The Two-User Seating Buck:
Enabling Face-to-Face Discussions of Novel Car Interface Concepts

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ABSTRACT

The automotive industry uses physical seating bucks, which are minimal mockups of a car interior, to assess various aspects of the planned interior early in the development process. In a virtual seating buck, users wear a head-mounted display (HMD) which overlays a virtual car interior on a physical seating buck. We have developed a two-user virtual seating buck system, which allows two users to take the role of the driver and co-driver respectively. Both users wear tracked head-mounted displays and see the virtual car interior from the respective view points enabling them to properly interact with the interface elements of a car. We use this system for the development, test and evaluation of novel human-machine interface concepts for future car models.

We provide each user with an avatar, since the two co-located users need to see each others' actions. Our evaluation of different head and hand models for representing the two users indicate that the user representations and motions should be as realistic as possible even though the focus is on testing interface elements operated by the users' fingers. The participants of our study also expressed that they clearly prefer the two-user seating buck over a single-user system since it directly supports the face-to-face discussions of features and problems of a newly developed interface.

Keywords: mixed reality, multi-user systems, collaborative virtual environment, human-machine interfaces, co-location.

Index Terms: I.3.1 [Computer Graphics]: Hardware Architecture—Three-dimensional displays; I.3.6 [Computer Graphics]: Methodology and Techniques—Ergonomics; I.3.6 [Computer Graphics]: Methodology and Techniques—Interaction techniques; I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Virtual reality

1 INTRODUCTION

The automotive industry uses increasingly virtual models instead of real prototypes [3] [11]. While CAD systems and simulation packages are in regular use, the acceptance of virtual reality technology is rather limited so far. This is the case even though there seem to be many prime application areas for virtual reality technology such as the study of car ergonomics and the test of new human-machine interfaces in cars. One reason is the missing support for multiple users, since the test and evaluation of new interface concepts is typically done with two or more experts discussing various issues in front of or inside a real car or car mockup.

We developed the two-user virtual seating buck (Figure 1, Figure 2), which allows two people to investigate new interface concepts in a virtual car interior. Both users wear HMDs and take the role of the driver and co-driver respectively. The seating buck is a minimal car mockup consisting of two seats, steering wheel, pedals, and a few appropriately positioned interface elements such as the light switch, the air condition controls, or the navigation system. These interface elements provide passive haptic feedback, while the virtual environment allows the user to explore e.g. a new navigation system interface. Since two co-located users are present inside the virtual car, it becomes important to represent each user with an avatar such that they can see each others' actions. We were interested in finding out which fidelity is required for the avatars' visual appearance and the motion of the heads and hands to be acceptable for studying new car interfaces.

Figure 1: The two-user seating buck scenario. The image on the left side shows the hardware setup. The right side shows the same perspective for the virtual car model including the two avatars.

For some time we were working with a single user seating buck to explore the qualities of and requirements on new human-machine interfaces in cars. Recently, we performed a survey with participants of the three potential user groups for the virtual seating buck technology: electronics developers, interface designers and ergonomists. The goal was to get a prioritisation of the next steps which are required to increase the acceptance of the seating buck technology. Our vision is that this technology should serve as a communication and evaluation platform for human-machine interface developers of the aforementioned user groups and it is supposed to become a basis for decisions in the future. The results of the study revealed that the limited haptics and the imperfect rendering quality are major obstacles towards acceptance, but it was also mentioned as the third problem that the co-driver is missing. Due to the single-user nature of our previous system, other users had to watch the actions of the driver on a regular monoscopic projection screen, which was set up at some distance from the seating buck. Thus communication between the passive observers at the large screen and the driver in the seating buck was quite difficult.

The main contributions of our work are the design and setup of a two-user seating buck system as well as the evaluation of potential avatar representations for collaborative evaluations of car interface prototypes. Our seating buck provides the driver and co-driver with perspectively correct views through tracked HMDs. Both users' hands and fingers are tracked as well to support complex interactions with the car interior. We have evaluated different head and hand models for representing the two users in this co-located scenario. Our findings indicate that the user representations and motions should be as realistic as possible even though the focus is on testing of interface elements operated by the users' fingers. The

