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The virtual railway station. Wayfinding experiences in a virtual environment and their application to reality.

Abstract

In an increasingly privatized and commercial environment the character of railway stations has changed considerably. From being a functionally dedicated transport hub, stations nowadays are shopping centers, office blocks and hotels with transport services. This balancing act between shops clamoring for attention from passers-by and much needed clarity for transportation services information constitutes a major challenge for orientation. Wouldn't it be great to be able to model such complex situations before they were built, and test the quality of the orientation system?

A government-funded research program provided the opportunity to put this to the test. Two research institutes, the Austrian Federal Railways, and three SME partners including is-design were granted research funding to develop and test novel techniques for evaluating and optimizing guidance systems in a fully immersive virtual environment that modeled the new Vienna Central Station.

From an information design point of view, two questions were particularly relevant: 1) How applicable are results from a virtual environment to the real world? And 2) Is this type of virtual environment suitable for testing with elderly people and people who are partially sighted? The article describes evaluation methods, limits and strengths of the virtual environment and lessons for real world application of results.

1. Introduction

Modern transport hubs are much more than stations. Sometimes the transport services even appear to be an appendix to shopping, office blocks and hotels. This constitutes a major challenge for orientation within the transport system. A government-funded transport research program (ways2go, Austrian Federal Ministry for Transport) provided the opportunity for is-design (a small information design consultancy in Austria owned by the author) and five partners including the Austrian Federal Railways to evaluate how an immersive virtual environment could be used to test the quality of orientation in a building that does not yet exist.

As a test case the new Vienna Central Station was the perfect candidate. The hardware and basic software of the virtual environment had already been developed by one of the project partners, Fraunhofer Research Austria (Lancelle, Settgast & Fellner 2008). Building plans and renderings of the station were made digitally available by the Austrian Federal Railways. The orientation system

had already been planned according to corporate design guidelines and their digital files were also available and could be mapped onto the relevant surfaces.

Although the project was a technology research call, is-design made use of the opportunity not only to introduce some information design research questions into the project, but also to take charge of the work package responsible for user trials. While our colleagues from the research institutions gathered data for attention modeling and further development of the software, we were able to observe other aspects of orientation and navigation.[1]

1.1 The virtual environment

The Fraunhofer-developed virtual reality setup (Figure 1) is called DAVE, which stands for “Definitely Affordable Virtual Environment". "Affordable" means that by mostly using standard hardware components it is less costly than other commercial systems.

The system consists of a room-size frame structure (3.3 x 3.3 m / 10.10 x 10.10ft) with back projection material stretched around three sides. Images are projected onto the three sides and the floor to create a fully immersive experience (Figure 1). Three effects are mainly responsible for making DAVE so convincingly immersive. The first regards the use of our stereoscopic vision. 3D-perception is the result of slightly different visual information from each eye arriving in the brain, which is then converted by the mind into a three-dimensional picture. This is replicated in DAVE by using two projectors for each wall, showing alternating images for the left and right eye. The user wears lightweight LCD shutter glasses that are synchronized with the projectors so that the respective image appears.

The second important effect is motion parallax. The closer an object is in our field of vision, the more it seems to change when we move around, thus, objects that are in the distance appear more stationary. DAVE employs an optical tracking system that focuses on small reflective marker balls that are fixed to the shutter glasses (Figure 2). With triangulation their 3D positions are measured and translated into movement in the virtual environment. By moving the head sideways, it is possible to look left and right.

The third effect is the integration of natural body movements. Some key movements are tracked making it possible to simulate walking (by walking on the spot) and turn corners (by moving head and shoulders in the desired direction).

For the research project, the additional element of eye-tracking was introduced into the setup (Schrom-Feiertag, Schinko, Settgast & Seer 2014). Eye-tracking glasses replaced the normal shutter glasses, the laptop recording eye-tracking data was carried in a rucksack by the test participants.

