Moving Between Contexts - A User Evaluation of a Transitional Interface

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Abstract

Navigating between different virtual worlds, interface scales or task contexts has emerged as an interesting research area for Augmented and Virtual Reality interfaces. We have developed a transitional interface which allows users to smoothly move between exocentric Augmented Reality and egocentric Virtual Reality views. In this paper we report on the first user study to investigate performance, usability, presence and awareness issues with transitional interfaces. The results of this explorative study provide initial guidelines for future research and development of multicontext-navigation environments and raise interesting questions for future research.

1. Introduction

Over the last decade both augmented reality (AR) and virtual reality (VR) applications are becoming more widespread. Each of these technologies has different advantages and disadvantages for interacting with virtual content. VR offers an immersive environment for easily navigating between different viewpoints, and it facilitates spatial knowledge acquisition. AR on the other hand offers an exocentric view embedding virtual content in a wider real world context. The transitional interface concept introduced by Billinghurst et al. [2], combines the advantages of Augmented Reality and Virtual Reality environments. In the MagicBook work the authors present a system that enables the user to easily switch from an exocentric AR viewpoint to an egocentric VR viewpoint using a transitional interaction metaphor. Immersed in the VR world the user can navigate based on a gaze steering technique. Over the years, the concept has been explored in different projects [5], [6] (see Figure 1). However, very few usability studies have been conducted to formally evaluate the concept empirically.

In addition to transitioning between AR and VR spaces, transitions can also be made between multiple information contexts. As computing devices have become more ubiquitous people typically use a wide range of diverse associated interfaces. This creates multiple information contexts and operating environments, and the need to easily navigate or switch between them. This is very similar to issues encountered with transitional interfaces moving between AR and VR spaces. However, we still know very little about how to properly design such systems. Thus there is a need to identify guidelines for the development of interfaces to seamlessly switch between multiple information contexts.

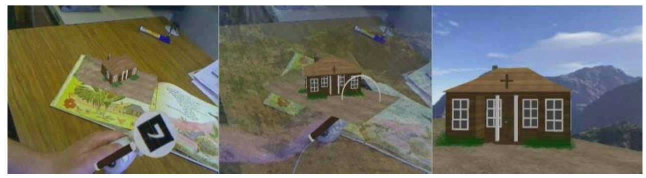

Figure 1. Transitional Interface example: switching from an exocentric AR viewpoint of a 3D scene to an immersed egocentric VR viewpoint.

Grasset et al. [8] introduced a basic framework for transitional interfaces and related research issues. Yet we need a better understanding of the task domains in which such interfaces can be used and how dealing with and moving between contexts affects the users perception and sense of presence. To find some answers to these questions we designed an empirical pilot user study with a prototype application based on the proposed transitional interface framework. We compared task performance, interface usability and presence across different kinds of tasks.

In the remainder of the paper, after the discussion of related work we report on the general context of our research methodology followed by the description of the user study and results. Finally we discuss the implications of our findings on future research and development of transitional interfaces.

2. Related Work

To our knowledge, no empirical studies have been conducted to evaluate the transitional interface concept introduced by Billinghurst et al. [2]. However, we can find research that focuses on evaluating the impact of multi-perspective or multi-viewpoint (spatially or temporally separated) interfaces or the benefit of animated viewpoint transition.

It has been hypothesized that using multiple views of information is an efficient way to improve the understanding of spatial scene. However, with respect to user orientation, Bowman [4] has shown the negative impact of a teleportation metaphor (i.e. temporally modulated views) for navigating between different viewpoints in a 3D virtual environment. This underpins the need to provide smooth movement between viewpoints and the importance of user control during this action.

In 1999, Bederson et al. [1] discussed the importance of animated contexts and views between data to improve the understanding of the information. This followed a previous study [7] in the context of using animation to improve decision making. Both showed performance benefits through the use of animation techniques. More recently studies have been conducted by Bladh et al. [3] (3D Tree-Map visualization) and Shanmugasundaram et al. [19] (based on node-link diagrams). They raised the importance of visual and perceptual consistency between the different views.

Other research has explored more asymmetric and heterogenous types of collaboration between different types of spaces or views [10], [18], [20] (readers can refer to [8] for a more complete bibliography). However, none of these research projects have provided any mechanism for transitioning between these different spaces. Most can be categorized as mixed-reality collaborative environments.