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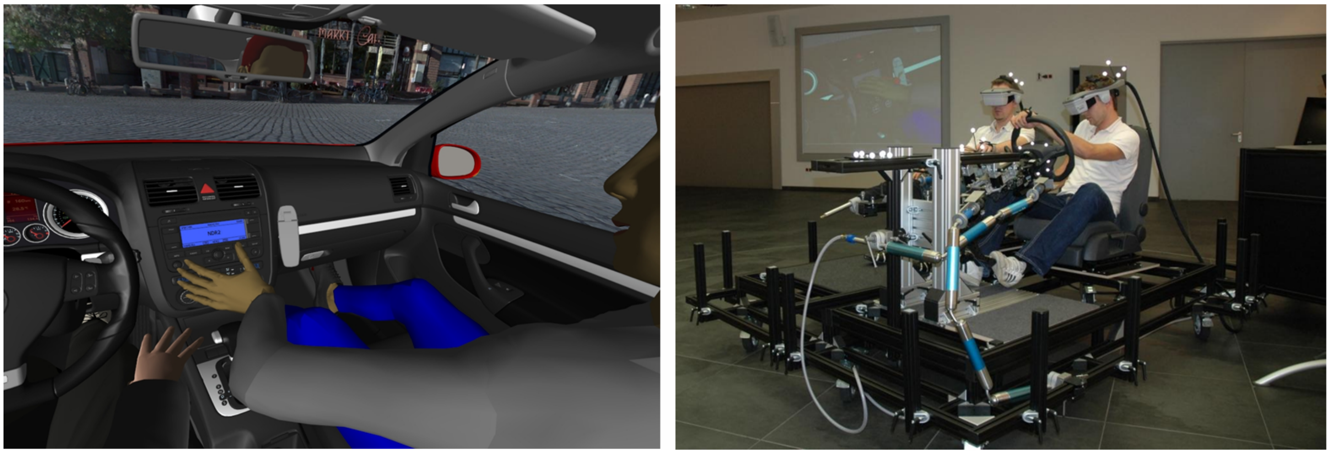

Figure 2: The right picture shows driver and co-driver in the real environment wearing their HMDs and discussing about functions of the navigation system. The left picture shows the corresponding virtual view of the driver.

participants of our study also confirmed that the two-user seating buck is a major step towards the acceptance of virtual reality technology for interface studies in virtual car interiors since it allows the discussion and exploration among two people in a co-located virtual face-to-face situation.

2 RELATED WORK

The research topics touched by our work are multi-user scenarios in collaborative virtual environments (CVEs), virtual ergonomic simulations using seating bucks and user studies investigating the degree of realism in VEs.

Seating bucks are a common tool used in the development process of many car manufacturers. The term Virtual Seating Buck (VSB) is also used for VR-augmented seating bucks, e.g. by Monacelli et al. [11]. Bordegoni et al. [3] describe how seating bucks support virtual prototyping and what their benefits are. The main application area is the investigation of the ergonomics during car development, for example reachability of the light switch or the readability of the navigation system's display. Bordegoni et al. [3] and Monacelli et al. [11] employ a single user VSB while we extend this idea to support the driver as well as the co-driver. Caputo et al. [5] give an overview of the most common features of non-VR seating bucks and how their features changed since VR was added. It is also explained which steps have to be taken to build the virtual scenario (data preparation, calibration) and that a tracking system, besides aligning the virtual geometry with the real world, could additionally be used to extend such a VE with virtual manikins.

Collaborative virtual environments (CVE) support the interaction of multiple remote or co-located users in a shared virtual environment. Our system has some similarities with the Studierstube project [16], where two or more users are co-located in the same room and experience the same virtual scene. Each user wears a tracked see-through HMD which provides an individual stereoscopic view and enables free user movement as well as the perception of the surrounding real world. Since we have to use non see-through HMDs it becomes inevitable to provide virtual body representations for each user as they are commonly used in distributed/networked virtual environments.

Slater et al. [18] and Thalmann [19] summarize the basic functions of these avatar representations: the visual embodiment of the user, means of interaction with the world, and means of sensing various attributes of the world. The importance of avatar representations in HMD configurations should not be underestimated: Sanchez-Vives et al. [15] report that it can be even shocking for users if they are not able to see their own body. Thalmann further describes the crucial avatar functions for networked virtual environments, which also apply to co-located multi-user environments:

- perception (to see if anyone is around)
- localisation (to see where the other person is)
- identification (to recognise the person)
- visualisation of others' focus of interest (to see where the person's attention is directed)
- visualisation of the other's actions (to see what the other person is doing and what is meant by gestures)
- social representation of self through decoration of the avatar (to know the other participants' task or status)

These roles of the avatar also apply to our scenario, in particular the visualization of the driver's or co-driver's actions and focus of interest are of relevance. The movements of these direct controlled virtual humans [4] are based on information from the optical tracking system. As we have rather limited tracking information available - head and hand only - realistic body movement has to be computed by inverse kinematics.

Jorissen et al. [9] report on various studies on embodiment in CVEs. In most of these studies it is concluded that so called virtual humans increase both the realism of interaction and the sensation of presence in CVEs. According to [2] the embodiment in our specific case can be classified as follows:

- **Presence** - the two users are more or less detailed humanoid looking 3D-forms with tracked heads and hands
- **Location** - each user has a fix location and limited orientation, except for heads and hands (sitting in a car)
- **Identity** - there are two different-colored body models according to which role the user is playing (driver or co-driver)
- **Viewpoints and actionpoints** - the focus of interest for each user is represented by his tracked hand- and head-models
- **Gesture** - realized by two finger-tracking gloves for each user
- **Facial expression** - is not implemented, only static faces

- **Degree of presence** - tracked hands/heads and voice

For our study on body representations we decided to use a questionnaire and the participants were interviewed while experiencing the VE, but most of the questions only aimed at a subjective rating on a scale of 1 to 5. As mentioned by Slater [17] there are a lot more human factors that should be taken into account and questionnaires are a too universal method to make reliable statements about user's presence sensation in a VE. Our goal was the evaluation of different body representations for our particular scenario instead of directly evaluating presence.

