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Research Article

DeapSea: Workflow-Supported Serious Game Design for Stroke Rehabilitation

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The design and development of a serious game are complex due to different and often numerous stakeholders involved. Different guidelines for general best practices exist, but those are not specific and often do not include therapists or patients as essential stakeholders especially in the context of individualisation of a serious games. Although there are a lot of serious games in the area of (stroke) rehabilitation, design guidelines and indications of what is important are quite scarce. Identifying individualisation possibilities to adapt a serious game to the specific needs of patients was identified to support and improve the design and outcome of serious game development. A literature research and the analysis of previously designed serious games created the foundation for this research. The identified configuration possibilities, additional requirements, and the developed workflow were then evaluated with the gathered insights of therapists trough an online survey. 20 generic configuration possibilities for therapists, as well as seven requirements, were identified and are presented, which can be used when designing a serious game in the context of stroke. In addition a workflow, called "DeapSea" is proposed for supporting the design as well. These results should be used as an addition to already established design recommendations to deliver an adaptable and flexible serious game in the area of stroke—helping to fulfill individual patient needs from the point of therapists and other involved medical stakeholders within the rehabilitation process.

1. Introduction

When suffering from a stroke, the cause is an interruption of the blood supply to the brain. As a result, the brain cells are starved of oxygen, and brain tissue deteriorates and are damaged [1]. There are different types of strokes—one type is called ischemic stroke, which happens when the blood flow of an artery to the brain becomes blocked. Another type is hemorrhagic stroke, which happens when an artery in the brain is ruptured and the blood puts pressure on it [2, 3].

Stroke is the second leading cause of death worldwide and the third leading cause of disability-adjusted life years [4]. Each year, 13.7 million new strokes are registered worldwide [5]. The mortality rate is about 5.5 million, and it leads to an average of 650,000 deaths in Europe each year [6, 7].

Stroke survivors can suffer from a variety of disabilities, ranging from paralysis, problems controlling movement, sensory disturbances, problems using or understanding languages, problems with thinking and memory, and emotional disturbances [8].

When suffering from a stroke, in most cases, rehabilitation must be conducted. Rehabilitation is a possibility to regain certain functionality. Interventions include fitness training, high-intensity therapy, and repetitive task training [9]. One of the principles for cognitive rehabilitation is that it needs to be personalized for every patient individually [10].

To encourage patients to perform repetitive tasks, game-based intervention can be used. Serious games, in particular, provide an opportunity for customized gameplay [11]. These serious games are used to bring more than entertainment aspects to players as they also contain mechanics often found in interactive media like video games [12]. Research showed that the benefit of game-based rehabilitation systems, which can be used at home, is, on the one hand, more appealing, and, on the other hand, it increases motivation for stroke patients [13].

There are a lot of serious games available in the area of stroke rehabilitation. However, for most of these games, it is unclear how they were designed and what was important, especially from the therapist's point of view. Also, the inclusion of a generalized process and workflow integrated into the patient and therapist interaction is not described in the literature yet. Therefore the so-called "DeapSea workflow" is presented together with requirements and configuration possibilities of serious games.

The following sections are structured as follows: Section 2 contains related work, Section 3 describes the methodological approach to define the proposed "DeapSea workflow," corresponding requirements, and configuration possibilities, which are outlined in Section 4 together with an evaluation and an example integration. This publication concludes with a discussion and possible future work in Section 5.

2. Related Work

This section provides an overview of already existing rules, recommendations, and frameworks to develop serious games. First, health-related solutions will be discussed, which influenced and strengthen the "DeapSea" workflow. In addition, general ideas in terms of serious gaming are also presented and discussed. To conclude the novelty and differences will be reflected.

2.1. Health-Related Solutions. A process framework for serious game development for motor rehabilitation was developed by Alcover et al. [14]. The development strategy is based on Scrum as an agile model to develop serious games for rehabilitation therapy. A five-phase process is proposed: therapy selection, interaction mechanism, interaction elements, serious game, and clinical study. For the serious game phase, the necessity to be validated by therapists and tested by real patients is emphasized to verify the effect. Also, requirements and configuration possibilities (screen distance and elements) for specific interaction modalities for the use case of Kinect hand tracking are delivered. In the developed serious game, patients have to interact with colored circles that must be deleted by touching them as quickly as possible.

From a psychotherapy point of view, a serious game design model for adolescence was described in [15]. This model consists of a game perspective and a therapeutic perspective defining different elements that need to be looked at when designing a serious game. From the gaming point of view, those are analysis (e.g., patient age), game elements (e.g., goal), game aesthetics (e.g., emotional response), player experience (e.g., immersion), and evaluation (e.g., requirements met).

de Souza et al. [16] proposed a semiotic-based approach for designing digital therapeutic games. This approach consists of methods and artifacts within four stages containing problem clarification (understanding the use context of the game), interaction modelling (use domain-specific modelling language), design materialization (sketching and prototyping), and evaluation, which should happen in all stages of development.

Recommendations for the design of video games in therapy were proposed in [17]. Based on observations of different therapists and their multiple sclerosis (MS) patients, recommendations were derived. A game should be easy to start up and configure, allowing to support the patient while playing (including adjustments during gameplay), and should enable the possibility to track the performance of the patient. It was also mentioned that difficulty levels should be configurable during the game and should be pausable.

Eleven different game designers of serious games for health were interviewed about their perceived values, challenges, and practices in [18]. The identified four success factors were direct interaction with target players, stakeholder communication and cooperation, game design elements and choices, and iterations. In addition, six challenges were identified (combination of engagement and SG goals, consolidating interests of stakeholders, evaluating the efficacy, limited resources, lasting impact, and overcoming stereotypes).

A framework for motor-impaired users (MIU) is proposed in [19] to support experience enjoyment in serious games. Their solution contains eight factors for designing a user interface that makes the MIU experience enjoyable when playing serious games. The factors are player skills (skill must match the challenge provided), challenge (the game should be challenging), concentration (concentration is a requirement), feedback (provide feedback in the game), immersion (immersion should be experienced—e.g., with audio), learning opportunities (how opportunities for learning are received by MIUs), accessibility (people with special needs should be able to use the system), and adaptability (the system will adapt to special needs of users).