[1] The activities of is-design were led by Veronika Egger. Lisa Ehrenstrasser co-developed the methods of evaluation and contributed significantly to the analysis of results. The user trials were conducted by Veronika Egger and Sandra Dietinger, a graduate student of the Vienna University of Technology.

Figure 1: Schematic of the virtual environment DAVE

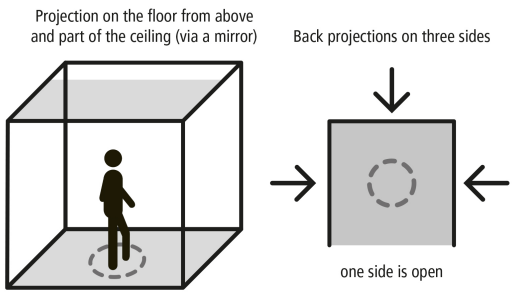


Figure 2: Participant being fitted with eye-tracking glasses, reflective marker balls for triangulation are fixed to the upper part of the frame.

1.2 The physical experience in the virtual environment

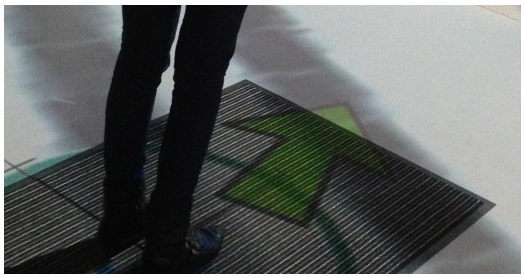
The first reaction is always: wow! However, coming to grips with movement is a little bit more difficult. It takes several minutes to get used to the way the virtual environment reacts to movements of the head, shoulders and knees.

To walk on the spot, it is necessary to stay within a defined area which is projected on the floor (Figure 3). Head movements allow you to look around, but in order to turn a corner, you need to turn your upper body to “bring around” the environment so you can walk around a corner while in reality facing in the same direction. The projection adjusts to your forward facing position. This movement has a slight delay that can cause nausea, for some people this happens within a few seconds. In this case we stopped the trial. Most people can walk around in the virtual environment for about ten minutes before they begin to feel nauseous.

Being fitted with the special glasses and a rucksack does not inhibit movement. The normal shutter-glasses are large enough to fit over the top of spectacles. However, using eye-tracking glasses made this more difficult. As a result, eye-tracking was not possible for those participants whose spectacles did not fit under the eye-tracking glasses.

Also, you are not alone in virtual space. The environment is populated by other "agents" that move around. It can be surprising and quite startling when the agents' movements intersect with the path of the participants.

Figure 3: Inside the projected circle is the area where tracking of movement is most accurate, the arrow indicates the direction you are facing.



2. User trials

2.1 Content and procedure

We were in the lucky position that at the time of testing part of the new central station were already in use. This provided us with an opportunity for direct comparison between virtual and real environments. Thus. two scenarios were created, and participants got familiar with the scenario they would be testing before coming to the trial.

- Scenario 1 was dedicated to identifying the differences between virtual and real space. Therefore, the tasks were confined to areas of the station already in use. A printed map was available for reference showing a partly operational station. Results from this scenario were considered extremely important for the interpretation of results from the second scenario. The virtual railway station had been adjusted to incorporate the restrictions of the building site experience.
- Scenario 2 was set in virtual space only to explore navigation and orientation covering the whole station. Participants were given a choice between using an app for indoor navigation on a smartphone or a printed map showing the fully operational station.

In the virtual environment. At the initial technical setup the participants' basic data was re-checked, and the eye-tracking glasses were calibrated. Participants were carefully led by the researcher into

the virtual room to make sure they didn't trip (once fitted with the glasses it was difficult to discern obstacles in the real environment).