There have been a few examples of interfaces for supporting transitions. Koleva et al. [13] proposed the concept of a traversable interface for passing seamlessly between different worlds. Looser et al. [14] discussed the idea of using a tangible Magic Lens tool to select the destination viewpoint and initiate a transition between AR and VR views.

Other research projects have also reimplemented a similar concept to transition from an AR view to a VR view [5], [6]. However, these projects did not conduct user evaluations to test their approach or propose new designs for the transitional interface.

3. Research Context

We summarize here the context of our research, our research approach, and related research questions.

3.1. Research approach and methodology

Mixed Reality (MR) is a relatively new research area, and interface theories and general design guidelines are largely missing. For instance, the notion of presence in Mixed Reality [16] has not been investigated very strongly. With a transitional interface we deal with even less explored research areas such as presence in multiple contexts (AR and VR).

Recently we have been focused on defining and investigating the general concept of a transitional interface. We did so by gathering and analyzing previous work on collaborative systems that transitioned between contexts, and developing a formal model to generalize and characterize these systems. We tried to identify the main research issues in this area. Our first results were presented in [8] and [9]. Based on this research framework we recently conducted several different studies to evaluate transitional interfaces. In this paper we present one of these studies, which is a first step to better understanding transitional interfaces and several related issues. We focused on a simple scenario where a user can transition bi-directionally between an AR exocentric context and a VR egocentric context (see Figure 2).

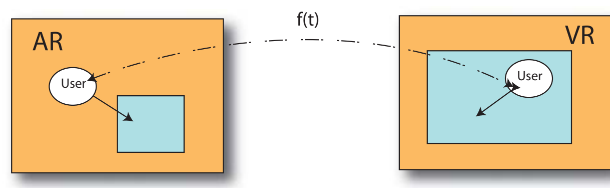

Figure 2. Evaluated Scenario: Transition between AR exocentric context to VR egocentric context.

3.2. Research questions

This scenario raises different questions around transitional interfaces. The user has access to different contexts and is able to seamlessly move between the two. So how does moving between contexts influence a persons' sense of *presence* and how does presence differ in either of the contexts. It is unclear whether users can keep up a coherent sense of presence over the whole transitional interface experience. There might be a unique state of presence in a transitional interface that is different from presence in either AR or VR.

Another important issue is the *awareness* of the user while transitioning. How does the user perceive the switch between contexts? Awareness can be explored at the beginning, during and after transitioning. In the related work we discussed projects that have examined the impact of an animated transition between multiple viewpoints. They have isolated some factors related to their use: sustaining spatial orientation and perception, estimation of the appropriate speed and length of the animation, and capability of the user to correlate both contexts of information. In the case of transitional interfaces, these elements are very important. However, in a transitional interface the user may not only change viewpoints (e.g. egocentric to exocentric) but also contexts (e.g. AR to fully immersive VR). Therefore these issues have to be investigated in more depth.

We also have to study appropriate ways to initialise and control the transitioning process. Users may also have to deal with different navigation techniques in the different contexts. Thus there are various *usability* issues that have to be investigated in appropriately designing the transitioning process and simplifying navigation.

To summarize, we are investigating research questions in four areas: user performance, presence, and awareness issues of transitioning, and usability of the interface, the transition technique, and the associated navigation modes in and between the contexts.

4. Evaluation study

For this study we chose a within-subjects design. We compared the number of transitions, task completion time, time spent immersed in VR and several subjective measures such as system usability and disorientation in the contexts across 8 different tasks. Furthermore we compared simulator sickness scores before and after the study session (using the Simulator Sickness Questionnaire of Kennedy et al. [12]).

Participants

Fourteen volunteer University students, 11 male and 3 female, aged between 18 and 30 ($M = 23, SD = 3.71$) participated in the study. For this study we aimed at a mixture of people with and without experience with AR and VR environments.

Apparatus

The participants used a video-see through HMD (eMagin Display (800x600, 60Hz) + VGA Logitech USB camera) and a MagicLens interface (mouse ball + ARToolKit marker [11]).