Mader et al. [20] defined the play/game/therapy model for analyzing and describing their relations and designing a therapeutic game. It is stated and recommended to make such a game as interesting and fun as possible to smooth out the medical effect. Two features are identified as important in game design: challenge and variability (for longer motivation). A minimal assessment of a game's efficiency is needed. It is also advised to create personas, including extreme profiles for the targeted players. The design should always be validated by evaluating play, game, and therapy relations (e.g., can the player perform a specific task?).

The concept and evaluation of design parameters for rehabilitation showed longer playtimes and a higher level of interest [21]. Conventional design techniques were used (beating the game, scoring, operant conditioning, and feedback). Within a designed game (marble maze), a device is used that needs to be held by players where a marble needs to be controlled within a labyrinth. The goal is to utilize game design in order to maintain longer therapeutic interactions.

A game design method for therapeutic games is proposed in [32] to address the main design challenges within those games. This process contains three phases: investigating the problem with health experts (phase 1), designing the gameplay (phase 2), and prototyping the game (phase 3). The before-mentioned play/game/therapy model [20] is

also used for the first phase. This method provides guidance for every step of the design, along with tools for every design challenge.

How tailored exergames for stroke patients can be developed based on a theoretical framework are described in [22]. The identified motor learning principles are variable practice and progression. These two should be considered within a rehabilitation program. A taxonomy of motor skills with their proposed 16 skill categories for different games is also presented. Within this taxonomy, also seven difficulty levels were identified. It is stated that therapists must select individual exercises, tailored to the patient's demands (i.e., tailored to abilities and functions).

The RAGE project offers an interoperable set of components supporting serious game design [23]. Created assets (e.g., game balancing, data analytics, and language analysis) might be used to enhance the quality and diversity of serious games.

Another framework for cloud-based exergaming was defined in [24]. Although within this framework, doctors and other stakeholders can set up suitable exercises, adapt game levels, and provide insight into the rehabilitation process, and this solution does not describe in detail how and which parameters should be involved.

An overview of current requirement recommendations and guidelines for serious games for health and a proposal for a framework was discussed in [25]. The findings contain five categories of high-level requirements (e.g., methodological approach) together with 20 low-level requirements (e.g., psychological theory). Together with 5 identified stages (scientific foundations, design foundations, development, validation, and implementation), the focus lies on building strong scientific and design foundations for creative and technical development.

The design, play, and experience framework were proposed by Winn [33]. It was later on discussed in the context of health and exergaming [26] to enhance the fun and enjoyment during exergame play. Within this framework, design (mechanics), play, and experience aspects are proposed, which identify the design features and gameplay interactions that may lead to a fun or enjoyable experience.

Different design considerations in therapeutic exergaming were defined by Doyle et al. [27] focusing on visual feedback for patients stating that this can negatively affect exercise performance in terms of the feeling of confidence. Some of those requirements were identified as follows: interaction should be hands-free, minimized number of sensors should be used (setup time), feedback should be easy to add or remove, and one size that fits all is not applicable. These requirements were extracted based on a study with 8 healthy participants.

An approach for integrating game design, motor learning, neurophysiology changes, and rehabilitation provides criteria to support choosing games for patients by therapists stating that well-designed game mechanics augment patient engagement and motivation. Six key principles for engagement and motivation are extracted—rewards, optimal challenge, feedback, choice/interactivity, clear instructions, and socialization [28].

Similar research was conducted by Pirovano et al. [29], identifying three steps (requirement identification, transforming exercise into virtual exercise, and realization of exergame by adding good game design and game elements) for a safe therapeutic exergame. A four-step methodology consisting of an exercise definition, virtualization (defining input/output requirements), game design (adding game elements), and secondary goals (correct movement) is defined. It was shown that the integration of these aspects in designed balance and posture exercises and rehabilitation neglects games. Seven input parameters for specific exercises were defined (e.g., spatial accuracy and trial duration) together with corresponding output parameters (reaction time, maximum movement, and accuracy).

A framework to develop a serious game focusing on the distinctive characteristics of MCI (mild cognitive impairment) patients is the MCI-GaTE (MCI-Game Therapy Experience) framework [30]. The focus is to develop a serious game that is suitable for cognitive and physical rehabilitation. The research was based on literature research, an analysis of the profiles of residents from a nursing home, and in-depth interviews with occupational therapists. To apply the framework, the game design and development is based on four sectors: MCI player profile, representing the capabilities of the player; core gaming elements, adding gameful and playful activities; therapeutic elements, supporting rehabilitation; and motivational elements, to enhance the player's attitude. The serious game "A-go!" was developed based on the framework and the evaluation with the occupational therapists.

A serious game that is aimed at rehabilitating for upper limb motor disorders after stroke has been developed and evaluated [34]. To evaluate the effectiveness, a pilot study was performed with 8 participants who have suffered from a hemispheric stroke. One group received functional training and serious games interventions, whereas the other group only received functional training. The results showed that all participants improved significantly after the intervention and that the group with the serious game showed a more effective intervention.

An assessment tool for patients with Alzheimer's disease was based on serious games and evaluated with eighteen patients with Alzheimer's disease and a control group of twenty people [31]. The serious game is a simulation of a daily living situation, where the participant had to do different tasks. The focus of the study was to evaluate the usability and the assessment potential of the tool.

2.2. General Ideas. More general guidelines in a nonhealthcare context were also analyzed. After finding a few possible related and usable topics, it became clear that none of them can be used and did not directly influence the results of this research. A brief overview of some will be given here for a general context. Some of these concepts might be usable in very specific serious gaming settings for stroke as well but can not be used within the configuration ability, requirements, and "DeapSea" setting.

An overview of methodologies, frameworks, and models was given in [35]. 11 approaches for serious game design

and several influence factors were found (e.g., age and immersion in the analysis phase, reasonable game narrative in the design phase, integration techniques in the development phase, and game feedback in the evaluation phase). However, within the systematic literature research, only two therapeutic-related papers were identified. The main research paper is on promoting learning and therefore focused on pedagogical aspects only.

Cognitive-behavioral game design (CBGD) is a framework to create game design blueprints for serious games. This framework encapsulates psychological aspects within a game design setting and contains five elements necessary for a behavior change: knowledge, self-efficacy, goals, outcome expectations, facilitators, and impediments [36].

Abeele et al. [37] described a framework for serious game design and development. It has four pillars which are player-centered design, where players should be involved throughout the design (e.g., participatory design), iterative development, interdisciplinary teamwork (all team members participate in every step of the development), and integration of play and learning (game mechanics should be chosen to provoke a desired emotional response and aligned with serious objective). The solution was designed to help craft an effective learning experience.

