THE EFFECT OF NON-LINEAR STRUCTURES ON THE USAGE OF HYPERVIDEO FOR PHYSICAL TRAINING

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ABSTRACT

The growing number of elderly people combined with financial cuts in the health care sector lead to an increased demand for computer supported medical services. New standards like HTML5 allow the creation of hypervideo training applications that run on a variety of end user devices. In this paper, we evaluate an HTML5 player running an e-health hypervideo for the support of pelvic floor exercises. In an experimental test setting we compared the hypervideo to a primarily linear version regarding usability and utilization for self-controlled training. Our results show the hypervideo version leads to slightly more usability problems but facilitated a more active and individual training.

***Index Terms*—** Hypervideo, non-linear Video, Practical Training, Usability Test, Expert Review, User Test,

1. INTRODUCTION

In many regions of the world like Europe and North America the population's age is constantly rising. This demographic trend leads to a growing demand for high standard medical services. One way to meet this challenge is the increased use of information technology in the healthcare sector. Internet-based health applications are considered to have advantages over more traditional health education and communication approaches: They offer convenient access to health information and services for a broad user population [1]. Furthermore, applications can employ multimedia components like image, video, or animation to effectively communicate complex health information and tailor messages for individual users [2].

Hypervideo, which can be described as interconnected video clips that constitute a hypermedia structure [3], has promising potential for e-health applications. The non-linear structure enables users to explore the content in a manner that supports individual needs and cognitive capacities. Video as a presentation medium has advantages in communicating spatial and temporal changes. Especially for human movement, video facilitates better comprehension than static images or text [4]. Hypervideo combines the benefits of a dynamic audiovisual presentation with a high level of interactivity. Nevertheless, Hypervideo has not been used within e-health applications until recently.

In this paper, we illustrate the use case of a hypervideo application in a health scenario and present the user evaluation. The pelvic floor trainer was developed to supports the rehabilitation of prostate cancer patients. Requirements for a hypervideo player that supports the execution of physical exercise in a rehab setting were already presented in [5]. Amongst other things, the player should be able to log user data, provide an online and an offline mode, and allow users to control the display of additional content (annotations). The prototype was evaluated in a usability test with users of the target group. To test the effect of non-linear structures the studies compares hypervideo with a primarily linear video version. This work aims to answer the following questions:

- Is hypervideo better suited for the support of physical exercises than linear video?
- Which usability improvements can be made to optimize the hypervideo player?

In the remainder of this paper, we will first describe the usage scenario (Section 2), the current state of research in multimedia and hypervideo design (Section 3) and the software (Section 4). We then present the user test (Section 5) and its results (Section 6). The paper ends with a discussion of the findings (Section 7) and its limitations (Section 8).

2. USAGE SCENARIO

The surgical removal of the prostate leads to incontinence. Physical exercises that strengthen the pelvic floor are essential for the rehabilitation. The patients start their rehabilitation approximately two weeks after surgery. During the stay in the rehab clinic, patients attend daily group training conducted by physiotherapists. To regain continence, they have to continue doing the exercises for 6 to 24 months after leaving the clinic. Therefore when returning home, patients need ongoing support to perform the exercises without the help of a physiotherapist. The pelvic floor trainer provides this support by offering two workouts each containing several pelvic floor exercises.

For our study we collaborated with a local rehabilitation clinic which serves approximately 150 patients at a time. The patients are male and aged between 45 and 85 years. They possess only limited computer skills but are assumed to be highly motivated to participate in the therapy. Since the pelvic floor trainer ought to support the execution of practical exercises, it needs to be used directly within the training setting. The patients use a notebook or tablet PC to watch the videos while lying on a gymnastics mat or sitting on a gymnastics ball.