Providing passive or even active haptic feedback during the interactions increases the realism of the user's experience [10]. In our case, real parts of a car, e.g. a light switch or navigation system mockup, are mounted at the appropriate locations to provide haptic feedback.

3 THE TWO-USER VIRTUAL SEATING BUCK

We developed a two-user virtual seating buck as shown in Figure 2. The system consists of a minimal car-mockup, two HMDs for driver and co-driver, an optical tracking system, and precise finger tracking gloves. The Seating Buck is based on a chassis with two car seats, a steering wheel and real pedals. All of those physical items can be easily replaced by parts from other car types. The mockup can be adjusted in many ways, e.g. position and height of seats, steering column position, and foot rest can be changed. This allows us to represent a variety of cars, from small to large.

The seating buck is framed by an aluminum rack where pneumatic mounts called "flexi-holders" can be attached. Each mount consists of two joints, which can be arranged and fixed in almost arbitrary configurations. The flexi-holders are used to hold and position prototype or real car parts such as navigation-systems, touchscreen displays and several switches at their appropriate locations (Figure 3). These parts are typically tracked to insert them at the correct position into the virtual environment. The position of these passive haptic elements can be interactively changed during an evaluation session to adapt the setup to a new configuration of interface elements.

The tracking system consists of six cameras on the ceiling, which track the following objects:

- seating-buck, to align the virtual car model with the physical mockup
- steering wheel
- up to three moveable objects mounted on flexi-holders
- four fingertracking gloves
- two HMDs

The virtual seating buck requires precise calibration since it is quite important that there is no penetration of virtual fingers and the virtual representation of a real car part while the user is touching the real part of the car.

The system is driven by the Virtual Design 2 software running two synchronized instances on separate computers. The functionality and interface of future car displays such as navigation systems and other multi-functional displays is typically prototyped in external programs running on separate PCs. The images generated by these display simulation programs are mapped onto polygons in the virtual environment. Events from real buttons and from fingers touching the display surface in the virtual environment are sent back to the simulations. This is done with early and inexpensive hardware models, which have only the buttons connected to a USB-controller. If a button is pressed the controller sends key-events to the external display simulation (real fingertip and real button). Since both users are able to touch the same hardware prototype mounted on the flexi-holder, for example a navigation system, one user can see which virtual/real button the other is touching and how it changes the virtual display content. Alternatively key-events can be generated by collisions between object bounding-boxes representing the virtual fingertip and virtual buttons. These events are sent from the VR system to the simulation PC. Thus fully functional car displays can be integrated into the virtual environment and operated like in a real car including passive haptic feedback. Figure 4 shows the most important software and hardware components of our system in a schematic view.

Figure 3: On the left side the navigation system panel mounted on an arm of the flexi-holder is shown and on the right side the corresponding virtual image through the driver's HMD.

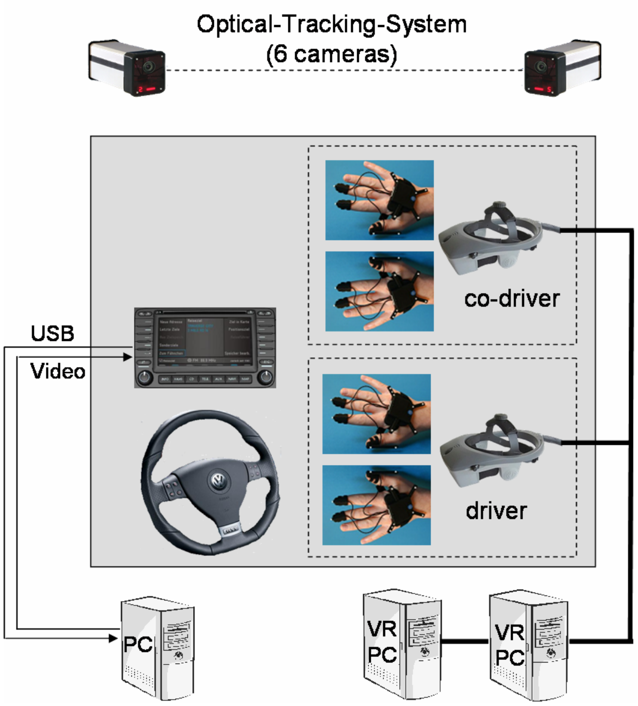

Figure 4: Schematic diagram of the two-user setup. Two separate PCs drive the HMDs. There is an additional PC for the simulation of the navigation system behavior. Both hands of driver and co-driver as well as the HMDs and various other objects are tracked (steering wheel, objects on flexi-holders, etc.)

4 BODY REPRESENTATIONS

Our setup allows two users to act as driver and co-driver while sitting in the virtual seating buck and viewing a virtual car model. Natural voice communication is also possible and the shared virtual environment allows interactions by each user which should be also seen by the other. As we need to use non-see-through HMDs it becomes necessary to find a suitable virtual representation for each user.