The software implementation is based on the osgART library [15] and our earlier transitional Framework (supporting scene synchronization and user awareness). To transition from AR to VR the participants pointed the MagicLens interface at the desired location and pressed a button and to go back to AR they just pressed the button again. In the AR mode computer vision tracking of ARToolKit markers was used for spatial registration. The HMD had a built-in inertial tracker that was used for gaze-steering navigation in VR mode.

Tasks

For the evaluation tasks we used seven different virtual scenes from the eyeMagic book [17] and one scene of a 3D molecule. The molecule was included to see how the participants could deal with a scene with fewer spatial orientation cues. In each scene the participants started with the AR view, giving an overview over the whole scene. The tasks fell into the following categories:

1. Identify an element not visible from the exocentric AR viewpoint because of its small size.
2. Identify an object not visible from the exocentric AR viewpoint because it is inside another one (i.e. occlusion).
3. Identify an object not visible because you can't 'reach' a certain viewpoint from the exocentric AR viewpoint (e.g. looking under something).

Figure 3. Illustration of task 7: in oder to count the number of apples in the bowl the participants had to transition into VR.

For example in the scene shown in Figure 3 the participants were asked to count the number of apples in a picnic basket. In the AR view the participants were able to see the virtual picnic basket (Figure 4). To solve the task, however, they had to transition into the VR view to be able to count the apples. Other tasks involved finding hidden objects, having to change to a close up view to get information, and frequently changing between AR and VR views to get overview and close-up information. In task 5, for example, three signs were separated by walls and the participants had to change between AR and VR views several times to identify all signs.

The tasks for the study involved:

1. What is the tool beside the right foot?
2. What is the object under the right hand?
3. What is the word on the back of the church?
4. What is the object in the cloud?

5. Read the words on three signs. (restricted range of movement)

6. What is the word on the blue cell? (molecule)

7. Count the apples in the bowl and find the word on the sign.

8. Find the sphere in the cloud; what is the colour of sphere?

Figure 4. Left: exocentric AR view; right: egocentric VR view; The task is to count the number of apples in the basket

Procedure

The participants completed a questionnaire about demographic information, computer experience and previous simulator sickness. Next the experimenter showed the participants how to navigate in the AR view, how to use the magic lens interface, and how to navigate in the VR view. A training session followed which allowed the participants to practice transitioning and navigating in AR and VR environments. During the actual trials the experimenter explained each task to the participant and recorded their answers. The participants completed a short questionnaire after each task and a final questionnaire after they had finished all tasks. These questions were:

- The task was easy to complete
- I felt disoriented while completing the task
- I found the interface useful / usable to accomplish the task
- It was efficient to interact with the system

The experimental sessions were video taped to give the experimenters the chance for further in-depth analysis.

4.1. Results

Number of Transitions

Participants had to change from AR and back to VR at least once in each task. Thus the minimum number of transitions is two. Data examination showed some outliers. A closer look at the video showed that these participants seemed to have problems with depth perception and frequently selected a transition location quite far away from the target (e.g. participant 14 transitioned 8 times in task 6, whereas in general people transitioned only twice in this task). Datasets with outliers (1.5*IQR (interquartile range)) were not included in the respective analyses. Task number 5 was designed to encourage the users to move several times between AR and VR so it was also not included in the number of transitions and task completion time analyses.

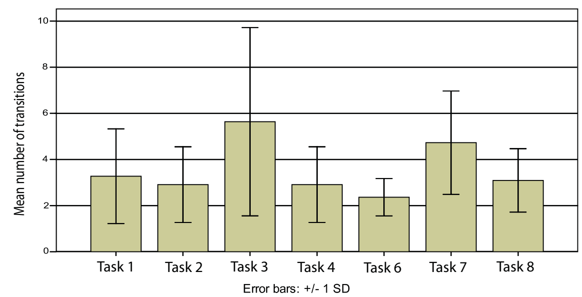

Figure 5. Number of transitions for each task.

The comparison of the number of transitions over the tasks (repeated measures ANOVA) showed, that participants transitioned more ($F_{3.89,38.94} = 5.97, p < .01$) in tasks 3 ($M = 6.6, SD = 3.89$) and 7 ($M = 5.20.SD = 2.35$) than in tasks 4 ($M = 2.60, SD = 1.35$) and 6 with just one movement form AR to VR and back.

