a metaphor for seated flying, which supports immersive data analytics tasks. However, the participants did not report any difference regarding the perceived naturalness of the metaphor (see Table 3 and Figure 3, Q3). Additionally, the answers to the questions Q7, Q8 and Q10 (see Table 4) vary a lot regarding the virtual table and how well it is embedded into the IVE. As a side note, almost all personal and written feedback about the leaning metaphor was positive. Only one participant positively commented on the table. This was not surprising as the participants believed to participate in a study investigating navigation techniques as they were told so.

In summary, we had expected the substitution of the table to have more positive and/or negative impact. The overall conclusion can be that it is possible to integrate a table substitution like the presented one without significantly reducing performance or generating any other significant negative effect, such as cybersickness, but to enable the usage of the table for tactile menus, the inclusion of tangibles located on the physical desk or even to augment a physical keyboard into the IVE for text input.

5 Secondary Observations

During the study, we made several observations that are worth to be reported here. None of the following observations were statistically analyzed. A first observation is that some participants always flew backwards though the graph when searching for the spheres. We think that it was just more comfortable for them to lean back in their chair than leaning forward. Thus, it might be worth considering in actual applications to make the forward direction invertable.

A second observation was that participants did not want to lose their target out of sight once found. This led to the behavior that they rarely first oriented their virtual body to the target and then directly went forward, as this would have required turning the head away, but leaned in the direction of the target, which had to be less comfortable than only leaning forward/backward. We already noticed that the rotation part of the method was not the best solution. One reason is that the rotation interferes with looking around. Thus, we plan to develop better solutions in future work.

6 Conclusion

In this work we investigated the effects of an office desk being substituted by a virtual surrogate in a seated visual data analysis task involving travel. In the conducted user study ($n = 52$), we found no significant difference between study (showing the virtual desk) and control condition (showing no virtual desk) in the measured parameters cybersickness, task performance and presence. While this indicates no direct advantage of a substitution it also suggests that such a substitution may have no negative effects, either. The latter opens up the path for a seamless integration of extensions like menus or a keyboard on the desk, which may enrich a productive analysis scenario.

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