Other than in real space we had to consider an introductory phase to the technology as well as the time limits before participants started to feel nauseous. As a result, both scenarios were set up in two parts with a brief orientation phase for participants to familiarize themselves with the system at the start and a short break in between. At least two researchers were situated outside the virtual room. One of them reminded participants about their tasks, helped with movement issues, and acted as "passengers" or "staff" if a participant decided during the trial to ask someone for direction. The other researcher observed the test, taking notes. The break was used for a brief interview on participants' first impressions, and another interview followed after the second round. Figures 4 to 8 illustrate participants at various stages during the test.

Figure 4: Participant familiarizing herself with the virtual environment. In the top right hand corner of the picture the upper limit of the projection is visible.

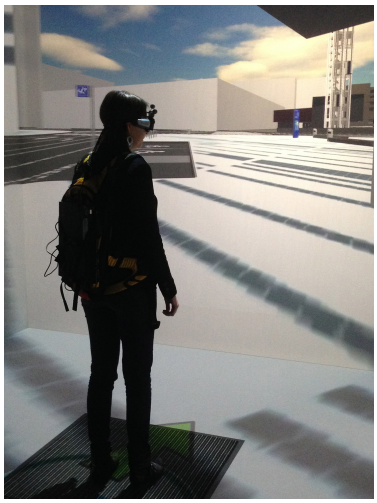


Figure 5: Asking for directions at the desk – the role of the agent was played by the researcher.

Figure 6: Over 80 years old, this woman had no trouble using the virtual environment. During trials we found that having something to hold on to helped with balance, remaining in place and moving more effectively.

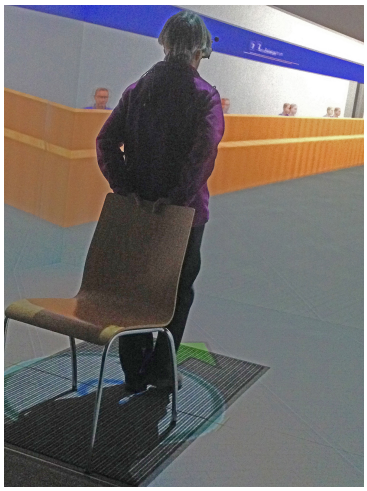
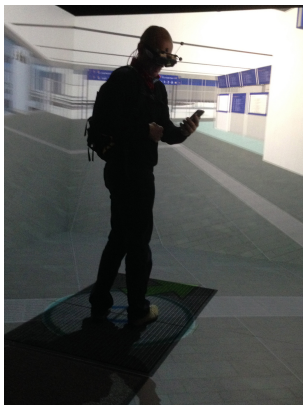


Figure 7: Checking whether a map is still readable after the eye-tracking glasses had been fitted.

Figure 8: Interacting with a smartphone



In the real world. Participants were met in an office not far from the station and fitted with eye-tracking glasses and a rucksack with the laptop. Then everyone (participant, the two researchers and a technician) travelled together two stops on a regional transport train to the central station. They alighted on the same platform in roughly the same place as the starting point of scenario 1 in

the virtual environment (Figure 9). Again, one researcher did all the talking, the other one took notes. An interview concluded the trial.

Figure 9: Real world orientation with eye-tracking glasses

Trials with partially sighted users. After discussing the project with representatives of organizations for the blind and partially sighted, it quickly became clear that the organizations were very interested to participate. If technologies such as DAVE would be used in the future to assess the quality of orientation systems, then the aspect of accessibility couldn't be ignored. They were also not aware of any user trials with partially sighted people in a virtual environment and there was some doubt whether a technology that relied on stereo vision would be usable at all. It was also unclear for the technical team whether eye tracking data could be obtained.

Partially sighted participants were not given a scenario. The researchers acted as guides and explored the same route through the station together with each participant. In the dialogue along the way it became apparent at what point certain elements were or were not noticeable and how visual clues from the environment were interpreted.

