A Dual Screen Concept for User-Controlled Hypervideo-Based Physiotherapy Training

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ABSTRACT

Dual screen concepts for hypervideo-based physiotherapy training are important in healthcare settings, but existing applications often cannot be adapted to personal needs and do not support correct posture. In this paper, we describe the design and implementation of a dual screen application (handheld and TV) that allows patients to view hypervideos designed to help them correctly perform their exercises. This approach lets patients adapt their training to their daily needs and their overall training progress. We evaluated this prototypical implementation in a user test with post-operative care prostate cancer patients. From our results, we derived design recommendations for dual screen physical training hypervideo applications.

CCS Concepts

•Human-centered computing → Hypertext / hypermedia; Graphical user interfaces;

Keywords

Hypervideo; Dual Screen; Navigation; Training

1. INTRODUCTION

Fitness and healthcare applications have become increasingly important for the healthcare sector, especially in physiotherapeutic rehabs. After short stays at rehab clinics, patients have to continue their exercises at home. While videos allow for much better comprehension of human movement processes than static images and text [6], leaflets are still the most popular form of home rehab support. However, they are not optimal for ensuring the correct execution of rehab exercises. At the same time, the omnipresence of mobile multimedia devices facilitates the uptake of applications that support patients in user-controlled training sessions.

Hypervideos have been shown to be very valuable for providing a portable means of guiding training processes when played on mobile devices [16]. Hypervideos consist of videos that are hyperlinked to each other, often providing additional information. This information can include detailed explanations (images, text, videos, audio) that cannot be shown in the root videos but provide more facts to users if needed. With respect to physical exercises and physiotherapy, the underlying graph structure of hypervideos allows for the provision of additional navigation through the training material, helping users adapt the sequence of training units to their individual needs.

While hypervideos provide additional navigational means and a richer set of information, a clean interaction concept is hard to achieve due to their complex structures. Performing a physical training unit might require the viewer to switch between different positions depending on the exercises (like lie, sit, or stand on a mat or training device). The correct posture during an exercise is very important to ensure the desired training and healing effect and to not strain or wrongly train muscles. A single screen concept using a laptop or tablet (for example, as described by Meixner et al. [16]) reveals the following problems: (1) Positioning the screen that it can be watched easily during an exercise without moving the upper body or head (which may lead to improper exercise performance or a lower training effect) is difficult and sometimes not possible at all. (2) Controlling the hypervideo flow requires a movement towards the device (e.g. get up from a lying position, interact with the hypervideo, and lie down again) which can interrupt the exercise. So, in a single screen situation, the playback device is either positioned well for watching the videos or for interacting with the hypervideo - but not both at the same time.

Dual screen applications with a TV and a touch screen for remote control offer a solution that optimizes the training setup. However, up to now, the design and interaction patterns of such dual screen applications for hypervideo-based physiotherapy training are not clear. In this paper we make the following research contributions: We a) designed and realized a dual screen hypervideo application (Section 3), b) evaluated three designs for touch screens in a user test (Section 4), and c) propose recommendations for placing functionality and media on two screens (Section 5).

2. RELATED WORK

Hypervideo players like Klynt [11], the SIVA Player [14, 15], and the Ambulant Open SMIL Player [5] provide functions that are necessary for hypervideo-based training. However, they are not capable of splitting content on two screens. Bibiloni et al. present a platform for augmented reality on

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Figure 1: TV screen used in tests.

interactive TVs, but their concept of hypervideo is limited to an "interactive video stream" that provides hyperlinks allowing "non-linear navigation, searching, sequence skipping, etc." [3]. This framework does not allow navigation in the underlying hypervideo graph, but only in the additional information. The works described above hint at the implementation of mobile hypervideo player apps with HTML5, but do not deal with the requirements of training settings.

Second/dual screen applications mainly combine a TV screen with a second screen application showing information about content on the first, or primary, screen (TV). The secondary screen is used to "control, enrich, share, and transfer television content" according to Cesar et al. [7]. Beeson et al. [2] provide play-lists with video streams that can also be started on the first screen. Cruickshank et al. [8] show timelines for several TV channels that can provide information about TV shows. Information is viewed on the second screen without hiding content on the first screen. Leyssen et al. [12] describe concepts for adding additional information to items in the video, separating main video controls and additional information which can be applied to our concept. However, none of the described applications is tailored to physical training scenarios, where the viewer, following the instructions on the screen, is in an active participatory role.