3. HYPERVIDEO DESIGN

According to Multimedia Learning Theory, video and animation are well suited for the learning of procedural skills [6]. Especially for motor skills like body movements, learning with animation is superior to learning with static images [4]. Nevertheless, the dynamic and transitivity of animation imposes strong demands on the working memory [7]. If the speed is too high, learners miss parts of the information or process it in a superficial way. User control can help to overcome these negative effects: If users are able to control the

pacing they can adapt the presentation to their cognitive capacity. Furthermore, a continuous video can be segmented into short clips, after which the playback stops. This way, users gain time to make sense of the information, before starting the next clip [8, 9].

In hypervideo, a continuous video is not only segmented, but it is structured in a non-linear way. Gerjets and Kirschner [10] define hypermedia learning environments as network-like information structures, where fragments of information are stored in nodes that are interconnected. In hypermedia learners may be allowed to determine the order in which they access different information (sequencing) and may decide which contents to receive depending on their prior knowledge (selection). There is widespread argumentation that the high level of control facilitates self-determined exploration and therefore increases interest and motivation [11]. It furthermore supports users to manage their learning by setting goals, monitoring and controlling their cognition and behavior. But hypermedia can also cause a variety of usability problems [11]: Disorientation occurs when users don't know where they are in the network and how they can get to the desired content. While browsing through the network users can get distracted from their original goals. Therefore, users must develop sophisticated metacognitive strategies and invest a great amount of cognitive resources to effectively interact with hypermedia.

In hypervideo research, experiments in the context of university teaching have revealed that hypervideo can lead to high user satisfaction [3]. Tiellet et al. [12] developed a hypervideo to support veterinary students in learning surgery techniques. After studying with the application, students were capable to perform the surgery without using real animals in the training. The examples illustrate the positive effects of a hypervideo on learning. But the studies did not compare the hypervideo to linear multimedia environments. Therefore it cannot be assured that the positive learning outcomes are actually caused by the hypermedia structure.

4. SOFTWARE

The pelvic floor trainer is based on the HTML5 player for interactive non-linear videos described in [13]. The player provides selection panels, a table of contents (TOC) and keyword search for navigation in the non-linear video structure. Furthermore, the player provided four areas for annotations as well as overlay annotations which are displayed in the video area. Based on the current state of research we conducted a thorough redesign of the existing player. According to Zahn [14] interaction with hypervideo can either take place on the macro- or the micro-level. On the macro-level, users can navigate through the hypervideo structure and select individual content elements. On the micro-level, users control the playback and the display of information within a specific content element. This includes standard VCR functions and annotations that enhance a video clip. Before the redesign, all micro- and macro-level functions were placed in a single panel at the bottom of the player. The title of the currently played video clip was not visible for the viewers. The redesigned player consists of two control panels (see Figure 1). The top panel contains all elements for macro-navigation in the video structure. Besides a TOC button at the left side, the top panel has navigation buttons to the previous and the next scene, a search button, and the full screen button. The title of the current scene is displayed in the middle of the panel. The table of contents opens in full screen mode above the video and pauses the playback (see Figure 2). The results of the keyword search are displayed on the right side (see Figure 3, right). A selection panel opens at the left side of the player area at the end of each video clip and allows users to choose

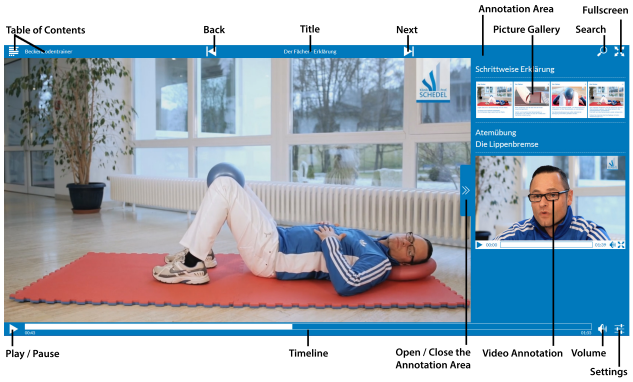

Fig. 1. The player with two control panels (at the top and the bottom), and one annotation area on the right side.