2.2 Participants

Sighted participants. Participants were chosen based on profiles for four different "Personas" (Cooper, 2004). Personas were given context-relevant attributes: familiarity with public transport and familiarity with technology. Because age and sensory/mobility restrictions were part of the profiles, it was important for the team to investigate whether DAVE was a suitable tool for working with the elderly (70+) as well as people who are partially sighted, age and sensory/mobility restrictions were part of the profiles. The recruiter was briefed to interview participants in advance to determine these factors and to prepare them for the experience. To this end the recruiter also had to test the system.

In the initial interview nearly all participants stated that they were experienced users of public transport. The main information source when preparing for a previously unknown journey were digital media, also among the elderly. During the travel, our participants would tend to rely on information around them and on other people--either at an information desk or other passengers.

Thirty sighted participants in the virtual environment delivered 26 valid data sets (four trials had to be stopped due to nausea). Five participated in the comparative trial at the central station. In total we had 35 sighted participants with varying educational levels and affinity with technology, 15 of them were over 70 years old, eight under 25, 16 women and 19 men.

Partially sighted participants. Seven partially sighted men participated in the virtual environment. Before the trial they were asked how their vision loss would affect their visual experience. Three of them were completely blind in one eye**,** four had a severely restricted field of vision**,** and all had some color vision. Two of them relied nearly exclusively on acoustic information, the others could read text if displayed appropriately. For all of them, contrast between major surfaces and objects is extremely important for a rough perception of structures and orientation.

3. Analysis

Evaluation was based on the following data sources:

- Video from the perspective of the person participating in the trial, in most cases including the eye-tracking positon
- Audio from „Thinking Aloud"-recordings
- Notes from interviews and observations

Sifting through the data, certain patterns began to emerge. Based on these patterns, in order to help clustering and quantifying individual events for analysis, six categories were defined. Each of these categories was further refined with specific attributes:

1. Targeted, successful search: using signs, asking someone, using an analogue map, a mobile app, tactile guidance lines, contrasts/colors (tags: 1 s,f,p,a,b,k)
2. Person is confused: the result may be disorientation, insecurity or frustration (tags: 2 u,f)
3. Understanding and interpretation: failure due to a particular symbol or the overall logic of the system (tags: 3 v,l)
4. Getting lost: if someone went far off the track or didn't find the intended goal (tag: 4)
5. Technical restrictions: leading to difficulties with readability, nausea, proximity judgement, functional problems, interaction problems, poor contrast, missing sensory clues (tags: 5 l,s,p,at,al,k,g)

A Trial stopped: due to nausea, technical failure or the researcher decided that completion was not possible for other reasons (tags: A s,t,v)

Significant events--whether they occurred on video, in audio or in the notes--could then be identified and tagged. Thus we were able to quantify the qualitative data and define 11 key situations (Figure 10):

1. Consulting an analogue map on the wall
2. Emerging from a tunnel
3. Reading sings parallel to walking direction
4. Reading overhead signs
5. Interpreting arrows
6. Abortion of the trial
7. Confusion between ticket counter and information point
8. Horizontal spread of information above a wide exit area
9. Using the mobile app
10. General navigation complexity
11. Faulty reaction of the technical system

Figure 10: Example of identified events tagged with attributes per participant

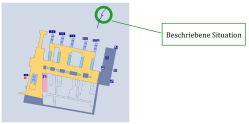
ID	***A***	***1***	***2***	***3***	***4***	***5***
P1		1s				
P2			2u	3l		
P3			2u	3v		
P4		1s	2f			5al
P5	As	1s				5s, 5at
P6					4	
P7	At		2u		4	5at
P8					4	
P12			2u	3l	4	5al
P13	As					5al, 5s
P14			2u	3l, 3v	4	
P15	As		2u	3v		5s, At
P16		1s	2f	3v		5at
P17			2u	3v	4	5p, 5s
P18				3v, 3l		5l
P22				3v, 3l		5l
P23		1s		3v, 3l	4	
P24	A			3v, 3l		5al

