Adapting Playware to Rehabilitation Practices

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Abstract

We describe how playware and games may become adaptive to the interaction of the individual user and how therapists use this adaptation property to apply modular interactive tiles in rehabilitation practices that demand highly individualized training. Therapists may use the interactive modular tiles to provide treatment for a large number of patients who receive hospital, municipality or home care, although the tiles can as well be used for prevention with elderly or for fitness with normal people. In this paper, we describe the extensive use of the modular tiles with cardiac patients, smoker's lung (COLD) patients and stroke patients in hospitals and in the private homes of patients and elderly. Through a qualitative research methodology of the new practice with the tiles, we find that therapists are using the modular aspect of the tiles for personalized training of a vast variety of elderly patients modulating exercises and difficulty levels. We also find that in physical games there are individual differences in patient interaction capabilities and styles, and that modularity allows the therapist to adapt exercises to the individual patient's capabilities.

KEY WORDS: REHABILITATION, PLAYWARE, MODULARITY, ADAPTIVITY

Introduction

Using artificial intelligence in digital games allow the development of games that adapt to the individual users and become personalized. A prominent example of such intelligent game technology is playware. Playware is defined as *intelligent hardware and software that creates play and playful experiences amongst users of all ages* (Lund et al., 2005). It is our view that the intelligent hardware and software may allow the playware tool to become adaptive to fit the individual user's needs and competencies, and this adaptivity may distinguish the playware tool from other play and game tools. Indeed, the intelligent hardware may allow us to create systems that can change their roles based upon a physical construction with the intelligent hardware, and the intelligent software may allow us to create systems (e.g. games) that can change their behavior based upon the user interaction with the systems.

We developed the modular interactive tiles with inspiration from modern artificial intelligence and modular robotics in order to explore flexibility in activity creation for end-users. The aim is to allow the end-user (e.g. a therapist or a doctor) to utilize her professional knowledge to adjust the technology in a fast and easy manner, for instance to the physical capability, mental capability, treatment level, fatigue level, and so forth of a particular patient.

It is our hypothesis that the inspiration from modular robotics may lead to a *highly flexible* and *easily adjustable* system for the end-user, and we investigate this with the development and practical use of modular interactive tiles for rehabilitation.

Material

The modular interactive tiles (Lund, 2009; Lund and Marti, 2009; Lund et al., 2008, Derahkshan et al., 2006) have been used in numerous experiments over the last few years for cardiac and stroke patient rehabilitation in hospitals, for therapy in children's hospitals, for physical play in kindergartens, for prevention in private homes of elderly, for physiotherapy of physically impaired in Africa, for soccer training, and music performances. The hardware of the modular interactive tiles has evolved over several generations to become the user-reconfigurable platform used for the rehabilitation experiments in this paper.

Each tile contains: one 8bit RISC Atmel ATMega 1280 processor, eight RGB LEDs, four infrared transceivers, one piezoelectric pressure sensor, and a slot for XBEE communication chip (the XBEE allows for communication to an external computer. Tiles having an XBEE chip automatically become master tiles). On the back of each tile are four super magnets for easy attachment to metal plates on walls. Connectors are formed like large jigsaw puzzle pieces (Figure 1, left), which mean tiles once linked together will not disconnect, even under heavy use. The modular interactive tiles are individually battery (Li-Io polymer battery) powered and rechargeable. A fully charged modular interactive tile can run continuously for approximately 30 hours and takes 3 hours to recharge.

The modular interactive tiles can easily be set up on the floor or wall within one minute (Figure 1). As with a jigsaw puzzle, the modular interactive tiles can simply attach to each other, and there are no wires. The modular interactive tiles can register whether they are placed horizontally or vertically, and make the software games behave accordingly.

Also, the modular interactive tiles can be put together in groups (i.e. tiles islands), and the groups of tiles may communicate with each other wireless (radio). For instance, a game may be running distributed on a group of tiles on the floor and a group of tiles on the wall, demanding the user to interact physically with both the floor and the wall.