Our main question was how detailed the avatar representations need to be in the context of a virtual seating buck. Most important are the positions and orientations of the virtual hands and heads since they provide information of the actual focus of interest as well as the current action of each user. Thus we decided to track both hands and the head for each user in addition to the tracked car parts. Based on the tracking information body models of different quality could be animated with lower or higher fidelity. Our first study uses a simple body model and uses the tracking data to manipulate head and hands or arms with rigid body transformations. The second study compares the best result from the first study to a kinematic body model. For both studies we did not use finger tracking since we did not have the finger tracking hardware available for both users at the time of the study.

4.1 Simplified body model

Considering that we are working in the field of new human machine interfaces for the automotive industry, we are mostly interested in the effective and intuitive manipulation of our interface elements. Thus a basic visualization of head and hands and their movements might be sufficient for the evaluations of the new interface concepts. The question is how basic such a representation can be to be acceptable for our users such that the manipulations are perceived as being realistic.

4.1.1 Description of model

The position and orientation of a simple head model or even only a model of the HMD worn by the user might be enough to show the current focus of interest and might be considered adequate. Since our head model did not support different facial expressions, it might be more appropriate to use a head model wearing an HMD, which hides a large part of the face and thus facial expressions could not be seen anyway. Thus we created three different head models: just an HMD, a male human head, and a male human head wearing an HMD (Figure 5). We also wanted to experiment with different hand/arm configurations. We decided to use just the hand, the forearm, and the whole arm (Figure 6).

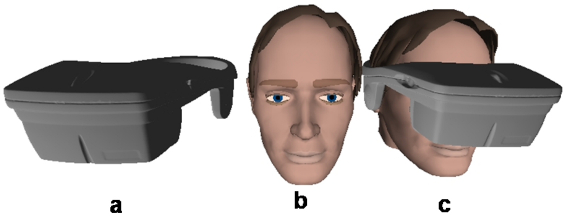

Figure 5: Head models for the first part of the user study. a) HMD model, b) male human head, c) male human head with HMD.

Sanchez-Vivez et al. [15] observed that it is disturbing for most users if they look down on their body and do not see it. We decided to always show a male person sitting in the driver respectively co-driver seat each wearing a different dress. These models were taken from the software Poser [13]. The different head and hand/arm models were cut off from the static model in the driver respectively co-driver seat. These disconnected head and hand/arm models were connected to the head and hand tracking data and they moved thus independently from each other and the rest of the body. Thus gaps between the different body parts can occur, which might destroy the illusion of a virtual human (see Figure 7). However, we are mostly focused on the action of the hands or the viewing direction of the head.

Figure 6: Arm/hand models for the first part of the user study. a) hand, b) forearm, c) arm.

Figure 7: When the user leans forward and stretches his arm in order to reach the navigation system the simplified body model produces gaps between the moving body parts and the fix torso.

We chose a car model, which was known to the participants of our study to avoid severe distractions by focusing on the features of a new car model. The environment around the car was a static city model to make the participants feel like being in a real car. A driving simulation would further enhance the realism, but the focus of this work was on the initial evaluation of novel interface concepts for the navigation systems and other multi-functional displays, which could be very well done in a stationary car.

4.1.2 Description of tests

The study was designed to evaluate user preferences for the introduced representations of heads, hands and arms. Three different arm/hand models and three head models had to be compared. 13 users volunteered to participate in our study. Ten users had some experience with HMDs and VR, but they do not use such technology on a regular basis. The remaining three participants did not have any VR experience at all. All of them knew about the single-user seating buck or had even used it. The participants took place in the driver seat while wearing the HMD. The interviewer asked some questions about the participants' perception of their own avatar and then they had to evaluate the co-driver's avatar and actions while the co-driver showed the following interactions to each subject:

- Looking at the center console and touching buttons, like volume control and on/off-switch, of the navigation system using the left hand
- Looking up and touching the sunroof controls with the left hand
- Looking to the right and touching the electric window lift of the co-driver's door with the right hand
- Looking into the eyes of the driver

At the beginning of each interview each participant was briefly shown the different arm/hand-models and the user had to rank the models with respect to their suitability for interface tasks. Then we asked how much the participant likes the appearance of the model and the next question asked how good the movement of the model is. Both questions were rated on a one to five scale (1=very bad, 5=very good). Questions were asked for each arm. The ranking results, reflecting the first impression the participants had of the models, should establish a reference to approve the results from the scaling questions or to find differences. The same procedure was carried out for the different head representations of the co-driver. These subjective ratings and rankings of the body parts were analyzed using a t-test for repeated measures to check the equality of means under a 95% confidence interval. We also asked in a closed question (”yes” or ”no”) if the legs and feet should be moving. At the end of each interview, shortly after the participant dismounted the HMD, we finished with the following questions on disorientation and 3D-experiences and the possibility to provide general comments:

- How do you rate the appearance of the virtual hand/arm/head representation?
- How do you rate the movement of the hand/arm/head representation?
- Do you think that the legs and feet should be moving according to the movement of your real feet and legs?
- To what extent did you feel disoriented?
- How do you rate your own experiences with 3D applications?