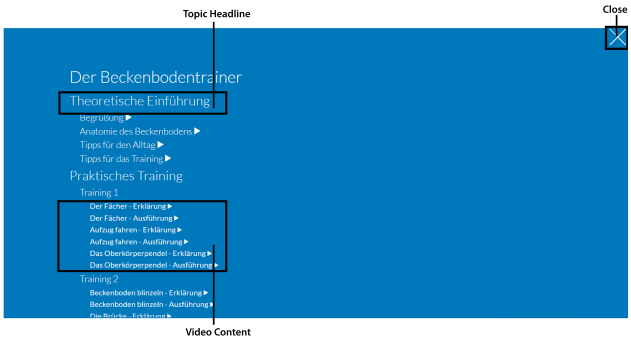

Fig. 2. The player with the table of contents.

the following clip (see Figure 3, left).

The bottom panel contains a play/pause button and a timeline for the micro-navigation within the scenes. It furthermore includes the volume control and the settings button (see Figure 1, bottom). The playback can also be paused and restarted by clicking on the video image itself. At the end of each scene, a replay function allows users to repeat the scene. The player has one annotation area (see Figure 1, left side). Here, additional information such as texts, images, or videos are displayed. With the flap on the left side of the annotation area users can open and close the additional content. Picture galleries and video annotations can be maximized by the user. Apart from the interface, also the design of the content elements and the hypermedia structure have a major effect on the usability and utilization of the application.

5. USER TEST/EVALUATION

Based on the current state of research, the effects of structuring videos in a hypermedia network are still uncertain. Therefore, it is the aim of the present study to investigate the effects of the hypervideo structure on:

- the usage of the functions of the hypervideo player,
- the occurrence of usability problems during the usage, and
- the utilization of the hypervideo player for a self-determined training.

Fig. 3. Search area (right side) and selection panel (left side).

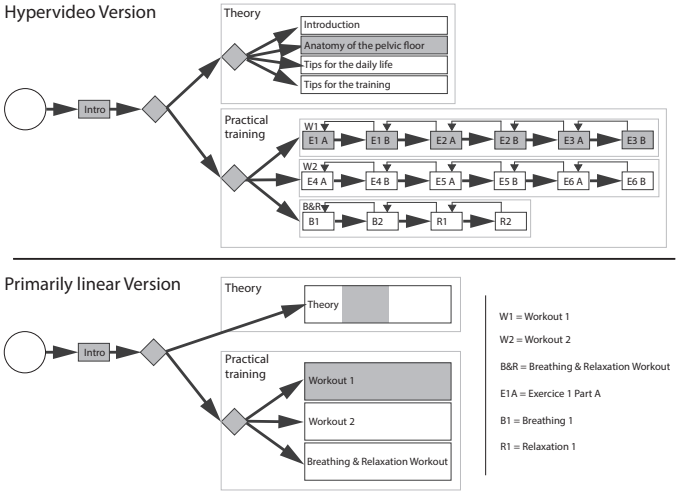

Fig. 4. Structures of the two versions of the pelvic floor trainer.

5.1. Hypervideo Content & Structure

The pelvic floor trainer has two workouts, each containing three pelvic floor exercises and a workout with breathing and relaxation exercises. Each pelvic floor exercise consists of two parts, the first part explains the correct execution of the exercise. During the second part, the patients perform the exercise while the narrator guides them. The application also contains four theoretical units that offer anatomic background knowledge, information on how to deal with incontinence, and how to conduct the training.