Rehabilitation training often uses special equipment, like wheelchairs (Rossol et al. [18]), smartphones strapped to limbs (Spina et al. [20]), or cameras (Tang et al. [22]), which limits the systems to certain specialized scenarios. In their study to enhance rehabilitation after falls at home, Uzor and Baille conclude "that the visualizations and games encouraged the participants to do the exercises at the right pace" [24]. The users preferred to "use the visualizations and games to the instructional booklet" because of a more enjoyable experience and dynamic feedback [24]. None of the described systems for rehabilitation training is a second screen app or uses hypervideos.

3. DESIGN AND IMPLEMENTATION

Hypervideo playback requires special players that are capable of providing navigational elements like selection panels for follow-up scenes, a table of contents, or search functions. Areas for displaying additional information are necessary. An example hypervideo player user interface and exemplary training set are described by Tonndorf et al. [23].

The target group for our software are physiotherapy patients who have to do exercises for inner core muscles, especially cancer patients who have had surgery after a prostate cancer diagnosis. The age group that usually gets this type of cancer is 45 years and above. This leads to a further challenge for hypervideo-based physiotherapy training, because this user group has a mixed level of technical experience relative to using touch screens and apps on smartphones. Problems with eyesight also appear in this cohort. These limitations have to be taken into account when designing the hypervideo user control interface and lead to the following questions: (1) Which control elements are necessary for controlling an individual training session? (2) How should the multimedia elements of the training session be split up between TV and touch screen? (3) What are the requirements for a mobile app capable of controlling the TV screen in an individual training unit? (4) How should elements and function-buttons on a mobile app be arranged?

We iterated the design of the mobile app concept in the following three steps: We first created high-fidelity paper prototypes with screen designs guided by related work, existing apps, and hypervideo requirements. Two rounds of Pluralistic Walk-throughs [17](p.514) with experts for hypervideo-based physiotherapy training revealed three refined prototypes which were then tested with 164 participants in a survey. Taking all findings from [13] into account, three prototypes were implemented as smartphone apps: A split-screen concept showing a small preview of the main video, annotations, and control elements on one screen, visually separated by different colors (see Figure 2, left); a tab concept showing the video preview and the control elements on one tab and the annotations on a second tab (see Figure 2, center); a "drawer" concept (as seen in the Spotify app [21]) that distributes the screen space according to the currently focused elements (main video preview and video controls vs. additional information) but does not hide one area completely (see Figure 2, right). The prototypes had screens with selection buttons for follow-up scenes and a table of contents.

The TV screen showed the main video scene centered, the title of the scene on top of the screen for orientation in the hypervideo, and the timeline at the bottom of the screen for orientation in the scene/exercise (see Figure 1). Other concepts also showing annotations or showing more than just the video were not preferred according to the results of the survey [13]. Due to the structure of our hypervideo (all additional information was available until the end of a scene and not important to watch during the scene) we decided not to show hints for additional information at the TV screen.

The prototypes described above were implemented using a standard TV with an HDMI connector, a Chromecast [9] and an Android smartphone. Chromecast transmits HTML5 contents and enables us to display media on the TV. We used PhoneGap [1] to create the prototypical apps from the player implemented in HTML5, CSS3, and JavaScript.

4. EVALUATION IN USER TEST

The resulting three prototypes (Figure 2) from the previous section were tested in a user test. Our user test was conducted in a rehabilitation clinic with 21 male patients who had prostate cancer surgery and had to deal with post-surgery incontinence. They were between 31 and 75 years old ($M = 63.30$, $SD = 10.35$). The educational background was mixed through all levels of education. The technical skill levels (especially in using smartphones) also varied greatly.