4.1.3 Results (ranking and scaling)

Table 1 shows that the male human head with HMD was ranked best. So the option closest to reality was evaluated best and the minimal head representation showing only the HMD was the worst. Table 2 shows that the participants of the study favored the driver's full arm model over the forearm model. The hand model was ranked lowest. For the evaluation of the co-driver's arms the ranking led to the same results with slightly different values.

Table 1: Mean ranks for the examined basic head models (Friedman-Test).

	co-driver's head
male human head with HMD	1.54 ($\sigma = 0.52$)
male human head	1.85 ($\sigma = 0.90$)
HMD	2.62 ($\sigma = 0.65$)

Table 2: Mean ranks for the examined simple arm models (Friedman-Test).

	driver's arms	**co-driver's arms**
arm	1.46 ($\sigma = 0.66$)	1.62 ($\sigma = 0.77$)
forearm	2.15 ($\sigma = 0.80$)	2.00 ($\sigma = 0.82$)
hand	2.38 ($\sigma = 0.77$)	2.38 ($\sigma = 0.77$)

Figure 8 shows the rated appearance and movement of the head models. The movement of the HMD compared to the male human head (p=.001) and compared to the male human head with HMD (p=.002) was rated significantly better. This is in contrast to the ranking of the different head models, which was provided after a brief look at the head models. For the appearances no significant differences were found.

Figure 9 shows that the appearance of the hand was significantly worse compared to the full arm model (p=.01). It is also indicated that the full arm model had the best movement and appearance.

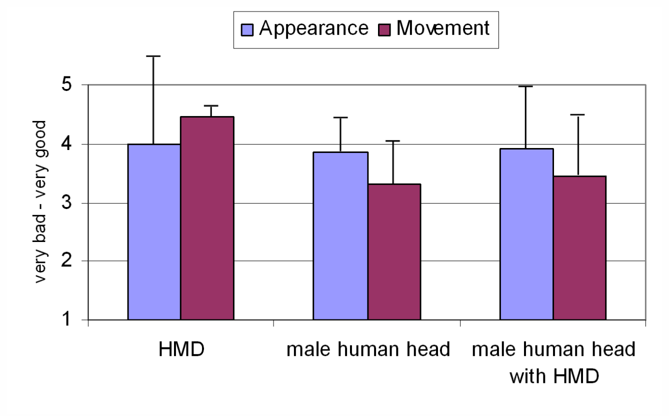

Figure 8: Subjective ratings of appearance and movement for the simple head representations.

4.2 Kinematic body model

The first study mostly indicates that the more complete and naturally behaving the body is, the more it is accepted for car interface studies - except for the head model, which we will discuss later. So we decided to go one step further and use a human body model which is controlled by inverse kinematics: the RAMSIS.

4.2.1 Description of model

The RAMSIS is a complete human body model developed by Human Solutions [14], which is widely used for studies on car ergonomics and also during modeling of car interiors. The RAMSIS model can be parameterized to represent different body models such as the 1.90 meters tall and 95 kilograms weighing man (95

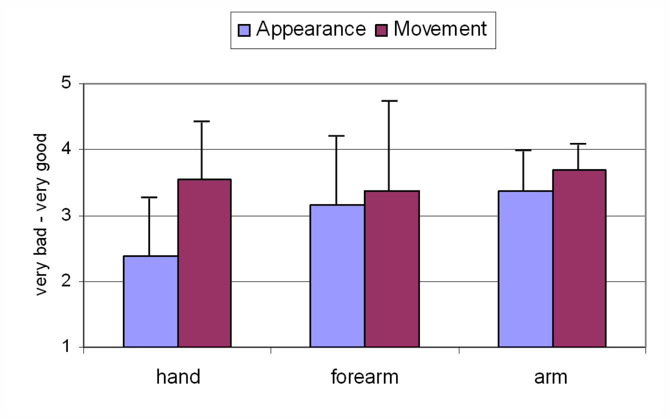

Figure 9: Subjective ratings of appearance and movement for the simple arm representations.

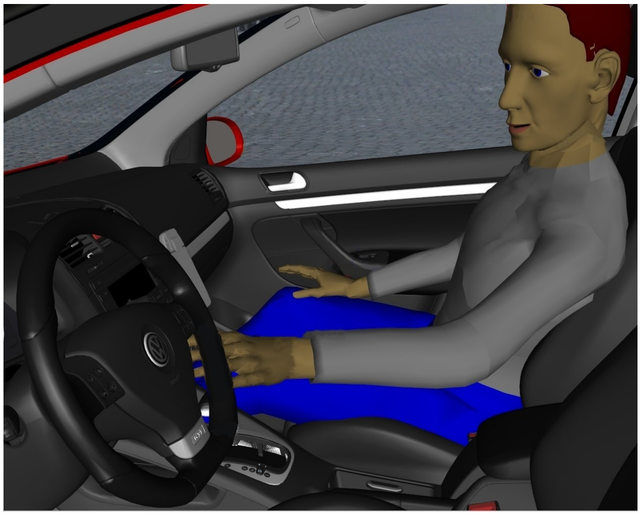

Figure 10: The RAMSIS model positioned in the co-driver seat.

percent male) or a petite 57 kilograms and 1.51 meters woman (five percent female). The interior of the cars is optimized in terms of ergonomics and visibility for occupants between these two extremes. This is the main application domain for the RAMSIS model, which is mostly used in CAD applications and real-time VR systems.