To test the effect of the hypermedia design, we created two versions of the application that contain the same content, but have different structures (see Figure 4). In the hypervideo version, each of the four theoretical units and each part of an exercise was an individual clip. These clips could either be selected using the TOC or the selection panels. The hypervideo was compared to a primarily linear version. Here, the content was only divided in the main sections "Theory", "Workout 1", "Workout 2", and "Breathing and Relaxation Workout". To navigate between individual units and exercises within the four linear clips, patients had to use the micro-level navigation. In both versions, the video was enhanced with additional content in the annotation area. Two picture galleries were added to the theoretical unit "Anatomy of the pelvic floor". Furthermore each pelvic floor exercise in "Workout 1" was enriched with a picture gallery. Additionally, the hypervideo version had video annotations with a relaxation exercise for each pelvic floor exercise.

5.2. Study Design & Procedure

The study uses an experimental design. Patients were recruited by the rehab clinic. To be eligible for the study, patients had to a) be fluent in German, b) have surgical removals of the prostate and c) have at least minimal experience using a computer. By the end of the recruitment process 39 patients agreed to participate in the study. Later, four patients were excluded, because they lacked basic computer skills. The experiment was conducted in patient rooms that where equipped with a gymnastic mat and ball. One member of the research team and a therapist were present to observe the usage behavior. The patients accessed the application with a laptop computer. After an introduction into the functioning of the pelvic floor trainer, patients were given detailed instructions for the test session. They were asked to first select the theoretical unit "Anatomy of the pelvic floor" and then execute "Workout 1" in the practical section. The playback time for the compulsory content was 18 minutes and 15 seconds (highlighted in figure 4).

To complete the session, users of the hypervideo version had to navigate with the selection panel and with the TOC. They had to make a selection after each theoretical unit and after each part of an exercise. During the session they had to interact at least ten times with the application. In contrast, users in the primarily linear version could only select the four main clips with the macro-navigation. Within these sections, the content was played back continuously. Patients had to use the micro-level navigation, to select an individual exercise or unit within this broader sections. In the course of the test session, they had to interact at least four times with the application.

It was the aim of the experimental arrangement to find out, how the different versions influence the utilization of the pelvic floor trainer in a self-controlled training session. Patients were asked to use the application in a way that supported their individual preferences. They were encouraged to pause the playback, repeat exercises, select additional content and integrate relaxation exercise whenever needed. This optional interaction with the application allows users to adapt the flow of information and the course of the training session to their individual needs.

5.3. Measures

Participants first completed a questionnaire including demographics and internet competence. During the test session, the use of the application was observed and documented using a standardized observation sheet. Conventional video is often used in a passive and lean back fashion. For the deployment in the training scenario we wanted to trigger a more active engagement with the provided content. In this study activity was first measured as the number of interactions with the interface. Second, we wanted to know, whether the patients actually use the various functions provided by the hypervideo player. Therefore we also measured the number of different functions that were used during the test session. The objective usability was evaluated based on the observed usage behavior. For each interaction with the application we rated, whether the patient had any problems identifying and using the function. Furthermore, we also analyzed whether the patients were able to utilize the application for a self-determined training. It was evaluated how the various functions of the application were used by the patients to select individual content elements and to control the flow of the video. In addition, it was analyzed whether the patients used breaks between the exercises to react to external circumstances and insert relaxation exer-

Table 1. Usage of the different versions.

Version		Duration (min)	Used functions	User interactions
Hypervideo	M	28.17	4.39	27.11
(n=18)	SD	4.96	1.38	12.99
Prim. linear	M	30.38	3.29	13.94
(n=17)	SD	8.31	1.72	10.40

cises. After the test-session a subjective evaluation of the usability was obtained using a questionnaire. The measurement is based on the dialogue principles stated by ISO 9241-110 including suitability for the task, self-descriptiveness, suitability for learning, conformity with user expectations, suitability for individualization and controllability.

6. EVALUATION RESULTS

The 35 patients had an average age of 64.5 years. Twelve of them had completed a university or college degree and seven had a higher education entrance qualification. 13 Patients either had secondary school level or a completed apprenticeship. Two patients only completed primary school. All of the participants had experience using the internet.