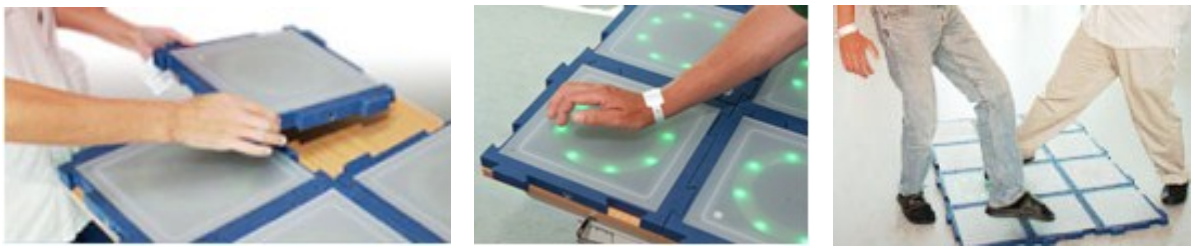


Figure 1. Modular tiles assembled and used for hand or feet interaction.

Currently there are 10 music games and 15 non-music games for both physical and cognitive training. For documentation of patients' exercises and progress, it is possible to make radio connection between the tiles and a PC with a small radio (XBee) communication USB-key. The documentation software will show time and points on the PC monitor, and collect the data in a database. Hence, the patients can follow their points directly on the PC monitor, and the therapists/doctors can collect and view the data for each patient.

The modular interactive tiles were used as a test bed for the presented work, since the modular approach allows us to make the games scalable (e.g. adapt the size of the tiles platform). One can simply add more tiles and the game will still be running, but possibly at a higher difficulty level due to the larger size of the tiles platform.

In earlier experiments with the modular interactive tiles (e.g. for play, rehabilitation and to motivate people to exercise (Lund et al., 2005; Lund et al., 2008; Lund, 2009), the same game

level was used for all players. The experiments did not look much into the difference between different players, but rather used programs that focus on being usable to as general group of players as possible. Some research has been done on classifying the players using a neural network and the results were promising (Derahkshan et al., 2006). In the present study, we focus on hardware adaptation, and how therapists may potentially exploit such adaptation possibilities in the daily rehabilitation practice (e.g. how they adjust levels by changing the physical set-up of the modular tiles).

Experiments

The modular interactive tiles have been tested as playful physiotherapy, which is supposed to motivate patients to engage in and perform physical rehabilitation exercises, with special focus on elderly training. The modular interactive tiles were tested for an extensive period of time (5 years) in daily use in hospital rehabilitation units e.g. for cardiac patients (Lund, 2009). Also, the tiles were tested for performing physical rehabilitation of stroke patients both in hospital, rehabilitation centres and in their private home. In the test cases qualitative feedback indicate that the patients find the playful use of modular interactive tiles engaging and motivating for them to perform the rehabilitation. Also, test data suggest that some playful exercises on the tiles demand an average heart rate of 75% and 86% of the maximum heart rate (Lund, 2009). The modular interactive tiles have been used in the places and periods mentioned in Table 1.

There are many challenges to prevention and rehabilitation of elderly. For instance, fall incidence rates currently pose a serious health problem for older adults. In the United States, about 40% of the population age ≥65 living at home will fall at least once each year, and the rates are much higher for persons aged >75 years and persons living in long-term care institutions (Rubinstein, 2006). The modular interactive tiles games and exercises enforce activities that combine physical training with sensory tasks and cognitive tasks. Based upon scientific findings with relation to elderly training, some of the games are designed to promote unpredictable, sudden movements, and the games allow a gradual increase of difficulty. The gradual increase of difficulty is provided in a very easy manner to the therapists and the elderly users who can simply change the difficulty level by changing the physical structure of the tiles construction, e.g. a smaller platform of tiles often provides an easier level than a larger platform of tiles for the same exercise.

Games:

A number of games were implemented for the therapists to use. An example is the “Color race” game, where patients have to chase ‘their’ color (i.e. one patient is red, another patient is blue, and so forth) which appear at random tiles. As soon as the patient hit a tile with the color on, then the color will turn off and appear on another tile, where the patient will move to hit the color. The game can be on time or on number of tiles hit (e.g. the patient who first hit 10 tiles with his/her color wins the game). Another example is the “Simon says” game. In the Simon Says game, initially a random tile lights up for one second, and the system waits for a response by the user. If the user presses the tile that lit up, the user proceeds to the next level, when two random tiles light up each for one second, one after another. The user then has to press the correct sequence of tiles that lit up. If the user succeeds, the user will progress to level three when three tiles will light up in a sequence, and the user has to press this sequence. The game continues like this level after level (i.e. longer sequences have to be remembered) until the user makes an error.