Task completion time

The analysis for task completion time showed a significant longer overall completion time for task 3 ($F_{6,60} = 5.60, p < .01$) with 123.10 seconds ($SD = 45.10$) than for task 6 with 58.82 ($SD = 12.83$) and task 2 with 62.55 ($SD = 29.56$). The high number of transitions and completion time for task three can be explained by the observation that the participants seemed to have problems with VR navigation and had to transition more frequently to accomplish this task.

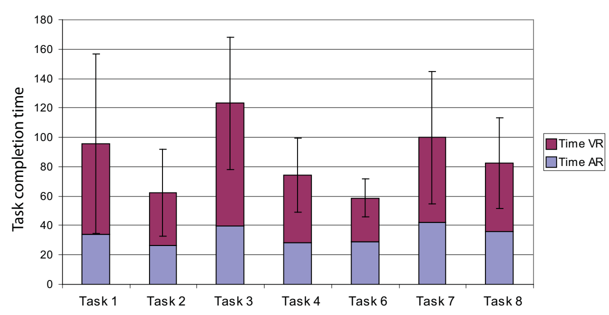

Figure 6. Time in AR,time in VR and combined total task completion times. SD shown for total completion time

Comparison of questions after each task

Task 3 got significantly lower ratings for the question 'The tasks were easy to complete' than tasks 2, 4, 6, and 8 ($F_{4.80,62.37} = 5.56, p < .01$). Task 5 did not differ significantly from the other tasks. In task 3 the participants also felt more disoriented than in tasks 4 and 6 ($F_{7,91} = 3.85, p < .01$). The interface was rated as being less useful to accomplish task 5 than to accomplish tasks 6 and 8 ($F_{5.38,69.88} = 3.30, p < .01$). For task 6 the participants felt that it was more efficient to interact with the system ($F_{7,91} = 2.79, p = .01$) than for tasks 3 and 5. These results can be explained by navigation related issues. For example in task three the participants had to turn their heads around in the VR view in order to see the sign. In task 5 some participants struggled with the restricted range of movement. Therefore accomplishing these tasks proved to be frustrating for many participants.

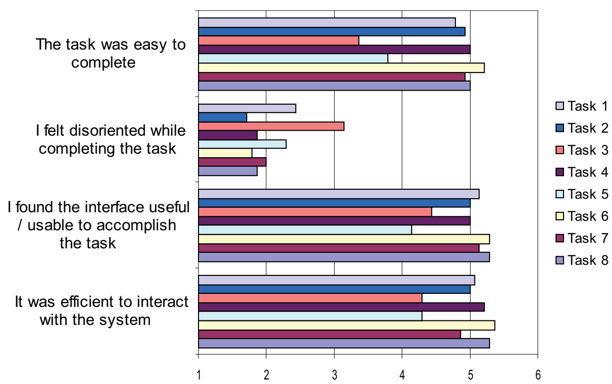

Figure 7. Questions asked after each task (Likert scale, 1 = completely disagree, 6 = completely agree)

Final questionnaire

The results of the final questions on general usability of the system and interaction devices were quite encouraging. Enjoyment and ease of use received relatively high ratings and the participants felt that it was not difficult to learn how to use the interface. The general ratings for disorientation were low as well.

Simulator sickness

Although there was a significant increase in ratings for headache ($t_{13} = -2.86, p = .01$), eyestrain ($t_{13} = -3.12, p < .01$), and difficulty of focusing ($t_{13} = -2.69, p = .02$), these pre- post differences and the means in general are very low. A closer look at the data revealed that after the treatment no participant reported severe symptoms in any of the questions, however moderate symptoms were reported for headaches by three participants, fullness of head by two, and difficulty concentrating and dizziness (eyes closed) by one participant respectively.

General observations and user comments

We observed that several participants often did not take the full advantage of selecting a transitioning position in AR before actually moving into the VR view. For example, when the participants had to look for an object in a cloud, most selected a position on the ground instead of directly pointing to the cloud and selecting the position there. Also with some tasks a lot of participants selected transitioning positions far away from the actual target. Some participants also found it difficult to navigate in VR. This was apparent in tasks where they had to re-orient themselves to accomplish the task (for example when the participants had to turn their heads around to see the virtual models). This was not only obvious from the observations but was also reflected in some user ratings.