6.1. Usage of the Pelvic Floor Trainer

The test session revealed considerable differences in the usage of the two versions. While the 17 users of the primarily linear version needed 30.38 minutes to finish the test training, the hypervideo group completed the training in 28.17 minutes on average. Despite the longer usage time, patients in the primarily linear version used fewer functions and interacted less with the application (Table 1). Results of a one-way analysis of variance (ANOVA) show that the number of used functions, F (1, 33) = 4.33, p = 0.045, and the number of user interaction, F (1, 33) = 10.85, p = 0.002, differs significantly between the two groups.

There are also differences in whether and how the functions of the application were used (see Table 2). While all 18 patients in the hypervideo used the TOC, this was only true for 10 users in the primarily linear version. The next button was used by three users in the hypervideo and one user in the primarily linear version. The macro-level navigation allows the patients in the hypervideo version to select individual content elements while the patients in the primarily linear version had to rely on the timeline to select individual content elements within a continuous clip. Therefore, the more intensive use of the macro-level functions in the hypervideo group is not surprising. To perform the test session as indicated in the instructions, patients in the primarily linear version had to use the timeline at least once. Nevertheless, only eleven of the 17 patients actually used this function (Table 2). In this version patients also had to use the play/pause function to stop the video after each exercise. Despite this, the play/pause function was only used by seven of the 17 patients in the primarily linear version. Users had the possibility to close and reopen the annotation area. This was done by eight users in the hypervideo version but only by three of the other users. The picture galleries were used more often in the hypervideo version. Video annotations containing relaxation exercises were only available in the hypervideo version. Nine of the 18 users used the video annotations at least once during the training session.

Table 2. Number of patients that used a particular function.

Version	TOC	Back Button	Next Button	Timeline	Play/ Pause
Hypervideo	18	3	3	5	8
Prim. linear	10	3	1	11	7

Version	Replay	Anno. Area	Picture Gallery	Video Anno.
Hypervideo	2	8	7	9
Prim. linear	2	3	5	—

Table 3. Number of patients that encountered usability problems.

Version	TOC	Back Button	Next Button	Timeline	Play/ Pause
Hypervideo	9	3	0	1	2
Prim. linear	0	2	1	4	0

Version	Replay	Anno. Area	Picture Gallery	Video Anno.
Hypervideo	2	0	2	4
Prim. linear	1	0	0	—

6.2. Usability

During the test session users encountered some usability problems (Table 3). In both versions, users had problems using the back button. Most users assumed the back button would bring them to the beginning of the current clip and were confused by the starting of the previous clip. Many of the problems in the hypervideo group occurred while using the TOC. Five users had problems finding the button or were not aware that they had to use the TOC to move from the theory to the practical section. Six users tried to click on the headline "Workout" instead of selecting the first video clip in this section. In the primarily linear version users did not have to use the TOC to complete the test sessions. Not finding the TOC button did not result in any observable problems. Furthermore, the table of contents only contained four entries that were all selectable.

Users in primarily linear version had more problems using the timeline than the users in the hypervideo version. It was especially difficult for them to find the starting point of a specific exercise. In the hypervideo version one patient wanted to jump within a clip but needed the help of the experimenter to find it. Two patients in this group also had problems with pausing and restarting the video. In both groups, patients had problems using the replay function at the end of a clip. The function was not marked properly, so the patients either used the function by accident or thought they would start the playback of the next clip. On average, users in the hypervideo version encountered 1.61 (SD = 1.09) different usability problems while the users of the primarily linear version had only 1.06 (SD = 1.02) problems with different functions during the session. Especially advanced functions that extend the functionality of standard video applications caused problems. However, the observed differences in the number of usability problems did not reach statistical significance $F(1,33)$ = 2.67, p = 0.134. As Table 4 indicates, there is a significant positive correlation between the user activity and the occurrence of usability problems for the primarily linear version. This relationship can not be found within the hypervideo version.

