A Virtual Reality Framework to Validate Persuasive Interactive Systems to Change Work Habits

Florian Langel[1], Yuen C. Law[1], Wilken Wehrt[2],
Benjamin Weyers[1]

Virtual Reality and Immersive Visualization Group, RWTH Aachen University[1]
Work and Organizational Psychology, University of Mannheim[2]

Abstract

Virtual reality technology enables the immersion of a human user into a virtual environment. With virtual environments, reproducible situations such as office work can be created in which a human behaves and acts in response. Because of the reproducibility and the accompanied measurement tools offered by virtual reality technology, virtual reality can be used for empirical research in organizational psychology. In this paper, we present a system architecture for creating a virtual environment that allows to empirically investigate a persuasive interactive system that addresses the change of work habits.

1 Introduction

In everyday working situations, an office worker might show habits, which can be defined as patterns of behavior automatically performed as a response to characteristics of a particular situation. Habits are created by consistently repeating a behavior in a specific context or situation (Lally and Gardner, 2013). Habitual behaviors can be triggered by events in working environments and accordingly perceived by office workers. Examples of events are the ringing of an incoming phone call or a colleague entering the office.

Because habits are "enacted automatically" (Lally and Gardner, 2013, p. 137), habits may help when working on tasks that benefit from such automatic execution, for example, switching on the personal computer after arriving at the office each morning. However, the office worker might sometimes perceive specific habits as unwanted or counterproductive. An example is that an office worker, triggered by a situation in which they are not able to advance in a complex

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task and gets frustrated, repeatedly checks their mobile phone for private messages. The worker might wish to refocus on the complex task or to try other task solution strategies (e.g. seeking feedback, pausing shortly to recollect oneself). Thus, the automatic reaching for the phone is perceived as undesirable.

To help office workers to change such unwanted habits, we are currently developing a context-aware and persuasive interactive system that provides counteracting cues. An example for a cue could be a pop-up text message. These cues have two major functions. First, the form in which the cue is presented to the user should disrupt the automatic execution of the unwanted habit. Second, the cue should provide information that describes an alternative behavior. For a successful implementation of such a system, we plan to use persuasive technologies (Fogg, 2002) embedded into a smart office environment (Röcker, 2010).

Beside the need to formalize habits to make them usable for a persuasive system, as discussed in (Law et al., 2017), a major challenge is the empirical demonstration of the system's effectiveness on changing work habits and the identification of human behavior in context. The latter is not trivial as a technical implementation able to identify human behavior requires a complex setup of sensors and software, e.g. as shown in ambient assisted living or smart office applications (Park et al., 2010; Röcker, 2010). Once installed, such a system would seem to bound the researcher to one specific scenario which conflicts with the high individuality of work habits. Therefore, we present a virtual reality (VR) system and discuss its potential for simulating a realistic office environment in which study participants can show their individual work habits. In other words, the system will be able to recreate various habit-triggering situations and thus allow for the high individuality of work habits. By having access to the position and movement data of the user and by the optional simulation of a sensor network, the VR system offers a flexible adaption to the user's habit and simultaneously creates a well-controlled environment that is necessary for an empirical investigation, thus addressing both identified challenges outlined above.

However, VR systems possess certain limitations. For instance, navigation in VR (moving from one point in the virtual environment to another) is usually not implemented with a one-to-one mapping of the physical position to the virtual position of the user due to space limitations of the physical space. Furthermore, the interaction with objects in the virtual environment is mediated via controller devices, which may decrease the realism of the interaction because it might differ significantly from the real physical interaction with an object. Therefore, in this work, we will present ongoing research on how to address these limitations of VR and thus how to make VR usable for the investigation of persuasive technologies applied to change habits at work.

After presenting more background information in Section 2, we will derive a set of requirements, which have to be addressed by a VR system. This will be followed by the presentation of an implementation concept which includes the discussion of a software architecture as well as the identification of limitations. In Section 3, we present a first prototype that implements this framework. In Section 4, by means of a small case study, we will further discuss how this implementation can be validated to gather a certain understanding of the gap between virtual and physical environment. The paper concludes with a short summary and aspects for future work.

2 Background

As mentioned, we are currently developing a persuasive system to assist users to change undesired work habits. In this context, to test the system's validity in a controlled environment, we are preparing a virtual environment (VE) that reproduces an office space in which users can be fully immersed. For instance, this can be achieved by providing easy-to-learn interactions inspired by natural manipulation of objects instead of using abstract menus. Additionally, tasks in the VE should be designed to imitate everyday office tasks as accurately as possible. During the execution of such tasks, other conditions of the environment can be recreated to imitate real situations in which habits are normally triggered, such as the ringing of the telephone, e-mail pop-ups, loud noises, etc. In the next subsections, we will discuss the VE framework and its requirements in more detail.

