“Grab-that-there”: Live Direction for Motion-based Games for Health

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Abstract
Many people suffer from a decline in their motor abilities and their sense of balance. Such complications are often related to a sedentary life style or specific illnesses. Physiotherapy can help with improving the situation, however, a lack of motivation to perform repetitive exercises, as well as achieving an adequate quality of execution and level of exertion are considerable challenges. Motion-based games for health (MGH) can motivate patients and support them in performing such exercises. But the important interaction between therapists and patients is often not sufficiently considered in MGH design and therapists’ means for intervention and adjustment of such games are limited. We integrate local live direction into MGH, enabling simultaneous adjustments by the therapist while the patient is playing. We evaluated our prototype with 9 therapists, collecting feedback on usability, user experience, and practical applicability. Our results show that the concept was received well, as evidenced by excellent quantitative usability ratings and very positive qualitative feedback.

Author Keywords
Games for health; exergames; difficulty adjustment; physiotherapy; live direction.

Figure 1: Screenshot of the therapist view.

Success of MGH

Positive outcomes regarding motivation and performance have been shown for a number of target groups, ranging from children or young adolescents with cerebral palsy [16], over amputees in phantom limb therapy [21], to people in stroke recovery [7], people living with Parkinson's disease [3], or older adults in general [10]. Medium- to long-term [23] and more clinically sound [1,2,27] studies are beginning to underline the wide-reaching positive indications of early exploratory work in this area [5,20].

ACM Classification Keywords

K.8.0 [Personal Computing]: General – Games.

Introduction

A large percentage of the population is affected by health problems that are tied to a sedentary life style and a general lack of physical activity [6]. Many suffer from a decline in their motor abilities, sense of balance, or a limited ability to flex and stretch their joints. Physiotherapy, such as *proprioceptive neuromuscular facilitation* stretching (PNF), can help with improving the situation. Yet, patients can lack motivation to perform their exercises, or they execute them poorly. In recent years, games in various forms have emerged as tools for supporting people in performing physical exercises; namely motion-based games for health (MGH), exergames, or other gamification approaches [5,20]. Such games cannot only motivate but also provide assistance, feedback, and analysis [23]. For an effective therapy it is important that the exercises are adjusted to the needs and abilities of each individual patient [13,25]. While some systems include experiments with advanced settings interfaces, or with automatic adjustments, the interaction between therapist and patient plays an important role in normal physiotherapy that is often not sufficiently considered in the design and implementation of MGH. Our work addresses this gap by integrating live direction (LD) in a MGH. With live direction, we enable simultaneous adjustments by therapists through direct manipulation of game objects while a patient is playing.

The concept was implemented in a prototypical MGH for PNF. We report on an explorative case study with 9 therapists designed to gather feedback on the usability, user experience, and applicability of the live direction approach. This work makes a contribution reporting positive outcomes regarding usability measures and qualitative feedback with LD, informing further research and developments in the growing area of MGH.

Related Work

A considerable number of research projects have investigated the promise of exergames [28] and MGH [22]. Despite the general success of MGH (cf. sidebar), there is room for improvements, especially regarding the situated real-world applicability. Personalization and the adjustment to the individual abilities and needs of the player-patients are frequently stressed as central challenges [13,25]. Generally speaking, the goal can be approached through manual adjustments (or *adaptability*), automatic adjustments (*adaptivity*), or with a mixture of methods from both areas. While difficulty menus for adaptability are a common occurrence in video games, they are often limited in expressiveness due to coarse mapping, may interrupt immersion [9], and do not support frequent detailed adjustments. More advanced configuration interfaces for therapists can tackle these challenges to some extent [22], yet they still require considerable effort and typically only allow adjustments between play sessions. Adaptivity, for example through *dynamic difficulty adjustments*, has the potential to avoid breaking immersion [9,24], and to support more frequent and nuanced adjustments. Related work has shown promising indications with such systems [8,17,18], however, adaptivity is also limited due to a lack of therapeutic insight. For example it may get caught up in local optima, and may suffer from cold-start problems [25]. Furthermore, recent work on MGH with semi-automatic adjustments has shown that, while interactions with such games can lead to functional benefits, important experiential measures, such