Table 4. Correlation between User Activity and Usability.

Usability Problems	Spearman's rho	Used Functions	User interaction
Hypervideo	Corr. coefficient	0.020	-0.125
(n=18)	Sig. (2-tailed)	0.937	0.620
Prim. linear	Corr. coefficient	0.616**	0.714**
(n=17)	Sig. (2-tailed)	0.008	0.001

Note: ** Correlation is significant at the 0.01 level (2-tailed).

In addition to the objective measures, users were asked to subjectively rate the usability of the pelvic floor trainer after the test session. Both versions were rated as very good: The primarily linear version reached an average of 2.19 (SD = 0.621), while the hypervideo version had a mean of 2.33 (SD = 0.810). Again, these differences are not significant, $F(1,33) = 0.323$, $p = 0.573$.

6.3. Revision of the pelvic floor trainer

On the whole, user were comfortable in using the pelvic floor trainer and rated the usability very good. Nevertheless, the test session revealed flaws in the hypervideo player that can be eliminated with minor changes in the interface and the hypervideo design. In order to help users find the TOC, the label of the button was changed from "pelvic floor trainer" to "table of contents". The test session also revealed that users expect all entries in the TOC to be selectable. We therefore transformed the section headings into clickable elements and linked them to the first clip within this section. The functioning of the back button was changed, and now restarts the current clip. Only if the users press the button within the first three seconds of the playback, the player moves back to the previous clip. Results also indicate that the selection panel should allow users to navigate through the whole hypervideo. To achieve this, the hypervideo structure was reworked so that users can move from the theoretical to the practical section with an additional button in the selection panel. In the test session most users weren't aware of the possibility to pause/play the video by clicking on the video. Therefore we inserted a play symbol over the paused video image. The replay function at the end of each video clip is now indicated by a dedicated replay button. After the implementation of these changes, patients should be able to use the pelvic floor trainer without encountering the described usability problems.

6.4. Utilization for a self-controlled training

In a realistic usage scenario, the pelvic floor trainer should support patients in conducting a self-determined training. This includes selecting individual content elements, navigating within the video clips, and integrating pauses and relaxation exercises into the course of the training. The two versions of the application offered different options to select individual content elements. To investigate the effect of these mechanisms, patients were asked to directly navigate to the "Anatomy of the pelvic floor" in the theory section. While patients in the hypervideo version could select this clip with the selection panel or the TOC, users of the primarily linear version had to use the timeline. As Table 5 indicates, the majority of patients in the later version did not follow the instruction but watched all four units of the theory clip without an active selection. In contrast, most of the hypervideo users made an active choice. They either exclusively selected the "Anatomy of the pelvic floor" or chose to watch one or two other theoretical units as well. A Chi-Square-Test shows

Table 5. Selection of content.

Selection	**Hypervideo**	**Prim. linear**
No Selection	5	11
Partial Selection	8	2
Exclusive Selection	5	4

Table 6. Patients that used the breaks within the training.

Patients use automatic or self-controlled breaks to ...	**Hypervideo**	**Prim. linear**
adapt the setting.	6	3
react to external circumstances or ask questions.	7	4
do relaxation exercises in between the exercises.	12	0

that the difference in selection behavior is close to significant, $\chi^2 = 5.94$, $p = 0.051$. After watching the theoretical unit, patients were asked to complete "Workout 1". In the hypervideo version all patients used the selection panel and 12 patients additionally used the TOC to select an individual exercise. In the primarily linear version only seven patients used the timeline to jump to the starting point of the individual exercise.