A serious game design assessment framework (SGDA) was introduced by Mitgutsch and Alvarado [38]. It is argued that analyzing a game's formal design (including elements and relations) is the first step to assessing a serious game. The SGDA was based on analyzing different serious game design patterns and contained six components which are content, purpose, fiction and narrative, mechanics, aesthetics and graphics, framing, and their relation within the overall game system (coherence and cohesiveness).

Another possibility when developing a serious game is using a design pattern canvas, which was proposed in [39] for serious games. It was argued that the design pattern provides a foundation for structured research and analysis of games. It is a visual chart containing different elements: pattern purpose, mechanic, audience, consequence, collected data, related research, and ethical considerations. It is aimed at assisting the designing process of serious games with a bottom-up approach.

Ten simple rules to create a serious game were proposed by Baaden et al. [40]. Those contain, for example, the definition of a serious goal (rule 1), the adaption of level design (rule 7), or using all modalities including sound (rule 9). Those rules were defined for citizen serious games (CSGs).

Another research [41] showed insights for the participatory design of exergames with one interview of a PE teacher and three focus groups with 15 children regarding their fitness. Eight themes were identified from the interview and from them with four overlapping themes with the children. Those themes were progression, multiplayer, exertion, and reward systems. One additional finding was that children find fun more important in comparison to the teacher who focused on effectiveness.

2.3. Novelty and Differences to Proposed Solution. The presented state of the art has mostly a strong methodological focus on the whole process and is not centered on therapists and possible individualisation possibilities. Whereas here, the presented research is focusing on a methodology that is centered around the therapeutic process of exercises as well as the adaptability and refinement associated with it. Overall, there are no specific design guidelines for serious games in the area of stroke rehabilitation at all. This is also the case for specific requirements and workflows, which should be followed or integrated into the overall process. There are a lot of pieces of advice and publications in the area of education and on general serious gaming aspects, but most of this research only covers the design phase and does not provide guidance in the context of configuration and adaptability from the therapist's point of view (for stroke patients). Therefore, this work should be considered a helping tool for creating a new serious game in the context of stroke rehabilitation.

An overview and comparison of the most relevant, previously described findings, can be found in Table 1, where also different aspects are derived and classified:

(i) *Focus*: for which stakeholder group a research is intended. Microview means there are specific details present, whereas macroview means that it has more of an overview character

(ii) *Domain*: for which disease it is intended

(iii) *Type*: which type of result the research presents

(iv) *Steps and requirements*: indicating if there are steps or requirements presented

(v) *Configuration*: if configuration possibilities are present

Based on Table 1 and the state-of-the-art section, a critical discussion of how these solutions back up the "DeapSea" workflow, and their influence on its creation can be found in the Chapter 4.

3. Methods

The used methodology consists of four different phases—an initial idea, an initial research, a result, and an evaluation and discussion phase. The initial idea for the definition of the "DeapSea workflow" is the preliminary results of before developed serious games including the experience gained from designing more than 60 serious games and gamified applications in different healthcare-related areas. Within these, different stakeholders (e.g., therapists and patients) were involved and gave feedback to different aspects in the context of individualisation. The most important (published) ones, especially in terms of stroke, are listed and described below:

(i) *Serious game 1*: a mobile serious game supporting the movement, gesture, and touch rehabilitation for stroke patients. To do this exercise, just a mobile device and its integrated sensors are needed. Within the overall process also, 13 patients were involved giving preliminary feedback [42, 43]

Table 1: State-of-the-art overview of health-related solutions.

Name	Reference	Focus	Domain	Type	Steps or Reqs.	Configuration
PROGame	[14]	Development	Cerebral palsy	Framework	Yes	Yes
Serious game-based therapeutic game design	[15]	Game design (macro view)	Psychotherapy	Game design model	Not specified	Not specified
Design of therapeutic digital games	[16]	Development	Therapeutic	Framework	Yes	Not specified
Videogames in therapy	[17]	Game design (microview)	Multiple sclerosis	Requirements	Yes	Yes
Challenges in health game design	[18]	Game design (macroview)	Healthcare	Success factors	Yes	Not specified
A framework for motor-impaired users (MIU)	[19]	Game design (macroview)	MIU	Framework	Yes	Not specified
Play/game/therapy model	[20]	Game design (macroview)	Healthcare	Model	Not specified	Not specified
Design parameters in multimodal games for rehabilitation	[21]	Game design (micro view)	Stroke	Game design parameters	Yes	Not specified
Design considerations for a theory-driven exergame-based rehabilitation program to improve walking of persons with stroke	[22]	Therapist	Stroke	Motor skill classification	Yes	Not specified
RAGE	[23]	Game design (macroview)	Healthcare	Components and architecture	Not specified	Not specified
Cloud-based rehabilitation exergame system	[24]	Game design (macroview)	Chronic arm pain	Framework	Not specified	Not specified
Theory-driven, evidence-based serious games for health	[25]	Game design (macroview)	Healthcare	Framework	Not specified	Not specified
Expanded design, play, and experience framework	[26]	Game design (microview)	Healthcare	Framework	Not specified	Not specified
Design considerations in therapeutic exergaming	[27]	Patient	Healthcare	Requirements	Yes	Not specified
Design principles to enhance engagement in physical therapy	[28]	Patient	Rehabilitation	Key principles	Yes	Not specified
Methodology for the design of effective and safe therapeutic exergames	[29]	Game design (macroview)	Stroke	Methodology	Not specified	Not specified
MCI-GaTE framework	[30]	Game design (macroview)	Stroke	Framework	Specified	Not specified
Serious game-based assessment tool	[31]	Evaluation	Alzheimer's disease	Serious game evaluation	Not specified	Not specified

(ii) *Serious game 2*: the research objective was to develop a serious game using the Nintendo Wii Fit Balance Board. The patient should be motivated to shift the weight while standing on the balance board. Especially, the customization (i.e., customization of training sessions and level exercises) was a big part of this research [44]

(iii) *Serious game 3*: this serious game introduced a novel technology-enhanced rehabilitation approach with a specific focus on cognitive abilities. By doing different exercises (point and click within different rooms of a house—e.g., making coffee), the patient is training the executive functions. The therapist can define tasks, and therefore, the game can be adapted to the patient's needs within the given setting, e.g., the therapist can choose one or more rooms and select different tasks for the patient to complete. Initially intended for people with traumatic brain injuries, this solution was also posed feasible for stroke patients [45]

(iv) *Serious game 4*: this serious game uses a mobile phone to support the rehabilitation of the wrist. The patient needs to hold the device in his hand and conduct different tasks, e.g., collecting fruits, and following a lying eight. This game (i.e., each designed level) can also be configured by the therapist. Initially intended for people with this specific injury, this solution was also posed feasible for stroke patients as well [46]

After the initial idea phase, an initial research, results, and an evaluation and discussion phase were conducted. During the initial research, a state-of-the-art review revealed design guidelines, workflows, and related serious game creation techniques generally available (also including other domains—e.g., learning) and in the context of stroke rehabilitation.