As a tool for a condensed view of key situations an adaptation of “multimodal analysis” (Norris, 2004) was chosen. This method takes a snapshot of a highly complex situation. The snapshot is representative for a particular point in the interaction process. The person documented in the snapshot is representative for all other persons in the test who had similar experiences at that point (Figure 11). We called the documentation for each snapshot a “frame”. The frame captures simultaneously occurring events: the image the user sees; what he/she says at that point; effects caused by the virtual environment; observation of gesture and body movements and emotions; description of gaze direction and movement of the eye-tracking recording if available; and how many and which ones of the other participants had similar experiences. For this project, the frame

also included a section with references to the results of comparative situations that were tested in real space.

Figure 11: Frame for key situation no. 3. The left page documents events in the virtual environment, in this case a technical limitation (it is not possible to glance upwards beyond a certain point). The right hand page shows the comparison in the real environment.

Frame 4: Überkopfwegweiser

Analysekategorie	**5 Technologische Einschränkungen**
	5I, Lesbarkeit, Betrachtungswinkel / 5p Proximity
Situation	Szenario 1, Aufgabe 2/2: Bahnsteig – Suche nach Linie D
Beschreibung des/der Teilnehmers/-in	ID 20, m, 75, keine Erfahrung mit virtuellen Räumen, ehem. Mathematikprofessor, orientiert sich gerne mit Plänen und Hinweisschildern, ist nicht oft mit Öffis unterwegs
Relevante Daten	
Bild	
	Video Stills: 20-Blickwinkel-DAVE.png, 10-Blickwinkel-DAVE.png Video: Participant 20-1-POR.avi, 9:27 – 9:42
	
	Trajectory_ID-20_Scenario_1-1.png
Ton	*„Information, dann 8, 0, jetzt sehe ich's nicht … so, jetzt seh' ich nichts mehr. Warum sehe ich nichts mehr?"*
Beschreibung der Aktivität	TP versucht das Schild zu entziffern, beginnt zu lesen. Will näher rangehen, schaut dann wieder hinauf. Mit dem neuen Blickwinkel ist ein Teil des Schilds verschwunden.
Verwendete Hilfsmittel	Hinweisschilder, Plan auf Stele
Beobachtungskriterien	
Physische Bewegungen	Hat Schwierigkeiten mit Fortbewegung (Zehenoperation)
Augenbewegungen	Schaut viel auf den Boden beim Gehen
Emotionen	Irritiert dass sich das System anders verhält als die Realität
Virtuelle Effekte	Lesbarkeit, besonders feien Striche (hat z.B. nur „8" statt „18" gelesen Korrekter Blickwinkel schwer herstellbar (TP ist sehr groß)

Hinweise für die Analyse	
Nutzungsrelevanz	Die stark eingeschränkte Sichtbarkeit und Lesbarkeit von Informationen am Rand des Gesichtsfelds in der normalen Gehsituation beeinträchtigt die Übertragbarkeit von Ergebnissen von Studien in der DAVE auf die reale Situation.
Quantifizierung	Beispielhaftes Ergebnis für alle Probanden in der DAVE.
Vergleich Realität	
Bild	
	Video Stills/25-Real-Erkennbarkeit-Winkel-1.png Video: Participant 25-TP-01-Wien.mp4
Relevanz	In diesem sehr steilen Winkel konnte die TP „D" bereits lesen – wäre in der DAVE nicht möglich.
Vergleichbare Situationen/ Zitate	
	Nahh! Jetzt bin ich zu weit! *Da ist ein Schild - Ah! Jetzt verschwindet's wieder* *„I siag goa nix auf dem Schild"* *„Ist das ein D oder ein O?* *„Das D ist klein, bin nicht sicher, das ist unscharf. Könnte auch ein O sein. Ich beschließe jetzt, das es ein D ist."*