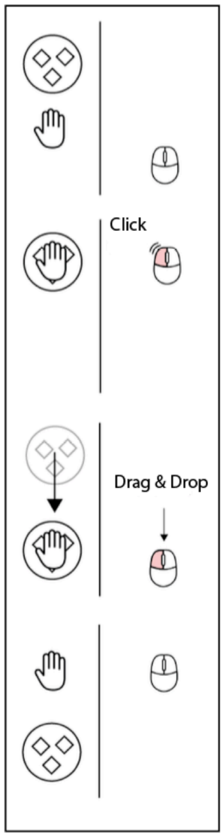

Figure 2: Drag & drop interaction for moving plates.

as *tension-pressure* and *effort-importance* as measured by the *intrinsic motivation inventory* [19] may actually be decreased compared to conventional therapy [24]. Arguably, this can be related to the more direct personal involvement of therapists with patients in conventional therapy sessions compared to sessions using MGH [24].

Related work on *game orchestration* in video games offers an interesting perspective in this regard [14]. Here, one player assumes the role of a game master [26] who controls a variable number of aspects of a game that is played by another person. While level editors or modding can facilitate a similar directive function, Graham et al. [14] specifically investigate real-time control of events by a game master who is observing a live play session and interacts with it, showing that such games can induce largely positive game experiences. Such real-time adjustments can influence many aspects of a game, including the type and form of actions required by players, as well as the game difficulty, while also deeply engaging both the player and the game master. This motivated the exploration of the concept in the context of MGH for physiotherapy with patients as players and therapists as game masters. This will be detailed in the following section. While general social aspects around MGH (e.g. in the context of cooperative or non-cooperative multiplayer) [15] and (difficulty) adjustments [11] have been the subject of a growing body of research, explorations of the therapist-to-patient interaction model as an abstract form of multiple-actor play have not yet been reported.

Interaction Design and Game Concept

Our work is based on general principles of user-centered iterative design. We conducted initial expert interviews with three physiotherapists. The therapists suggested the use case of PNF stretching, since it focuses on simple stretching motions and movement patterns that can be combined in flexible ways. Therapists also emphasized that a quick setup phase and easy-to-use controls would be crucial.

The interaction design is based on a co-located two-screen setup: the player-patient view is presented on one screen, typically a large monitor or projector. The therapist view is presented on a different screen, usually a standard monitor or notebook display. The patient plays the MGH and performs the exercises while standing in front of the large screen, being tracked by a Kinect or similar device. For increased flexibility, the screens are served by separate game instances either on the same machine or on different computers with a network connection. The therapist can use the mouse or a touch-screen to simultaneously create, adjust, and remove game objects while the patient is playing.

The gameplay idea is centered on baking a virtual pizza. The goal of the game is to put different ingredients on the pizza (Figure 1). To do this, the patient has to pick the correct ingredient from a plate using motion-based input to put it onto an appropriate spot on the pizza, which is outlined by different placeholders matching the shape of the ingredient. The therapist can adjust the location of the plates with the ingredients (Figure 2) and the location and ingredient type of a placeholder on the pizza in real-time and simultaneously using simple drag-and-drop mouse or touch controls (Figure 3). Thereby, therapists can lead the patients to perform specific exercises and control the difficulty by moving the plates and adding ingredient spots at spe-

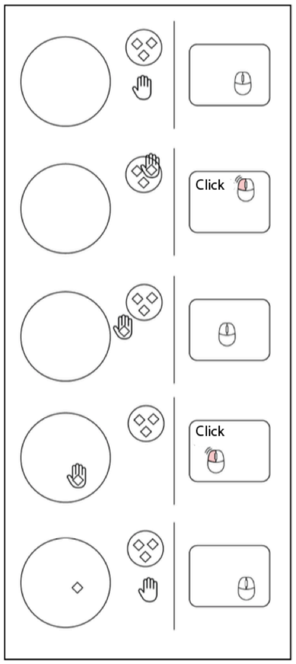

Figure 3: Drag & drop interaction for placing ingredient spots.

cific positions on the pizza, effectively putting them into easy (virtual) reach or further away.