2.1 Goals and Requirements

The main function of the framework is to enable empirical tests of the previously outlined persuasive system for habit change (assistant system). This means that the assistant system should be integrated into the VE with input and output that is in principle realizable in the real world. Additionally, the interaction with the VE, including navigation, should be intuitive and as natural as possible to reach a high level of presence (Bowman et al., 2004), and allow the users to feel a strong immersion into the virtual office. This includes offering multi-modal interaction by adding sound effects and other background noises to the VE. Furthermore, most objects of the VE should be interactive, such as small objects on the desk or shelves should at least be graspable and show physical behavior.

A secondary goal of the framework is to allow for the evaluation of VR scenarios in the context of habit change. Specifically, we are interested in validating if habits are able to manifest in VE. As a consequence, the framework must allow for the creation and adaptation of multiple VE's. In terms of technical implementation, it is necessary to maintain low coherence between the VE and the related evaluation and tracking system. This would allow for connecting other VE's to the existing monitoring and tracking system. In this sense, information on the users' actions within the VE must be passed to the monitoring system in an abstracted form. For example, if the user looks on a virtual mobile device, the VE will register this and pass on the information to the assistant system. The processing of this action will be provided by the evaluation component of the system.

2.2 The Virtual Scene

The scene, shown in Figure 1, consists of a large area that is functionally divided into smaller spaces. These are: a working area (desk and chair), a kitchen, a storage room, and a waiting area. The scene has been designed based on various photographs of different real office spaces originating from design and architecture websites as well as magazines. Objects and decorations within the VE office space have been chosen in order to create a relatively neutral but natural atmosphere, which is appealing to most users. Furthermore, the office is stripped of

Figure 1: A Screen-shot of the office virtual scene from a bird's eye perspective.

specific personalization such as portraits, names, cultural references or similar elements, such that users can get familiar with the environment and acquire a feeling of ownership.

3 System Architecture

We developed a system architecture able to create persuasive interactive systems for habit change that is suitable but not limited to VR systems as front end. Since we want to keep a high level of flexibility of the architecture, we separate the processing backend from one or multiple *Environment Tools* (components in direct contact with the user), which can be implemented using VR technology. A mixed approach combining the VR display and additional physical devices (e.g., a smartwatch) is also possible as well as a system that does not use VR technology at all. The latter is of major interest if the system is used in real context. The architecture is split into three major and loosely coupled components as shown in Figure 2: the *Environment Component*, the *Habit Designer Component*, and the *Evaluation Component*. The *Environment Component* comprises the front end with which the user directly interacts. In this work, this includes the simulation of the assistant system's front-end, which is responsible for presented cues to the user, and the VE, which offers all functionality necessary such as physics simulation, rendering, object manipulation, and navigation. The *Habit Designer Component* provides functionality that allows the user (or the researcher) to model habits. We are using Petri nets to model habits, but also consider BPMN (Business Process Modeling and Notation) combined with an algorithmic transformation to Petri nets (Law et al., 2017). In the current version of the architecture, we implemented the *Habit Designer Component* as a web-based and visual modeling tool for creating Petri nets. An *Evaluation Component* runs as a server application and waits for the environment and designer components to connect. The *Evaluation Component* also serves as the interface with the *Assistant System Logic*. While the user interacts with the environment (through functionality provided by the *Environment Component*), information on their actions is sent to the assistant system via the *Evaluation Component*. The *Assistant System Logic* can then use this information to match the user's behavior with the modeled habit (previously provided by the *Habit Designer Component* as Petri net). In response, the *Assistant System Logic* sends signals to the *Assistant VR Interface* (Figure 2) via the *Evaluation Component*. On this signal, the *Assistant VR Interface* presents the corresponding preventive or corrective cues to the user.

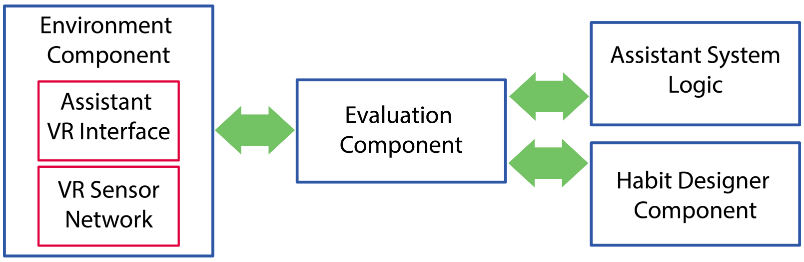

Figure 2: An overview of the system architecture. Designer tools and environment tools can easily be exchanged by others that utilize different technologies or implementations.

Communication between the individual components is implemented using WebSockets (TCP) and a protocol defined by a set of commands serialized with JSON[1]. The *Evaluation Component* listens for the registration of cues (or tools) by the *Environment Component* and by the *Habit Designer* via a specified port. This enables the *Evaluation Component* to map transitions in the Petri net to cues, both identified by name. During modeling of the *Assistant System Logic* using the *Habit Designer Component*, this mechanism is also used to announce all available cues and make them available as specific transitions for creating the corresponding Petri net. Therefore after a connection is established, JSON command objects are sent and executed based on its command type. The commands *RegisterTransition*, *GetTransitions* or *InsertNet* are used to setup the Petri net as outlined above (during modeling), which might be additionally used for adapting the logic to an individual user or a specific scenario. Commands *FireTransition* and *TransitionFired* are used to implement the communication between the simulated Petri net and the environment tool as front end to the user (during runtime or use of the assistant system).