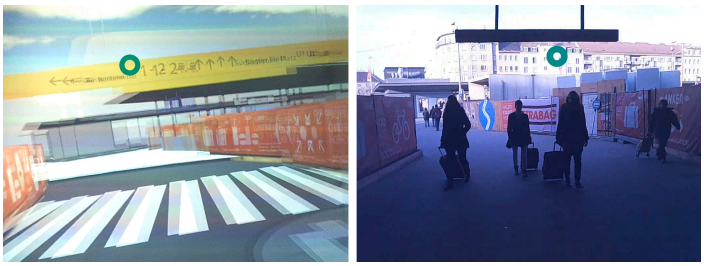
4. Findings

- Everyone who completed the trial in the virtual environment stated, that the second round in the scenario was easier, they were able to concentrate better on the task and less on body movement and system reaction.
- Participants did not act differently in the virtual environment in their overall orientation strategy, but they were slower and got more easily frustrated. Some examples are: Turning on the spot and looking for information--this is much harder to achieve because turning around physically 360 ° inside the virtual environment is not possible; Reading a sign while walking alongside it (parallel to the direction of walking)--the visual angle overhead is restricted, and a complicated maneuver is required to get into the correct position for reading; Walking up to a map or other information on the wall--it is very difficult to judge the point in time when to stop walking in order to stand at the correct distance for reading. The virtual environment may not react quickly enough and participants may find themselves standing "inside" the wall or having walked right through it.
- The results also showed that participants found it more difficult to recognize details and to interpret situations in the virtual environment. The former regards the clarity of the image as it is restricted to screen resolution--this is no match for sharp printed edges. The pixelated

images make pictograms more indistinct and thus making it more difficult to differentiate between similar symbols.

- Participants found that there are not enough sensory clues from other people, lifts, or elevators that help them to interpret a situation. For instance, seven out of 31 participants found the lift pictogram unclear, confusing it with WC or a security check. The symbols taken in isolation show some similarity, but in a real-world context the danger of misinterpretation-might be low. On the other hand, in the case of directional arrows, the results may highlight a potentially misleading or unclear situation. The arrow itself is unambiguous as a symbol. However, the results showed ambiguity on their meaning understanding, and this merits a closer look at the information design on such arrows. Eight out of 24 participants interpreted arrows pointing upwards at a 45 ° angle as an instruction to go up to another level. The intention, however, was to direct people to a route bearing left.
- Lighting and shadows appear more flat than in the real world, all surfaces show a similar kind of contrast and lightness. This difference is particularly noticeable in an outdoor setting. This was demonstrated by an overhead sign that was hardly readable in reality (as you can see in Figure 12) being positioned against a bright sky. The same sign was easily readable in the virtual environment because of the unrealistically uniform lighting.
- The virtual environment seems well suited for looking at overall orientation strategy, for understanding what terms people use to describe destinations, whether the positioning of indoor signs is correct, whether the signs contain the correct type of information. In all these aspects the results were comparable.
- Elderly participants are as able as young ones to use the virtual environment. Placing a chair as something to hold on to helped them with balance, remaining in place and moving more effectively. Young participants benefited from this improvement just as much. It is important to mention that eye-tracking data could not be obtained from several elderly participants because their spectacles did not fit underneath the eye-tracking glasses.

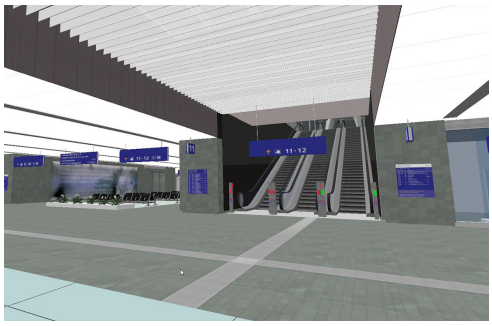
Figure 12: Glare from the sky obscures the sign in the real environment. In virtual space the sign is readable.