Each round starts with an empty pizza and plates placed equidistantly around the pizza. The therapist can reset the pizza without losing the plate setup during play. Motion-based input is implemented by providing an interaction space, which is centered on the player's body and scaled so that the player has to fully stretch her arms to interact with objects close to the screen boundaries. This accommodates for different body sizes and arm lengths, as well as for varying player, and sensor positioning. The player's hands are represented by hand-shaped cursors on the screen. Ingredients can be grabbed and released by bringing the hand cursor close to the location of a plate or of an ingredient spot on the pizza. Currently, the interaction with ingredients is limited to one hand at a time; whichever hand is closer to the motion tracking sensor takes precedence. Although the game was designed with PNF in mind, it provides complete freedom over how the therapists want to utilize the ingredient plates and the spots to create effective exercises. The visual design of the current prototype adopts a playful style. However, to eliminate potentially confounding variables, no other game elements or random events like scores, timers, or losing conditions were included at this point. The prototype was implemented using the *Unity* game engine (v4.6.5).

User Study

The study was setup as an explorative case study for gathering unconstrained feedback about the concept. Due to the early stage of the research, we opted against an explicit control condition. Instead, we asked the participating therapists to reflect on their daily work routine and experiences to provide feedback on the applicability of the approach. We focused exclusively on the therapist's view and decided that an assistant would act as the patient to facilitate a clear focus on the therapist perspective. The assistant simulated situations that would require intervention to guarantee that the therapists would get an understanding for the possibilities and limits of the concept and to display comparable and realistic behavior in all sessions. The study included individual interaction sessions as well as one semi-structured focus group interview.

The individual sessions consisted of a short introduction and collection of the participants' informed consent, followed by a short verbal tutorial on how to start and control the therapist's interface. A 5-10 minute "hands-on" session, followed by a questionnaire and finally a short semi-structured interview concluded each run.

The assistant received instructions to simulate the following four situations while playing: *unable to reach a plate*, *unable to reach an ingredient spot*, *easily reaching a plate* and *picking the wrong ingredient*.

The questionnaire included demographic questions, a German translation of the *System Usability Scale* (SUS), and 8 custom questions presented in Table 1. The interview aimed to gather feedback on the general impression, practical applicability, potential benefits and drawbacks, and suggestions for improvements.

The "hands-on" play session was conducted on a laptop running both game instances (patient and therapist view) over loopback networking under Windows 8 using the Kinect for Windows v1 in combination with the Kinect SDK v1.8 for tracking. The laptop was placed on a

Q1: *"It was clear how to control the game."*
Q2: *"My patients would physically be able to play the game."*
Q3: *"My patients possess enough technical knowledge to play the game."*
Q4: *"I think that with the game, a more focused and individual therapy is possible."*
Q5: *"I could imagine using the game in my daily therapy work."*
Q6: *"My patients would like the game."*
Q7: *"It takes too long to start the game."*
Q8: *"It is too complicated to start the game."*

Table 1: Custom statements included in the questionnaire to be rated on a Likert scale from 1: "strongly disagree" to 5: "strongly agree" (all transl. from German).

desk to the side of the player to provide an unobstructed view for the therapist sitting at the desk. The Kinect was placed at a height of approximately 1.1 meters and approximately 2.5 meters to the front of the player (Figure 4). A projector was used to provide the player view.

The focus group interview was structured along the same topics as the individual interviews and did not contain the questionnaires. In addition to the therapist view, the participants of the focus group interview also tried out the patient perspective for themselves for 5-10 minutes.

Overall, 9 therapists (8 physiotherapists, 1 health trainer; 4 males, 5 females) from two different local physiotherapy centers volunteered to participate in our study (both parts combined). Two participants also volunteered to participate in the focus group after doing individual sessions. One physiotherapist participated solely in the focus group interview. The participants were between 22 and 63 years of age with an average age of 43 and a standard deviation of 12.8 years.

Results

All participating therapists could successfully start and use the game. SUS scores in our study ranged from 75.0 to 97.5 (100 being the theoretical maximum) with a mean score of 90.0 and a standard deviation of 7.44. English translations of the custom questions are presented in Table 1. Means and standard deviations are shown in Table 2.