We created our RAMSIS model from a body scan of our co-driver, who performed typical interaction tasks while sitting in the co-driver seat. We decided to scan only one person because it would have been an unreasonable high effort to scan each person participating in the study. This meant that it was only possible to evaluate the RAMSIS co-driver only from the driver's perspective. The participant of the study, who was taking the driver's seat, was still represented by a simple Poser model. The RAMSIS was positioned on the co-driver seat and the model was fixed from feet to hip. The data from the three tracking targets for the two hands and the head was connected to the respective body parts of the RAMSIS model. The realistic movement of the rest of the upper body was computed based on the hand and head movements using kinematic laws. The RAMSIS simulation ran on a separate PC, which sends and receives information from the VR system.

4.2.2 Description of tests

The second user study was carried out among the same 13 participants as the first one, with some days in between. The participants took the role of the driver again, but this time their task was only to watch the co-driver acting. The representation of the co-driver alternated between the best ranked body model (full arm, male head with HMD, fixed torso and legs) of the first study and the presentation skin (most realistic looking) of the RAMSIS model. So this time only two pairs of arms and two heads had to be compared by ranking and by scaling questions. The virtual environment remained the same.

As in the first study we started by briefly showing both options to get a first impression by ranking and to remember the model from the first study as well as to get to know the new RAMSIS model.

Table 3: Mean ranks for the comparison of the chosen simple body model with the RAMSIS (Friedman-Test).

	co-driver's arms
Ramsis arm	1.23 ($\sigma = 0.44$)
arm	1.77 ($\sigma = 0.44$)

	co-driver's head
Ramsis head	1.38 ($\sigma = 0.51$)
male human head with HMD	1.62 ($\sigma = 0.51$)

4.2.3 Results (ranking and scaling)

The first impression of the RAMSIS model was rated better than the impression of the Poser model from the first study, regarding the arms as well as the head.

The scaling questions were asked after the participants had watched the co-driver acting. Figure 11 shows that there is no significant difference (p=.39) concerning the appearances of the arm models, but the movement of the RAMSIS arm was evaluated significantly better than the one of the full arm (p=.003). Accordingly we had corresponding results for the head models with no significant differences for the appearance of the male human head with HMD and the RAMSIS head. The RAMSIS head movement was judged significantly better than the rigid body motion of the male human head with HMD (p=.007).

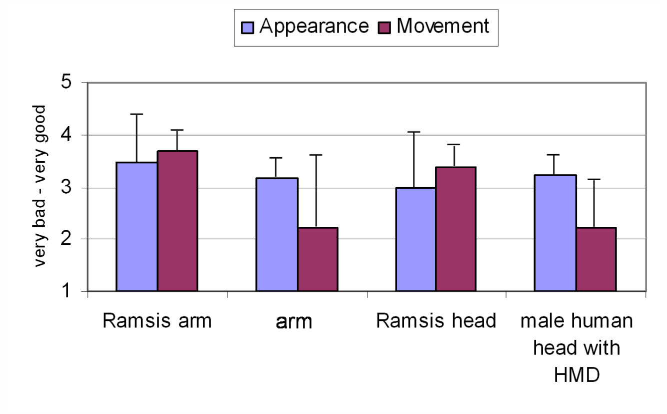

Figure 11: Subjective ratings of appearance and movement of body parts for the chosen simple body model compared to the RAMSIS.

4.3 Discussion

Overall the two-user seating buck was well accepted and seen as a major improvement over the commonly used one-user seating buck. There were even some comments that passengers of the rear seats should be present as well or that some additional people should stand around the car and participate in the discussion.

One of the interesting results of our first study was the first rank for the male human head with HMD after the initial brief look at the co-driver avatar. Our impression was that the participants still remembered the real person wearing the HMD and favored the avatar which looked most alike. In addition facial expressions were mostly hidden and thus the correspondence with the facial expression of the real person did not play a major role.

Surprisingly the plain HMD model was rated better for its movement than the other two head-models in the first study. We suspect that the head models movement relative to a static body torso was considered less convincing than the abstract HMD model moving around independently. In addition the HMD model did not provide any facial expression, which would have not matched the actual conversation between driver and co-driver.

In the second part of the study the appearance of the male human head with HMD was rated better than the RAMSIS head what might be an evidence for the too simplistic face model of the RAMSIS and the missing facial articulation. Participants who did not like the RAMSIS head rated the arm also as bad. This might indicate that the representations of both body parts are important to create a convincing avatar.