In the result, phase three main results were obtained. The focus was to extract configuration possibilities (result 1: R1), i.e., what can and should be configurable for a therapist to adapt different aspects of a serious game to fit the individual needs of patients. These were based on the preliminary results of the design of previous serious games including feedback for customization. To include the therapist within the adaption of a serious game (and to define the configuration possibilities) a process workflow (result 2: R2), which is called "DeapSea", is proposed. As an additional result, different requirements (result 3: R3) were derived and also included to be used for the overall development process in the context of serious gaming.

In the last phase—the evaluation and discussion phase—as an example integration for results 1 to 3, a mapping to an already existing serious game is done to see how those identified configuration possibilities could be included. Afterwards, an evaluation was conducted with an online questionnaire and was sent out to different stakeholders involved within the rehabilitation process of stroke (e.g., therapists) to get preliminary feedback for this proposed workflow and requirements.

Table 2: Evaluation participants.

ID	Role	Age	Gender
P01	Clinical psychology	32	F
P02	Psychology	42	F
P03	Psychology	25	F
P04	Occupational therapist	28	F
P05	Occupational therapist	33	F
P06	Occupational therapist	26	M
P07	Physiotherapy	41	M
P08	Physiotherapy	23	F
P09	Physiotherapy	58	F
P10	Physiotherapy	40	F
P11	Physiotherapy	21	F
P12	Occupational therapist	28	M
P13	Physiotherapy	36	M
P14	Therapeutic training	38	M
P15	Physiotherapy	26	F

The feedback from 15 people (see Table 2) with the help of a questionnaire showed a positive trend regarding all the proposed aspects.

Finally, all results were discussed, and conclusions for future work were derived (see Figure 1 for an overview of this process).

4. Results

As a result, a total of 20 configuration possibilities (abbreviated with a "CP" prefix), 7 requirements (abbreviated with an "RE" prefix), and a proposed workflow called "DeapSea" for serious games in the context of stroke rehabilitation (outlined in Subsection 4.1) were identified and developed.

Those results were mapped on a previously developed serious game to demonstrate how those aspects can be included (see Subsection 4.2). This section gives an overview and concludes with an evaluation of the configuration possibilities, requirements, and workflow (see Subsection 4.3).

4.1. Configuration Possibilities, Requirements, and Workflow. The main goal of the research is to give support when asking "how to develop a serious game for stroke patients," especially focusing on the view of therapists and the interaction possibilities in terms of adapting a serious game to fit individual needs. Current literature offers no specific help and indications for the development and design of a serious game in the context of stroke. Before proposing the "DeapSea" workflow, requirements, and configuration possibilities, it is important to explain how existing state-of-the-art serious games influenced these results. Although it is often mentioned that individualisation, personalization, and adaptability to fit the patient's needs are necessary [14, 17, 19, 22, 24], there is rarely any guidance on how to do so in the context of serious games in healthcare. Specifically for the case of stroke rehabilitation, no guidelines could be found in this context. Only two articles give a very brief

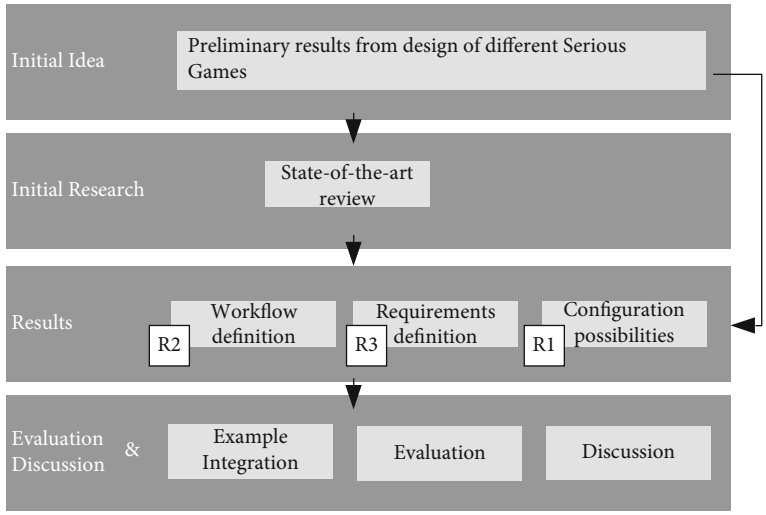

Figure 1: Used methodology.

indication of some specific configuration possibilities in the context of cerebral palsy [14] (stating screen distance and elements to be configurable) and multiple sclerosis [17] (covering adjustments during gameplay, performance tracking, and difficulty levels should be configurable and pausable). It was decided to add an option to pause the game (CP20) to the presented list here, since it was not specified in that context before. Although these are for different domains other than stroke and from a different perspective of stakeholders, the other options also fit within the proposed configuration possibilities here and are backing up its applicability. One drawback of these two solutions is that presented aspects are not generalized and defined on a very high level.

One possibility to add flexibility is the integration of a therapist, who might know the patient very well and knows the current level of ability, also within a serious game and the possibility to configure different aspects in it. In [24], this is already stated, also explicitly mentioning setting-up exercises and adapting game levels. But it is missing any insights and details on how this is achievable.

State-of-the-art applications do not cover any interaction within the workflow between patients and therapists. In [20], the direct interaction with target players is stated as a success factor, but it is not mentioned how this could be achieved and the specific role of therapists within this setting.

This is also mentioned in [19], where the skill must match the challenge provided. Giving the possibility to individually adapt the gaming experience, no configuration possibilities are mentioned, but adaptability could be delivered through different configuration possibilities. To fill these gaps and as a major intention, "DeapSea" and the corresponding configuration parameters as well as the requirements are proposed.