Participants generally commented very positively on the game in the individual interviews and in the focus group interview. Five therapists found the controls to be easy to use and four emphasized how much fun they had directing the game. Four therapists were sure that their real patients would like to use the game in therapy sessions, and two remarked that the game could have the additional benefit of distracting patients from pain. All therapists agreed that with a suitable layout of the plates they could reproduce patterns of the PNF approach. Five participants said that, for them, being able to move the plates and ingredients freely and simultaneously was the best feature of the prototype. One participant emphasized that is was excellent to be able to intervene directly instead of having to wait for the game to end before making adjustments.

The participating therapists had several suggestions for future improvements. They asked about the possible inclusion of the legs in the tracking and game concept and about a way to exercise balance. One volunteer remarked that the evaluated prototype was not utilizing the third (depth) dimension, i.e., motions towards or away from the screen. Other suggestions included adding weights or using other means to add physical resistance and increase the level of exertion. Some ideas evolved about how to make use of time limits or even dynamically moving plates to make the game more interesting and to increase the challenge. Participants also suggested a special level or mode to measure the patient's performance and progress before and during therapy.

Discussion

The results clearly indicate that the interaction with the system was received well. The mean SUS score represents a rating of "best imaginable", with all individual ratings being between "good" and "excellent" [4], suggesting an excellent usability for the live direction in-

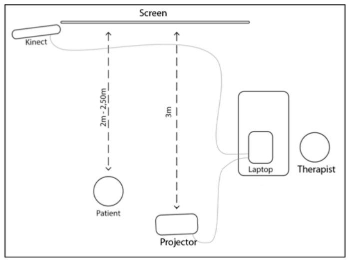

Figure 4: Schematic of the evaluation setup.

Question	Mean	SD
Q1	4.88	0.35
Q2	4.38	0.52
Q3	3.75	1.04
Q4	3.63	0.52
Q5	4.25	0.46
Q6	4.13	0.64
Q7	1.00	0.00
Q8	1.00	0.00

Table 2: Means and standard deviations for custom questions rated on a Likert scale from 1: "strongly disagree" to 5: "strongly agree".

teraction. Across all custom questions, the system received scores strongly in favor of the applicability of the prototype. The therapists reported that they could use the game to convey the targeted exercise style, that they believe their patients would enjoy using the system, and that they could in fact imagine using the system in their regular physiotherapy practice. Furthermore, they commented specifically on the positive benefits of being able to intervene directly and instantly.

The most noted drawbacks appear to stem from general limitations of current technology of MGH, such as missing physical constraints or feedback and tracking limitations. Some therapists also foresaw problems due to a lack of experience with digital technology when working with older patients. However, related work on MGH for older adults indicates that simple game designs can often be easily picked up, once initial concerns are overcome [12]. This early explorative study is limited due to not considering control conditions, nor including a rich game experience, and due to working with an actor patient instead of real patients.

Overall, this study with domain expert participants indicates excellent usability, positive projections regarding real-world applicability, and an altogether positive acceptance of the concept of life direction and orchestration in the context of MGH.

Future Work

Future work should consider studying the application of the concept with real patients (and therapists). Based on the positive indications, the effort to setup a more extensive multi-session study with more options for direction would also be justified. Any future study could compare the approach to different adjustment approaches, and include a focus on experiential measures that can be expected to relate to the level of directness of the interaction between therapists and patients [23]. The potential of an extension that allows storing setups and sequences should also be considered, in addition to an alternative physical full-body based manipulation modality for therapists. Additionally, the applicability of the concept in remote therapy sessions also presents a promising venue for future work.

Conclusion

Based on the promises of exergames and MGH we have discussed the need for personalization and the limitations of common approaches to adaptivity and adaptability with such games. We have also discussed the promising perspective of supporting closer therapist-to-patient interaction when using MGH in the context of physiotherapy. Together, these aspects indicate great potential for live direction, or game orchestration [14], where the therapists assume the role of a game master who can customize the MGH experience for a given player in real-time and at runtime. Our explorative study for the exemplary application area of PNF stretching indicated that therapists attribute a great usability and user experience to the system, highlighting the live direction as a helpful and interesting feature, and noting the potential of the approach. We thus conclude that the application of the general approach of game orchestration or live direction shows great promise in MGH and warrants more extensive future research.

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