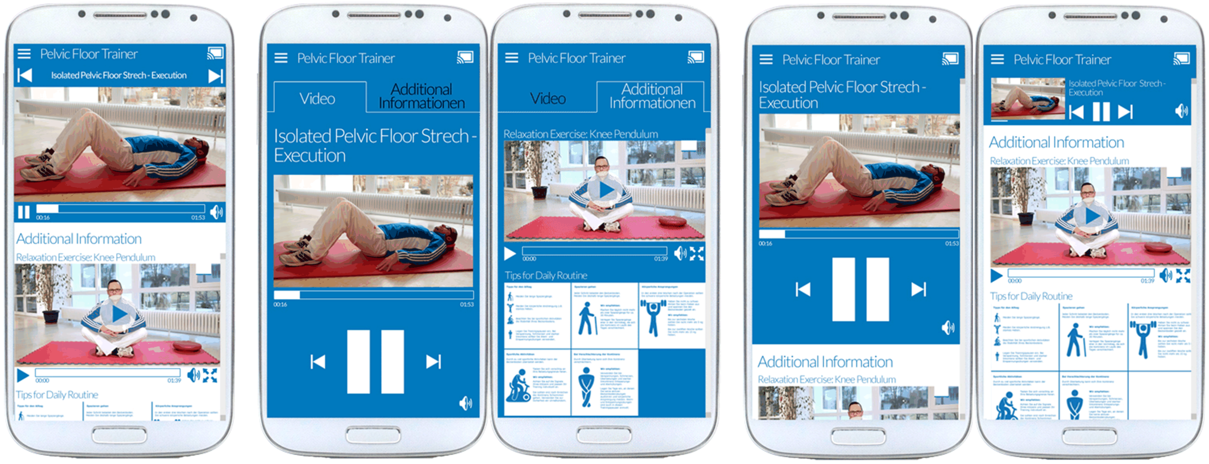

Figure 2: Mobile control app: split screen (left), tab concept (center), and "drawer" concept (right).

Their motivation to participate in the training and to do the exercises on a regular basis was very high.

4.1 Procedure/Data Collection

Besides the user test, where the participants (hereafter users) were observed, they were also asked to fill out two surveys mainly requesting assessments on 7-point Likert scales [4](p.73) (range: -3 to +3).

A **pre-survey** with questions regarding the pelvic floor training at the clinic was handed out before the test. It contained a self-assessment, questions about the individual's training progress, about device and application usage in everyday life, and about demographics.

The **user test** was performed in the patients' rooms at the rehabilitation clinic. Each room had a bed with nightstand, a TV viewing chair, a desk with a chair, and a TV bench with a TV. For the tests, the rooms were provided with a ball (approx. 25-30 cm diameter), an exercise mat, and a sitting ball for performing the exercises with the necessary tools. Besides the TV, a Samsung Galaxy Note II and an LG Nexus 5 were used for the test.

The video presented to the test users was a prototypical version of the hypervideo described by Tonndorf et al. [23]. It had an introductory part with four explanation videos and a practical part containing one training unit with three exercises. Each practical exercise had an explanation and an execution part; all videos contained additional information. The execution parts of the trainings had relaxation videos as additional information which could be chosen by the users if desired (accessible for the whole duration of a main video scene). The video had a table of contents and all elements had at least one keyword allowing discovery by keyword search.

The test users were instructed to watch at least one video in the introductory part, then open the table of contents, select the first practical training unit and do the training. They were also told that they could watch additional information whenever they wanted, and that they should integrate relaxation exercises into their training whenever they liked. The users were encouraged to think aloud [10](p.440) during the test (when possible), to comment about the experience and to ask questions at any time. Each user had two observers. A physiotherapist reviewed exercise execution correctness. A computer scientist/usability expert examined the app usage and noted problems during the test.

A **post-survey** was handed out to the users after finishing the user test. It contained questions regarding functionality, comprehensibility, adaptability, expectations, learning effort, exercise execution, and mental effort of using the app.

4.2 Results

The tripartite evaluation revealed that the app was mainly used in portrait mode. Different viewing behaviors could be observed, but exercise execution showed no significant differences between the three versions.

4.2.1 *Pre-Survey*

The self-assessment and state of training pre-survey subparts revealed that none of the users had post-op limitations or felt pain doing their exercises. Asked about their pelvic floor training competency before the user test, the users stated that they mainly knew how to perform their exercises ($M = 1.35$, $SD = 1.67$)[1]. Regarding the progress of the pelvic floor training, the survey revealed similar results ($M = 1.45$, $SD = 1.64$). Most participants use radio and TV, or the Internet several times a week or daily. Two thirds use a computer or laptop several times a week or daily. One third use a tablet PC. About half of the participants use a smartphone several times a week or daily.

4.2.2 *User Test*

The results for the user test are discussed for the two parts of the test video. The introductory part is more of a lean-back experience, while the practical part requires active participation in different positions during the exercises.

Introductory Part: While watching the hypervideo introductory part in a sitting position, all but one participant used the smartphone app in portrait mode (he wanted to adjust the smartphone orientation to the TV orientation). Most users (19 out of 21) held the smartphone in their hands, only 2 users laid the smartphone down next to them. Most of the test users (19 out of 21) watched the main video content on the TV screen, some of them switched views from

[1] M is the mean value average on the 7-point Likert scale over all sub-questions in a question block, SD is the standard deviations average thereof

TV to smartphone and back several times. Only 2 users watched the content on the smartphone. Additional information was invoked only by 9 users, while 8 users watched it on the smartphone, and one user watched it on the TV.