The experience of partially sighted users

- Partially sighted participants were able to use the virtual environment, varying in the degrees of confidence.
- None of them experienced nausea. This may be because partially sighted people react differently to the 3D-effect, but we have no data to support this correlation.
- Strong contrast in the environment is an important reference for understanding the layout of a space and for noticing obstacles. The tactile lines appear with good contrast in the virtual environment, therefore even those who did not normally rely on tactile lines used them to navigate (Figure 13). This is a case in point for tactile lines contrasting to their surroundings on principle because they lead to the most important functions in an environment and thus enforce the logic of the station.
- In general, moving in the virtual environment was difficult to both partially sighted and sighted participants. Nevertheless, some aspects had affected partially sighted participants more, for instance the hard-to-control proximity to an object. It was commented that the signs would be readable, if it was possible to get closer to the signs.
- The absence of other sensory clues than the visual ones is particularly difficult for partially sighted users--it is easier to locate, for instance, an elevator when it is audible, to identify the location of a cash desk by the familiar sounds, or cafés and restaurants by smell.
- Eye-tracking could be recorded from four of the seven partially sighted participants. However, it is unclear whether the position of the pupils also represents the point people focused their attention on. Clearly, this shows the limits of eye-tracking for this group of people.

Figure 13: This screen capture from the digital data shows the contrast of tactile guidance lines on the floor in the virtual environment.



5. Conclusion

Are the results from a virtual environment applicable to real life situations?

Yes and no. The comparative studies between real and virtual environments have demonstrated that virtual space can indeed reflect reality, but under certain circumstances. As it is the case in real life, participants have to make decisions along the way about the next step to take. These decisions result from the person's knowledge, experience and expectations from similar situations. However, being distracted by a limited range of movement in the virtual environment does not change someone's prior knowledge, experience and expectations. The participants seemed to employ the same basic problem solving techniques in both virtual and real environments if no negative physical effects (nausea) occurred. In the concluding interview, they stated that in a real environment they may have asked someone much sooner than they did in the trial, they "didn't want to give up too quickly". This competitive element can also be observed in the real-world trials.

Interpretations of results from the virtual environment have to consider that significant elements of subconscious orientation are missing: crowds of people, sounds, some contrasts, surface material, or temperature. As a result, people can only reference a reduced set of clues, causing an insecurity in interpretation that would not be present in the real world. This constitutes a loss of solution expertise. This seems to result in the virtual environment overstating isolated visual elements (such as symbol recognition) as well as requiring increased cognitive effort to interpret the situation.

Due to poorer readability and contrast, it is necessary to get closer to information displays and signs than in real life before being able to make a decision. This shifts the physical point of decision making to a different position, which may also influence the decision itself.

In the interpretation of data, separating irritations caused by mistakes in content from negative effects of the technology was easy. To minimize unwelcome effects and distractions from the technology, it would make sense to establish a "community of practice" (CoP). This is a group of people who are already quite familiar with the effects of the virtual environment and how to control movement to achieve a goal. In a test situation they would be better able to concentrate on content.

Can this type of virtual environment be used by someone with partial sight?

Yes. Not by everyone and not with every type of visual impairment. , Four out of seven partially sighted participants were able to use the virtual environment with reasonable confidence. They would be in a position to contribute towards the development of access features in this context. Partially sighted people should be included in a CoP.

Personal summary

From an information designer's point of view it was very important to investigate how effectively user behaviour and experience can be predicted based on a virtual reality experience. The results from this study help us understand the limits and opportunities of virtual reality in the context of orientation. They facilitate the interpretation of results from virtual reality wayfinding studies and inform our judgement for application in the real world.

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Image sources: screen and video capture in DAVE: Fraunhofer Austria; video capture in real environment: Austrian Institute of Technology; photos: is-design and Austrian Institute of Technology

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Photo: Vyhnalek

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