In both versions, patients could use the timeline to repeat or skip parts of a content element. Four patients in the primarily linear group and six in the hypervideo version used this opportunity. In the hypervideo version, the playback paused after each part of an exercise. Patients could use these breaks to watch annotations, adapt the training setting, talk to the therapist, or do relaxation exercises. In the primarily linear version patients had to actively use the pause button. As illustrated in Table 2, only seven of the patients in this group used the pause function to interrupt the playback. As a consequence, the number of patients that made relaxation exercises between the pelvic floor exercises was higher in the hypervideo version than in the primarily linear version (see Table 6). There was also a greater number of patients that interrupted the training to react on external circumstances or pose questions to the therapists. Some patients also used the break to adapt the training setting e.g. they repositioned the computer or moved from the gymnastic mat to the gymnastic ball. In the primarily linear version almost all patients adapted the setting without pausing the playback and therefore missed parts of the instructions.

7. CONCLUSION AND DISCUSSION

The presented research aimed to contribute to the understanding about the design of hypervideo and players for hypervideo. It investigated the effect of hypermedia structures on the usage, usability and utilization of hypervideo. The results of the observation show that patients in the hypervideo group encountered slightly more problems. Nevertheless, this did not effect the subjective evaluation of the usability. The patients in the hypervideo groups used the pelvic floor trainer in lean forward fashion will. They interacted more often with application and used more functions. In the primarily linear version users did not interacted much with the application. Here, a higher user activity was correlated to a higher amount of usability problems. This indicates that the users of primarily linear version did not have fewer problems because they handled the application more

easily, but because they avoided interaction with the application.

Apart from usability, the study also investigated the effect of the hypermedia structure on the utilization of application for a self-determined training. The observations show that the active usage in the hypervideo version led to a more individual and reflected training. Patients in this version tended to select individual content elements, navigated more within the video clips, and used the breaks between the exercises to integrate relaxation exercises. In contrast, the primarily linear version resulted in a more passive usage.

Patients in both user groups encountered 1.3 different usability problems on average. This finding must be interpreted, taking the special characteristics of the test users into account. The patients had a high average age and only a minority of them had competences in using online video applications. Thus, they constitute a critical user group for digital information systems. In contrast, it can be argued that a younger and more internet-savvy user group would have had fewer problems. It is also important to bear in mind, that the patients used the application for the first time. Many of the observed problems might vanish after users gain some experience in using the pelvic floor trainer. In a realistic usage scenario, patients would receive the e-health application from the clinic that is in charge of the rehabilitation program after surgery. A guided introduction and the ongoing support during the rehab could help to overcome initial usability problems and make the application usable even for patients with little internet competence. For a long-term usage the capacity of the hypervideo version to facilitate a more active and individual training is crucial. Patients should be encouraged to reflect their individual needs and physical condition when planning their specific training sessions. The application should provide easy access to individual exercises and allow users to repeat exercises and insert relaxation into the course of training. It can therefore be argued that the hypervideo version is more suitable for a long-term application of the pelvic floor trainer in a realistic rehabilitation context.

8. LIMITATIONS AND FUTURE RESEARCH

In this paper we investigated the effect of hypervideo structures on the usability and utilization of an application that supports the execution of physical exercises. Due to the experimental setting, the study only investigated short-term effects in a controlled setting. The extensive test sessions and analysis of the usage behavior allowed us not only to estimate the overall usability, but to gain insights into the various effects on the behavior of the patients. The time-consuming procedure, however, forced us to limit the study to a rather small sample size. This makes it difficult to reach statistically significant results. Nevertheless, the observed differences are still important, because they highlight aspects that are worth to examine in future research. The course of the test session was guided by instruction and the physical presence of a physiotherapist and a researcher might have also influenced the behavior of the participants. We can only speculate whether the effects would be persistent in a realistic long-term usage scenario. Longitudinal exploration along the rehabilitation process could better unravel how the hypervideo would be used by patients on a regular base. In future research we plan to use unobtrusive data collection methods like automatic logging to reconstruct the long-term utilization of hypervideo applications with a larger sample of patients. Furthermore, future research needs to test whether hypervideo is also capable to communicate other kinds of information.

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