Based on the results of designing serious games (initial idea, phase 0) and state-of-the-art research (phase 1), the following elements are proposed to be considered while creating or adapting a serious game in the area of stroke rehabilitation:

(i) *R1*: configuration possibilities: when making a game adaptable for the involved stakeholders, some elements need to be configured to fit the individual needs of patients and to adapt the difficulty of the games. Therefore, configuration possibilities were identified and can be found in Table 3. One example of such a configuration possibility is object sensitivity—e.g., a player needs to move an object from place A to B; how accurate and near the object need to be to complete a task

(ii) *R2*: "DeapSea workflow": a generic workflow containing different steps to make a serious game in the context of stroke adaptable to fit the needs of involved stakeholders (i.e., therapists). It is suggested that each serious game in the context of stroke containing patient/therapist interaction should incorporate it as a foundation to build on

(iii) *R3*: requirements: identified functional requirements, which could be included to make an adaption of a serious game easier. The presented ones here should be included for using the "DeapSea workflow" (see Table 4 for an overview of those requirements)

The requirements, workflow, and configuration possibilities (except two) are considered sensor independent. This means they can be used in different settings with different sensors (e.g., Wii Balance Board, Metamotion) or even none (e.g., cognitive rehabilitation aspects for training executive functions). Based on the sensor types, some of the configuration possibilities are not available.

4.1.1. Result 1: Configuration Possibilities. Previously developed solutions have in common that the involved therapists, patients, and stakeholders did see potential in the enclosed flexibility when creating and adapting different gaming aspects (e.g., levels). As mentioned in the state-of-the-art Section 2, one similar solution [14] contains configuration

Table 3: Configuration possibilities.

ID	Description	Game or level setting	Sensor need	Example
CP01	Speed	Level	No	How fast an enemy is moving
CP02	Time	Level	No	How much time is left
CP03	Placing/moving objects or obstacles	Level	No	Creating walls or obstacles to jump over
CP04	Life	Both	No	How much life the player has left
CP05	Sensor sensitivity	Game	Yes	How accurate the sensor data should be used
CP06	Objects/obstacle sensitivity	Game	No	Does a user need to touch an object or is it sufficient to be near it
CP07	Objects/obstacle behavior	Level	No	Moving enemy
CP08	Achievements, badges, goals, etc. (gamification elements)	Game	No	Achievement for playing daily
CP09	Number of playable levels	Game	No	3 levels can be played
CP10	Errors	Game	No	How many errors result in failure of a life
CP11	Difficulty	Both	No	Labeling the difficulty for a specific patient
CP12	Help	Both	No	Show the easiest way from A to B
CP13	Object/obstacle physics	Game	No	When hitting the wall, the user bounces back
CP14	Overall length	Both	No	How many levels are available
CP15	Used sensors	Levels	Yes	Sensor x is only available in level a
CP16	Scoring	Both	No	Score for collecting items
CP17	Other nongame mechanics	Both	No	Selecting font size
CP18	Exercise selections	Both	Yes	Selecting the exercise, which should be done
CP19	Other specific game mechanics	Both	N/A	Other to be defined mechanics and aspects specific for a game and not fitting in the other options
CP20	Pausability	Both	No	The game or level should be pausable by the patient

Table 4: Functional requirements.

ID	Description
RE01	Therapist should be able to create (initial) game levels
RE02	Results of game sessions should be displayed to the therapists
RE03	Game levels should be adaptable by the therapist
RE04	Game levels should be able to be assigned to individual patients
RE05	Configuration possibilities should be able to be stored for individual patients
RE06	Configuration possibilities should also be randomizeable
RE07	Deliver possibilities for preconfigured levels (defaults)

possibilities for a therapist, where three configuration requirements are mentioned (set time limit, how long the player must be in contact with the object to erase it, and adjustable conditions for interaction with objects). They were designed for a specific game, but they can also be mapped here to presented configuration possibilities (CP02, CP06, CP07, and CP13), where they are worded in a generally applicable way. Therefore, the importance of these is also shown by current state of the art. In [14], it was also mentioned that the patient performance must be stored for each session, and therapists must access this information during their conducted study, but no further explanation on how this could be done is given. This also maps to the evaluation part of the "DeapSea workflow," underlining its applicability. There, the therapists has the possibility to review different results from the patient (e.g., performance).

As a result, different configuration possibilities are proposed within Table 3. It is also important to note that there is a wide range of possible gaming strategies and domains (especially in the context of stroke). Therefore, the configuration possibilities in Table 3 should be seen as a starting point for further needed possibilities. In addition, the configuration possibilities were split into a per-game and per-level configuration. Some aspects can be changed for the overall game, whereas some aspects are adaptable within the whole game or both (e.g., speed can be changed per level).

It is also important to note that these possibilities can be combined, e.g., lives and placing/moving objects can both be used within the same serious game. While creating a serious

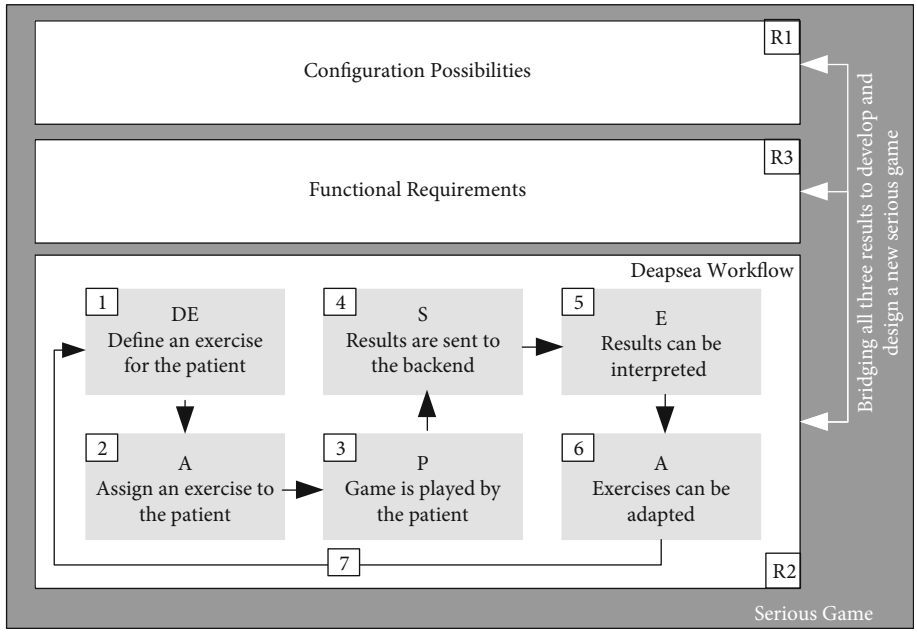

Figure 2: "DeapSea" integration into serious game.

game in the context of rehabilitation, randomization should also be considered. Given the previously designed games, it is also suggested to include randomization at least for the given configuration possibilities. This is, of course, very dependent on the game genre and involved stakeholders. For example, not every therapist would want to configure everything, even if it is possible and feasible. Because of the combination possibility for randomization, it is not stated as a single element within the given list (but is part of the requirement list).