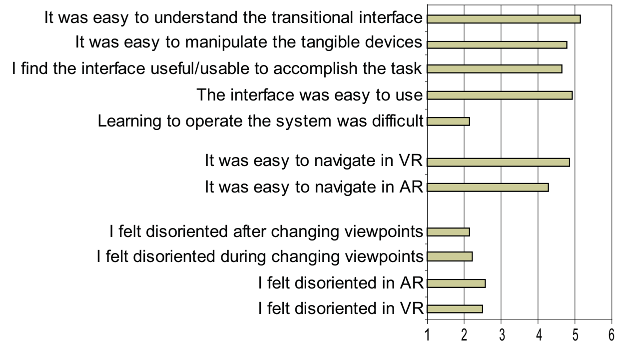

Figure 8. Final questionnaire (Likert scale, 1 = completely disagree, 6 = completely agree)

5. Discussion

Usability and Navigation

We observed that many participants seemed to have problems with properly selecting transitioning positions. One explanation for this may be that they did not fully understand how to use the selection tool. However, it is more likely due to problems with depth perception with the current interface which does not provide a stereo view.

It is interesting that although many participants found it hard to navigate in the VR environment they often selected transitioning positions far from the target. Although some moved back to the AR view to get an overview, others used the more cumbersome VR navigation to reach the target. In addition some participants frequently moved back to the AR view only to select a rather similar transitioning position which did not bring them closer to solving the task. Hence there is a need to improve the interface to facilitate more appropriate selection of the transitioning position.

The comparison of ratings shows that the participants found the system to be more efficient for the abstract molecule model and for tasks where the target was easy to access (e.g. in the clouds).

The number of transitions was highest for tasks in which the target either was hard to reach (task 3) or tasks in which more than one target had to be identified (task 7). In task 6 the target was rather easy to find and therefore only required one movement from AR to VR and back again. As can be seen from the relatively high standard deviation in task 3, some participants moved quite often from AR to VR and back, whereas others finished the tasks with fewer transitions.

Presence and Awareness

Overall the subjective ratings for the interface were quite positive. Spatial orientation in the VR view did not seem to be a problem as the cell model and the task in which the participants had to find an object in a cloud did not lead to more spatial confusion than the other landscape type models. These tasks were solved quickly and with relatively few transitions. Disorientation during and after transitioning were rated as low. The ratings were similar to the disorientation ratings of either of the two contexts.

With some participants, especially inexperienced AR and VR users, it seemed as if they did not really perceive much difference between the AR and VR contexts. Whereas this, to a certain extent, depends on the chosen environments and models, it raises interesting issues for presence and immersion in AR and VR. If people don't perceive much difference between the two contexts, how does the sense of presence differ for both types of environments? Some participants explained their experience as video game like but hardly commented on real world augmentation. We told them in the introduction and training phases that they will use and experience AR and VR views so we cannot clearly tell whether they really would perceive the two contexts as sufficiently different or not. In future research it might be worth to investigate further such perceptual issues and study the user perception of AR / VR with inexperienced users.

Lessons learned

Our study showed that we need to explore better techniques for selecting the transition location and the user endpoint in the VR view. One possibility would be to integrate better visual guidance for the user. Indication of where the user will end up after transitioning could be improved, for example, by showing an avatar or a small preview.

We also found that our transitioning techniques seemed to work well for the users with respect to awareness during and after transitioning. However, other techniques and their effect on user awareness and user experience should be investigated in further studies.

There is a relation between the design of the interface, the contexts, the transition technique, and the navigation in the contexts. The design of either of these elements has an impact on the entire system. In our case, problems with VR navigation lead to poor overall interface usability. Furthermore, in future studies we should make full use of the potential of AR instead of just putting a scene on an ARToolKit marker.

6. Conclusion

We have presented the first user study with a transitional interface. The interface enables users to seamlessly navigate between AR and VR contexts. Based on search tasks, we have analyzed user behavior with a testbed application. This helped us to study interface usability and presence and awareness factors with respect to the contexts and the phases during and after transitioning. We uncovered interesting issues that will define our future research strategies, and show that we need to further investigate presence in AR, VR, and during transitioning between contexts. How does presence differ in different contexts and how does an interface that offers access to both contexts influence presence? We also plan to further investigate different application scenarios and tasks domains in which we can fully expand the usefulness of transitional interfaces.

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