Practical Part: The users switched from sitting on a chair or the bed to sitting on the gymnastics mat when they started the practical part. All but one user held the smartphone in portrait mode. A part of the users (6 out of 21) held the smartphone in their hand while watching explanations and doing the exercises, the others put the smartphone aside (9 out of 21). A few users (6 out of 21) held the smartphone while watching the explanations but put it aside while doing the exercises. Two users put the smartphone away for doing the third exercise, where they had to sit on a gymnastics ball. Many users (18 out of 21) watched the video scenes with explanations and exercises on the TV. About one third switched views from TV to smartphone and back during the exercises. About one third closed their eyes or looked at the ceiling once they understood the exercise concentrating on proper execution. They only listened to the audio to keep the right rhythm. Additional information (except the relaxation exercises) was watched by only 3 users - two watched it on the smartphone; one watched it on the TV. The relaxation exercises (additional information in the three main exercise videos) were used by about half of the users.

Problems: Problems that occurred during the test were a lack of knowledge about smartphone usage and age-related long-sightedness, or a combination of both. Lacking experience with smartphones led to accidentally pressed buttons, especially when using the Samsung Galaxy Note 2 with the on/off button on the side. Age-related long-sightedness forced the users to put on their glasses when they wanted to interact with the app on the smartphone and to take their glasses off in order to watch the video scenes on TV.

Comparison of the Designs: No significant differences between the three different versions could be observed for exercise execution (assessed by a physiotherapist). This can be explained by the fact that the information displayed on the TV screen was the same for all three app implementations. The different versions were all usable, but showed different minor problems. The split view that allows a direct touch interaction seems to be easier to use for people with less smartphone experience, even though the screen contains more elements. Using the tab concept, users switched to the additional information tab to start an optional relaxation exercise, but did not remember to switch back to the video control tab after finishing it. None of the users used the swiping gesture to change the spatial distribution between video and additional information using the “drawer” concept (despite showing it in the introduction). They invoked the optional relaxation exercise by tapping on its small visible region at the bottom of the screen.

4.2.3 Post-Survey

The users agreed that the mobile app suitably supports user-controlled training ($M = 2.25$, $SD = 1.28$). Its functionality was also rated as very good ($M = 2.15$, $SD = 1.20$). The app meets the users’ expectations and habits ($M = 2.43$, $SD = 0.93$). An adaption of the app to users’ personal needs during training is possible ($M = 2.19$, $SD = 1.19$). The effort for learning to handle the app is rated as low ($M = 1.87$, $SD = 1.36$). The app has a good influence on the correct execution of single exercises ($M = 2.63$, $SD = 0.55$). It has a positive influence on practical exercise execution ($M = 2.53$, $SD = 0.73$). The mental load while using the mobile app is considered as neutral ($M = -0.08$, $SD = 1.62$).

5. RECOMMENDATIONS

The evaluation results of the proposed dual screen application allow us to draw tentative recommendations for similar systems where users have to do physical training or execute body posture changing tasks guided by hypervideos:

- **Display all videos on TV screen**: Videos (main video scenes and additional information videos) should always be displayed on the TV screen. All test users watched the additional information videos on the TV screen (instead of looking at the smartphone screen where the video was shown in parallel).
- **Use videos with sound**: During exercise execution, patients concentrated on the video sounds after they understood what they had to do during an exercise. For this reason, it is important that the video sets the pace and repeats the single steps for every repetition in the audio in addition to the video.
- **Show hints for mandatory interaction on TV screen**: Displaying buttons for selecting the next scene on the TV screen helped the users, giving hints on when to use the smartphone for interaction.
- **Focus on portrait mode for smartphones**: When the users were lying on the floor, they held the smartphone in one hand using portrait mode and touched it with their thumbs.
- **No hints for additional information needed on TV screen**: Most users watched the whole video scene first and looked at additional information at the scene end. Thus, showing hints on the appearance of new additional information can be considered optional (and may be made configurable in the app settings).
- **Display information at the scene end**: As a consequence of the users looking at additional information only at the scene/exercise end, it is very important to provide all additional information until a scene ends and with the last frame when the hypervideo pauses.

Commonly known concepts like keeping the interaction simple for inexperienced users and providing advanced screen concepts for experienced users (and others [19]) also apply.

6. CONCLUSION

This paper proposed a dual screen concept for user-controlled hypervideo-based physiotherapy training. We introduced a design for the TV screen and three designs for the mobile device. Implementing and evaluating them in a user test with rehabilitation clinic patients, we were able to derive guidelines for displaying media on the two screens as well as for how to effectively place functionality on them. In conclusion, we found that the dual screen concept allows for increased flexibility in positioning the body, improving exercise execution. Using the software on a smartphone was hard for some users because of less experience with the device. The user tests were only performed with male prostate cancer patients who are mainly of age 45 and above. Further tests with other scenarios of physical training and other user groups are necessary and part of our future work. A long term study with an analysis of logging data from unobserved situations is also desirable.

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