4.1.2. Result 2: "DeapSea" Workflow. The analysis, design, implementation, and evaluation of a serious game can be a long and iterative task with different stakeholders involved, including their different goals. One major aspect encountered during the design of different games was the adaptability to fit individual patient needs by creating/changing different serious gaming aspects within different steps from time to time. Another aspect, which is also important, is the positive aspects of longer interactions with the therapist [20], which is also something achievable with the presented workflow here. To keep patients engaged, they also need to stay motivated. Motivational aspects described in the dual flow model for designing exergames were proposed in [47]. Two dimensions are described: attractiveness and effectiveness. While attractiveness represents the gameplay and psychological part, the effectiveness describes physiological and exercise aspects. Both dimensions have a flow in between, where each dimension needs to be balanced accordingly.

"DeapSea" tries to give the therapist the opportunity to fit an exercise to each patient individually and to potentially increase motivation to help them to stick to those exercises. The flow is also controllable with individual exercises, which are adapted to fit the patient's current situation and possibilities of steady difficulty increasing, based on the game results during the whole "DeapSea workflow."

To incorporate all these aspects into a serious game in the context of stroke, a workflow is proposed, which is entitled "DeapSea" (D-E-A-P-S-E-A). An overview of this proposed workflow is shown in Figure 2 and consists of the following steps:

(i) *DE*: define an exercise for the patient—an initial exercise (e.g., a combination of different levels) is set up and configured/designed by the therapist or involved stakeholders based on different defined configuration possibilities (or randomization)

(ii) *A*: assign an exercise to the patient—afterwards, the therapists can assign the exercise to the patient (or multiple patients if possible from a therapeutical point of view)

(iii) *P*: game is played by the patient—the assigned game (or individual levels of a game) is played by the patient, and different parameters are captured. Possible capture parameters are not part of the presented research and are also very dependent on the used sensors

(iv) *S*: results are sent to the backend—after a play session, the results (i.e., a combination of different parameters/game progress) are stored within the defined backend/database (or locally stored and transferred at a later point in time)

(v) *E*: results can be interpreted (evaluated) by the therapist—based on these results, the therapist can draw conclusions and decide if something in the game (the defined exercises/configuration possibilities)

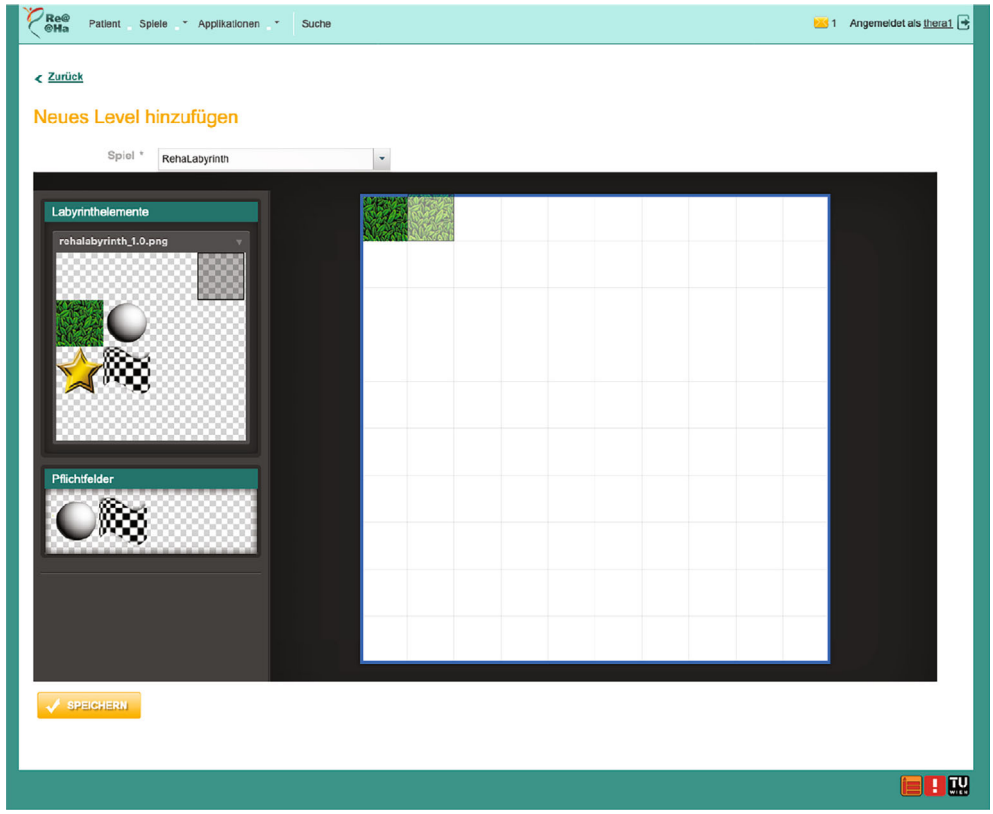

Figure 3: Create a level with different flexibilities.

should be changed. It might also be possible to conclude if an exercise is done correctly

(vi) *A*: exercises can be adapted to the patient's needs—the therapist can adjust the game to fit the patient's needs (e.g., change configuration possibilities and create new game levels). This might not just be done based on the game results—a personal evaluation and discussion with the therapist should always be conducted. Afterwards, the workflow starts from the beginning

It is proposed that this workflow should already be taken into consideration when starting to design a serious game in the context of stroke rehabilitation. Although this workflow was not formalized before, it (at least parts of it) was already used during the four examples given at the beginning of the subsection (i.e., therapists already proposed the requirements).