The RAMSIS arm was clearly rated better on average with respect to appearance and in particular with respect to motion than the rigid arm model. This is a clear indication that the more realistic arm motion produced by the inverse kinematics model is considered important for evaluating the usability and ergonomics of various controls and interfaces in a car interior. It is also a clear statement that a simple six degree of freedom tracked hand or arm model is of limited use in such situations. One thing we had also observed in earlier studies was that it was disturbing for the user, if the right virtual arm was moving corresponding to their real arm, but the left arm was not. Thus it is necessary to track both arms even though for the driver (right-hand driving) the actions of the right arm are much more relevant than those of the left arm.

Our work seems to add to the hypothesis of Garau et al. [6] who presume that the more photorealistic an avatar is, the higher the demands for realistic behavior are. In our case the Poser model can be seen as more realistic with respect to appearance than the RAMSIS, but it does not support realistic motions based on inverse kinematics. Overall there is no big difference with respect to the rating of the appearance of both models, but the RAMSIS was clearly rated better with respect to movement. One may speculate that realistic behavior seems more important than appearance and thus realistic motion compensates for less realistic appearance.

Concerning the inclusion of correctly moving legs and feet our study delivered no reliable answer. Eight of the participants answered with ”no” and the remaining five with ”yes”. This indicates that the majority did not consider articulated legs and feet to be of great importance even though the RAMSIS model would allow the simulation of these movements. However, we did not show them such an avatar since it is quite difficult to receive a stable tracking signal in the foot space of the car due to occlusions.

All 13 participants had no problems with disorientation after they dismounted the HMD and all of them rated their 3D-experiences as good. This is probably due to the high-resolution HMD (1280x1024), the precise tracking and calibration as well the high update rates of 30 to 60 Hz. In addition the virtual car was not moving during the studies, which reduces the susceptibility for disorientation and motion sickness. The participants did not complain about the HMD's limited field of view (60 degrees), which indicates that it does not play a major role for the evaluation of car interface concepts.

During the interviews the participants could also provide some general remarks about their experience with the system. One suggestion was to use a video camera to capture other participants in an evaluation session, who are outside of the car. The video stream should then be mapped onto an object, which can be seen by the driver and co-driver. The driver and co-driver could hear the other participants, but they also wished to see them. It was also suggested to equip the other participants with HMDs as well. Some users wanted to get out of the car and move around the virtual car, for example to have a look at the engine bay. In principle this is possible, but it would require to model the environment around the seating buck perfectly well to avoid that users would run into obstacles. In addition, the cabling of the HMDs would have to be flexible enough to support such movements. Some subjects expressed that they would like to hear the sound of the environment to increase the realism. An almost obvious question was if it is possible to drive the virtual car. This would be very useful if someone wants to evaluate how navigation tasks, like entering an address while driving, can affect the awareness to the traffic. We already tested a driving simulation in our system but - as expected - quite a number of users suffered from motion sickness. We think that the motion sickness is partially due to the limited field of view of only 60 degrees, but also due to the latency and update rate of the simulation system.

We have also received some negative comments on the weight and limited ergonomics of the head-mounted displays. In particular mounting the HMD while wearing the finger-tracking gloves was a difficult undertaking. The tracking system worked overall quite well. Sometimes the mapping of the real hand movements to the motion of the virtual hand was not perfect, which lead to collisions of finger markers with real objects in the car interior - in particular when users tried to interact like they are used to in a real car. This seemed to be a problem with hands of different size, since the system could not be adjusted for different hand sizes. Users wished also to avoid the time consuming calibration procedure for the virtual hand model, which took only two to four minutes.

5 CONCLUSIONS AND FUTURE WORK

We presented the design and implementation of a two-user seating buck scenario, which enables the test and evaluation of new user interface concepts for cars in a virtual face-to-face scenario involving the driver and co-driver. Our flexible setup allows us to experiment with different versions of real knobs, buttons, switches and display surfaces, while the virtual environment displays the appropriate actions and content of the connected interface simulations to both passengers. The main conclusion with respect to the required avatar representations is that the body movement should be based on inverse kinematics with at least tracked hands and head, like realized with the RAMSIS. This came as a slight surprise since we thought we could get away with less sophisticated models. Our assumption was based on the fact that the focus is on the interactions of the hands with the interface elements of the car. The participants of our study, who are actual experts involved in the car development process, clearly indicated that they would prefer sophisticated avatars. Even the appearance of the head should be as articulated as possible. Thus the two-user seating buck is a great application area for well articulated virtual humans. It even seems that the actual driver and co-driver in the seating buck would like representations of their own body best.

Distance perception in virtual environments is a much discussed topic. Some studies already examined distance perception in VEs which are comparably large. For example walking to different locations in one room [7] or walking in virtual rooms with different sizes [8]. Veridical distance perception in VEs is an important issue concerning realistic virtual simulations especially those based on HMDs. In one of our acceptance analyses several people mentioned that they have the impression that the dashboard is too far away on the co-driver side when looking from the driver's perspective. There is still not enough knowledge about factors that influence correct distance perception in the nearfield of smaller virtual environments like the interior of a car and thus this is an interesting avenue for further research.