[1] https://www.json.org/

4 Case Study

In this section, we present an example of how our system can be used. Recall the example habit described above where an office worker has difficulties in advancing with a complex task and automatically reaches for their mobile phone checking for private messages. This behavior is perceived as an undesirable habit. Thus, they might wish to change this automatic response and instead perform alternative actions that might help them advance in their task, such as seeking feedback or pausing shortly to recollect oneself. The following would then describe a possible interaction of the user within the VE, which includes the (virtual) assistance system.

The task can be simulated and implemented by asking the user to solve, for example, complex math problems in the VE while sitting at a virtual desk. An alternative could be to implement a boring repetitive task in case this kind of task also triggers the reaching for the phone response. Additionally, a virtual mobile phone that offers text and images should be made available to the user. To reinforce habit enactment, the system can fire events, such as a telephone tone to indicate that a new message has being received. During the whole interaction, the system (*Environment Component*) constantly monitors the user's hand movement, view direction and task completion and sends the data to the assistant system via the *Evaluation Component*. The behavior is compared with the Petri net model (originating from the *Habit Designer Component*) to detect: 1) the moment in which the user engages in their habit, i.e. grabs the mobile phone to check the messages and 2) when the user is not advancing in their task. In the first case, a corrective cue would be executed (triggered by a firing transition in the Petri net) by the assistant system to remind the user to stay focused on the task. In the second case, a preventive cue (e.g., a message) could be displayed to suggest alternatives in which the user could advance if stuck on the complex task.

From this case study, it is evident that some questions need to be answered according to presence and external validity. First, can the real situation be reproduced in a way that user's experiences, including thoughts and emotions, within the VE resemble those within the real working context? Thus, can the virtual task frustrate the user in a way that the habit is triggered? As mentioned, due to hardware limitations, e.g. display resolution, and interaction techniques, reproducing real world tasks is difficult, thus, other types of tasks that fit the VE must be designed. The key issue here is to find how different from the real tasks can the virtual tasks be without affecting habit-triggering responses. Additionally, if tasks must be as realistic as possible, we need to research new interaction techniques that feel more natural than the controllers, for example. Second, are the objects in the VE engaging enough so that the situation is able to trigger the habit? In this scenario, if the virtual phone lacks the personal messages and content specific to each user, will users still reach for it and be distracted, or does personalized content need to be included to trigger the habit? Third, will users show the changed behavior learned in the VE also in real working situations? Thus, before habit change can be tested in VR, the VE itself must be evaluated to test its limits regarding these aspects.

5 Conclusion and Validation

In this work, we have presented a system architecture for the development of a VR test environment for a persuasive system, which supports habit change in an everyday work environment. We have seen, with the presentation and discussion of a small case study, that such a test architecture can enable empirical studies. First, the use of VR allows to create configurable, controllable and traceable environments. In this way, user movements and actions can be registered continually. Moreover, their interactions with the environment and other passive elements in the scene can be tracked automatically without the use of a sophisticated sensor network (since everything happens in the virtual world). Second, time, events and other setting conditions, such as background noise levels and lighting can also be adjusted and controlled directly. For example, it is possible to make the telephone ring, or create e-mail pop-ups and other types of interruptions at determined times and desired frequencies. On the downside, it is not possible to accurately and completely reproduce every possible environment and scenario where potential users work in real life. This may prevent the users' real habits to be triggered in the VE. This aspect will be tested first in a pilot user study, where presence will be one aspect to be evaluated. In this context, it is important to note that the interaction with the VE is limited to the system capabilities. In this case, the HTC Vive offers two controllers that are hold in each hand, thus some real world actions cannot be imitated, such as typing with a keyboard. Additionally, the display resolution can limit the presentation of textual information, and make some common real life tasks that involve interaction with documents, difficult to reproduce. The questions here are in what degree these issues affect the triggering of habits in VE or in how far these limitations can be addressed by additional hardware, for instance using a tracked physical keyboard. Therefore, subjective measures such as usability and user experience questionnaires will be used to test for the suitability of the provided interaction devices as well as alternative concepts will be discussed in a qualitative interview. In order to investigate the question of external validity of the VE intervention, a diary study could be conducted. This would allow to assess if the made changes in the VE (i.e. abstaining from showing the undesirable habit) are transferred to the real working situation.

Nonetheless, we are convinced that having a VR-based framework and system to analyze habit change and validate assistant systems in a controlled laboratory environment can facilitate and speedup the development of assistant systems, since specific functions and ideas can be quickly realized and tested in the VE, whereas in real life these might require more effort.

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