4.1.3. Result 3: Requirements. Since some current solutions also mention requirements [14, 17, 19, 27, 28], it was decided to specifically add requirements to add configuration possibilities to the "DeapSea workflow." Current solutions cover different aspects, but none of them covers in-depth detail indications in terms of adaptability. In addition, state of the art even mentions that adding what one person finds is encouraging and helpful in terms of feedback, another might find annoying or obtrusive [27], pointing out that each serious game needs to be unique for each user as well, giving a few examples for corresponding requirements: interactions should be hands-free, minimized number of sensors should be used, and feedback should be easy to add. From a configuration point of view, no specifics were covered nor added to the list. But the requirements stated in Table 4 (functional requirements derived from the workflow and configuration possibilities) seem to be a good addition and fitting to be added there as well.

4.2. Example Integration. The described "DeapSea workflow", configuration possibilities and requirements were used during previous serious game designs, although it was not formalized before. The before mentioned abbreviation CP is used to indicate which steps relate to which configuration possibility within the serious game. To give a better overview, an example of how different configuration possibilities are integrated into a serious game can be seen in Figure 3, where a new level can be created with drag and drop by the therapist, also defining different levels of difficulty including start and end position. In Figure 4, results of a played level are displayed including duration (time), collected points, and the path the patient took. The therapist might draw conclusions from it to change and adapt levels and see the patient's progress based on it.

This is an example from a new advanced version of rehalabyrinth (see [44] integrated into a rehabilitation framework). The therapist can create different levels (CP09) for individual patients with the help of a level editor (workflow: DE). There, he can arrange the walls of the labyrinth and define a starting and endpoint (CP03) seen as marble and

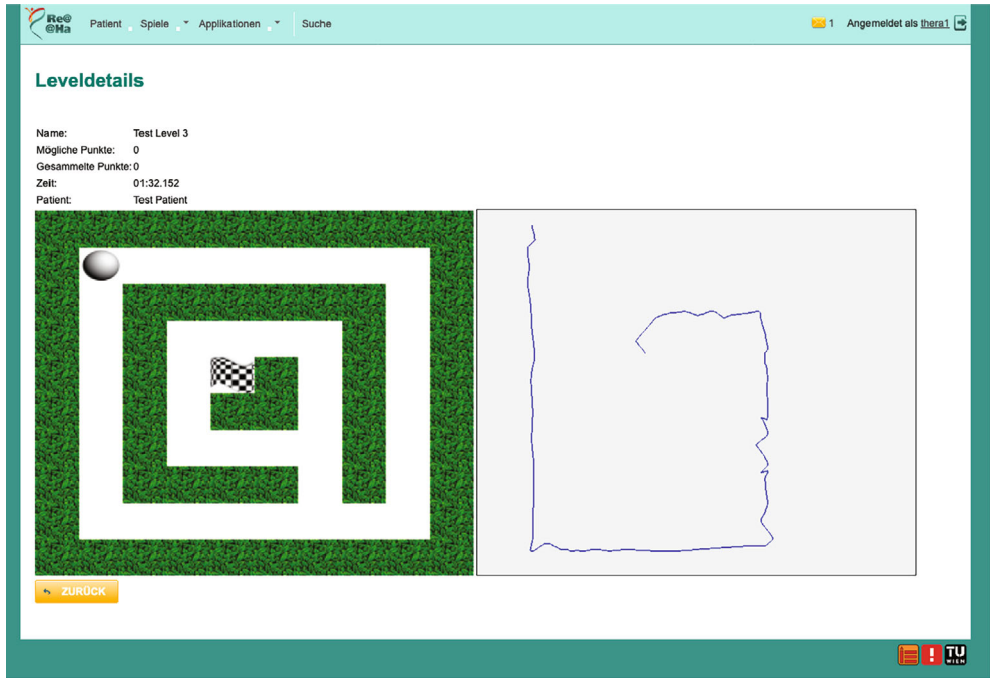

Figure 4: Review level to see how patient performed.

black hole, as well as different objects in the form of stars, which can also be captured by the patient (optional) and assigning a game difficulty (CP11). Afterwards, the exercise, which is a combination of different levels (CP14), is assigned (workflow: A) to a patient, and the patient can play the game (workflow: P). When the patient starts the game, he can configure the Wii Balance Board setting (or it is already preconfigured by the therapist), if necessary (CP05), to reach every point in the playing area. Then, the player can play the game and needs to do all assigned levels—in the given context, the whole exercise. After finishing the game, the data is transferred to the backend and displayed in the form of a movement graph—displaying how the patient moved within the labyrinth (workflow: S). When this is finished, the therapist can watch the data, which might indicate how the player performed, and talk to him. After evaluating this data, the therapist can adapt the exercises and reassign/change the levels and the overall exercise for a specific patient again (workflow: E). From a technical point of view, this serious game also features variables to set the speed of the marble (CP01) and the bouncing back of the marble if the wall is hit (CP06 and CP13) and the number of lives (CP04), which could also be used to display and to be set in the front end by the therapist as well. The game can also count back lives after hitting the walls, by adapting the configuration settings. A help function (CP12) in the form of a line or area to follow with the marble was already thought of in the context of future work but is not yet implemented.

As indicated in this example, the proposed "DeapSea workflow" can be integrated into a serious game easily with many degrees of freedom. Although most of the proposed configuration possibilities are included, not all of them are needed to be integrated into one single solution.

4.3. Evaluation. Within an anonymised google form online questionnaire, different stakeholders (physiotherapists, occupational therapists, and psychology) involved in the rehabilitation process were asked about their usage of serious games in general, feedback for specific serious games, feedback for a rehabilitation framework, and specific aspects in terms of the workflow. The questionnaire was pretested within the research group and later on distributed (mail and personal) among stakeholders who are currently involved in the research group's design of new serious games specifically asking them to also distribute it among colleagues.

The questionnaire contained 5 sections with 36 individual questions:

(i) General information and sociodemographic data (6 questions)

(ii) General serious gaming aspects (5 questions)

(iii) Description and questions to specific serious games (16 questions)

(iv) Description and questions to a specific rehabilitation framework (5 questions)

(v) Description and questions for design and evaluation in the context of the "DeapSea workflow" (4 questions)

For this research, only the first, second, and fifth sections are relevant—therefore, those questions and results will be addressed here in more detail.