Our two-user seating buck allows the simulation of a variety of new forthcoming HMI-features. One interesting example is a dual-view display where the driver sees navigation information and the co-driver may watch a video at the same time. These user-dependent views can be also used during the evaluation process to make annotations, which are by default only visible to the creator of the annotation.

In the future we would like to involve more participants directly into the virtual seating buck scenario. Each user will be provided with an individual stereoscopic and task specific view. Today we still have the situation that additional participants, besides the driver and co-driver, have to watch the session at a separate projection screen. Since these participants have typically different roles, the views might be tailored to the actual user. The ergonomist could see the RAMSIS model, while the designer sees the knits of the seats and of realistic clothing. The electrical engineer may see the electrical circuits at the same time. Involving multiple people with different expertise in the discussion process is essential to increase the acceptance of the virtual seating buck and to make it a reliable decision platform in the future.

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REFERENCES

[1] ART. advanced realtime tracking GmbH. http://ar-tracking.eu/index.php, July 2007.

[2] S. Benford, J. Bowers, L. E. Fahlen, C. Greenhalg, and D. Snowdon. User Embodiment in Collaborative Virtual Environments. In *Proceedings of CHI'95*, volume 1, pages 242–249, 1995.

[3] M. Bordegoni, G. Caruso, F. Ferrise, and U. Giraudo. A mixed environment for ergonomic tests: tuning of the stereo viewing parameters. In *Eurographics Italian Chapter Conference*, pages 127–134, 2007.

[4] T. K. Capin, I. S. Pandzic, H. Noser, N. M. Thalmann, and D. Thalmann. Virtual Human Representation and Communication in VLNET. In *IEEE Computer Graphics and Applications*, volume 17, pages 42–53, 1997.

[5] F. Caputo, G. D. Gironimo, G. Monacelli, and F. Sessa. The design of a virtual environment for ergonomic studies. In *Proceedings of XII Convegno ADM Design Tools and Methods in Industrial Engineering*, Rimini, 2001.

[6] M. Garau, M. Slater, V. Vinayagamoorthy, A. Brogny, A. Steed, and M. Sasse. The impact of avatar realism and eye gaze control on perceived quality of communication in a shared immersive virtual environment. In *Proc. CHI 2003*, pages 529–536. ACM Press, 2003.

[7] V. Interrante, L. Anderson, and B. Ries. Distance Perception in Immersive Virtual Environments, Revisited. In *IEEE Virtual Reality 2006*, pages 3–10, 2006.

[8] V. Interrante, B. Ries, J. Lindquist, and L. Anderson. Elucidating the Factors that can Facilitate Veridical Spatial Perception in Immersive Virtual Environments. In *IEEE Virtual Reality 2007*, pages 11–18, 2007.

[9] P. Jorissen, M. Wijnants, and W. Lamotte. Dynamic Interactions in Physically Realistic Collaborative Virtual Environments. In *IEEE Transactions on visualization and Computer Graphics*, volume 11, pages 649–660, 2005.

[10] B. Lok, S. Naik, M. Whitton, and F. P. Brooks. Effects of Handling Real Objects and Avatar Fidelity on Cognitive Task Performance in Virtual Environments. In *IEEE Virtual Reality 2003*, pages 125–132, 2003.

[11] G. Monacelli, F. Sessa, and A. Milite. An Integrated Approach to Evaluate Engineering Simulations and Ergonomic Aspects of a New Vehicle in a Virtual Environment: Physical and Virtual Correlation Methods. In *FISITA 2004 30th World Automotive Congress*, pages 23–27, Barcelona, 2004.

[12] NVIS. http://www.nvisinc.com, July 2007.

[13] Poser. http://www.e-frontier.com/go/products, July 2007.

[14] Ramsis. Human Solutions RAMSIS Automotive. http://www.human-solutions.com/automotive industry/ramsis automotive en.php, July 2007.

[15] M. V. Sanchez-Vives and M. Slater. From Presence Towards Consciousness. In *8th Annual Conference for the Scientific Study of Consciousness*, July 2004.

[16] D. Schmalstieg, A. Fuhrmann, G. Hesina, Z. Szalavari, L. M. Encarnacao, M. Gervautz, and W. Purgathofer. The Studierstube Augmented Reality Project. In *Presence Teleoperators and Virtual Environments*, volume 11, pages 33–54, 2002.

[17] M. Slater. How Colorful Was Your Day? Why Questionnaires Cannot Assess Presence in Virtual Environments. In *Presence Teleoperators and Virtual Environments*, volume 13, pages 484–493, 2004.

[18] M. Slater and M. Usoh. Body Centred Interaction in Immersive Virtual Environments. In N. M. Thalmann and D. Thalmann, editors, *Artificial Life and Virtual Reality*. John Wiley and Sons, 1994.

[19] D. Thalmann. The Role of Virtual Humans in Virtual Environment Technology and Interfaces. In *Frontiers of Human Centered Computing*, pages 27–38. Springer London, 2001.