Details about the participants can be found in Table 2.

Overall, 15 people answered the full questionnaire. The age ranged from 21 to 58 years (median = 32). Most of the participants were women (10) in comparison to only 5

participating men. Their work experience in the field ranged up to 38 years (median = 6). Stroke is complex and involves different types of therapy and also involves different stakeholder groups (e.g., occupational therapists). The participants were also asked if any experience regarding serious games is present, which was the case for 7 of the participants, compared to 8 with no prior experience. Mentioned serious games were RehaCom, Cogniplus-Schuhfried, MS Kognition, Freshminder, Armeo, Amadeo, COgpack, MediTutor, Agility Board, Wii Fit+, and different counting games (not individually specified) also indicating that patients who use these games give generally good feedback.

Also asking where/in which setting serious games are used—from the participants, only two said that serious games are also additionally used for home therapy as well. All others (5) who answered this question only use it together with the therapist on-premise.

Only 13 participants answered the question if there is a need to individually configure game levels for patients (2 did not want to answer this question). Of them, 7 said yes, 5 maybe, and only one answered no. In terms of adapting game levels based on gaming results, 11 answered yes, as opposed to 2 people saying maybe—2 people did not want to answer that question.

In addition to these questions, the "DeapSea workflow" was proposed, and feedback was asked in a free-text form. Overall, this workflow seemed promising for the participating stakeholders, one of them also explicitly stating that this is a very good idea and another saying that this might also be well integrable into the daily business. But some of them also argue that it might be time-consuming, and this workflow is only feasible if/when the patient is doing home exercises. If the patient is playing the game together with the therapist, the data does not have to be transferred to the backend since the therapist can see the results right away and is, therefore, able to change things immediately. Data privacy was also mentioned, and this workflow should be accompanied together by a consent form. It was also noted that this workflow might be working differently when doing stationary rehabilitation (staying longer for the rehabilitation process within a facility—e.g., staying for two weeks after a stroke) or ambulatory rehabilitation (staying just for executing exercises in the facility—e.g., once a week for one hour). Another aspect that was mentioned is that there also should be some reflection and also asking the patients how it went.

Although patients were involved during the design of different serious games (to get insights in terms of acceptance and usability), there was no specific feedback on the presented results here.

5. Conclusion and Future Work

The requirements and process for the design of a serious game in stroke rehabilitation suggest creating such by allowing flexibility in the configuration, evaluation, and adaption of available/new levels. Based on the results of the evaluation, previous serious game designs, and state-of-the-art analysis, therapists should be able to individually configure parts of a game (e.g., a level), although this should not be mandatory for every patient where default settings of a game could be used as well.

To support this flexibility, different configuration possibilities were identified and discussed. By implementing the proposed workflow into the serious game and rehabilitation setting here, benefits for therapists as well as patients might be present. Although it is necessary to do a more extensive evaluation including patients, the presented results should pose a good starting point. The workflow, configuration possibilities, and requirements are intended for all types of stroke-associated rehabilitation tasks/serious games (e.g., motor, cognitive, and speech). Due to the fact that a stroke affects different parts of the body and therefore a lot of different types of serious games and configuration possibilities might be present there, this research should be seen as an open list if deemed necessary. Different types of sensors, which are also a very important aspect of rehabilitation and gameplay, are not the main focus of this research. It might be possible that some sensors have specific requirements as well (e.g.. adjust saturation), which are not explicitly mentioned in the configuration possibilities. Although the game design and game design principles as well as motivational aspects (e.g., intrinsic motivation) play an important role when designing a serious game, those aspects are not part of this work but should also be looked into when starting to develop a serious game in general.

Within future work, it might also be possible to see differences between the rehabilitation results when using a (automatically generated) serious game compared to using a serious game with a manual adaption of different gaming aspects and levels by therapists.

As mentioned before, future research should also look into the differences between stationary and ambulatory rehabilitation in the context of "DeapSea," since this came up within the questionnaire. The proposed requirements and workflow were implemented in different serious games, and the therapist's (and, partly, also the patient's) feedback suggested a good acceptance among them. Besides the previous usage and integration, a questionnaire among therapists pointed out different positive aspects in terms of such a workflow as well as possible drawbacks (e.g., time consumption), which should be analyzed in further research as well. The differences in the usage between the patient's home exercises (i.e., playing the serious game) and playing it together with the therapist should also be considered in future work. The "DeapSea workflow" should be feasible for both scenarios, but some differences in changing the levels or the game may still arise. An example would be to adapt the speed while doing exercises together with the therapist, which is probably not possible during rehabilitation at home. In this scenario, the data should be transferred to a backend for subsequent analysis. More details in terms of possible parameters to send back to the therapist should also be considered and looked into when designing a serious game. The current workflow defines only configuration possibilities and not the analysis of the exercises. Therefore, generic parameters for analyzing exercise results (e.g., how often the patient played or how often an obstacle is hit) should also be considered. Finally, also patients should be

integrated into an evaluation gathering feedback and insights. Although some patients were involved in the design of serious games during the initital phase, giving positive feedback to these solutions, no further involvement in terms of an explicit evaluation of the "DeapSea" workflow was performed.

This research tries to formalize game design aspects from the point of view of therapists, which is intended as a starting point for a serious game in the context of stroke, to hopefully support a more flexible and better treatment through individualization of such games.

Data Availability

The data collected from the questionnaire is available upon request. Interested parties may access the data by contacting the author directly. The author can be reached via the provided contact information for the purpose of accessing the questionnaire data. Access to the data will be granted in accordance with the applicable data protection and privacy regulations. The author will ensure the confidentiality and security of the data during the process of providing access.

Ethical Approval

The research project was conducted with the utmost integrity and adhered to the highest ethical standards.

Disclosure

It is hereby declared that the research conducted as part of the employment at Technischen Universität Wien was not financially funded by any external sources. The research project was undertaken solely as a part of the professional responsibilities and within the scope of the university's employment. Furthermore, it is affirmed that the research outcomes have not been influenced by any external financial interests, and any potential biases have been minimized through rigorous methodology and impartial analysis. The research project was carried out with complete transparency, objectivity, and academic integrity.

Conflicts of Interest

The submitted manuscript is original and has not been published anywhere else. There are no conflicts of interest associated with this publication. It is confirmed that there is no conflict of interest arising from any financial funding received from any other parties involved.

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