Table 1. Use of the modular interactive tiles for rehabilitation.

Place	Period	Patient group	Estimated number of patients
Sygehus Fyn Hospital	2006-11	Cardiac	>200
Svendborg Municipality	2007	Home rehab	>10
Svendborg Municipality	2009-10	Stroke	>20
OUH Svendborg Hospital	2009-11	Stroke	>30
Ringe Neurorehabilitation center	2009-11	Stroke	>60
UH Hospital Kiel, Germany	2010-11	Bone marrow transplant	>20
Neema Rehab Unit, Tanzania	2009-11	Physiotherapy	>30
Odense Municipality	2007-08	Rehab	>30
OUH HCA Children's Hospital	2007-11	Children therapy	>100

The tiles exercises address the challenges of elderly with relation to balancing, fall risk, muscle strength, reactivity, memory, attention, and concentration. There are numerous different exercises that each targets different challenges for the elderly and for specific patient groups, i.e. some exercises for cardiac patients, some exercises for stroke patients, some exercises for smoker's lung (COLD) patients, some exercises for private home rehabilitation, some exercises for brain training, etc.

For a specific patient group, the tiles exercises should be used in practices that match the individual aims of the therapist and patient. The tiles and exercises should allow set up in a flexible manner to target the individual patient needs and aims. Experiments with the therapeutic use of the modular tiles for stroke patients, smoker's lung (COLD) patients, cardiac patients and home rehabilitation patients is set up to try to verify if this is the case in the daily therapeutic practice, and the experiments are summarized below.

In 2009 we started a project with three departments of rehabilitation placed at three different hospitals in Denmark. The tiles have been part of these departments of rehabilitation from May 2009 and until now (July 2011). The new intelligent exercise-equipment is systematically used and assessed by therapists and patients connected to the three departments of rehabilitation.

The purpose of this study was to determine if our hypothesis regarding the high flexibility and easy adjustability of the system for the end-user stands. Therefore, we investigated and systemized how the tiles work as a tool in specific practices by gathering information about the users' opinions and experiences. Since we are studing a subject - the new pratice with the tiles - of which we only know roughly in advance what consists in, the appropriate research methodology for data collection is qualitative (Flick, 2009). In this study, we have been focusing on capturing both the patients' and the therapists' opinions and experiences. We have observed how the patients and therapists interact with each other and with the tiles in different training sessions. After each training session we have interviewed both the patients and the therapists and asked them questions in relating to an unstructured interview-guide and the just ended training session. We have collected data by video recording, taking notes, writing log books and by using a Dictaphone.

The target groups in this particular study have been physiotherapists and their patients who are cardiac, stroke and COLD patients. The tiles have been used for training individuals and groups of 3-4 patients with apoplexy or different heart diseases at the departments of rehabilitation at the three hospitals. The therapists have also used the exercise-tool for training groups of 9 patients at a time with chronic obstructive pulmonary disease (COLD) two times a

week. For the study presented here, the exercise-equipment has been used by 9 therapists, of whom we have interviewed five.

Tests

We have investigated how the tiles have become part of the rehabilitation praxis by following the interaction between the physiotherapists and the patients during different training sessions. Through the analysis we have found some characteristic pattern of adjustments between the physiotherapists' knowledge, the patients' individual goals and the tiles. In this section we will start by introducing one empirical case where we describe a process of adjustments. This will lead us to an overview of the different exercises we have found.

An empirical case:

The physiotherapist Mette has organized a training session for her patient Marie who is a stroke patient. Marie has a high physical level but her balance and vision on the right side and her cognition has been reduced due to her illness. The purpose of this training session is to improve Marie's balance, her cognition and her field of vision. The tiles are according to Mette obvious to use in this case because this way Marie can train more than one of the three areas at the same time.

In the table below we have listed the different exercises in Marie's training program for this session (see Figure 2).

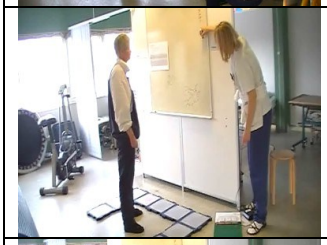
	**Exercise 1** *Game:* Colorrace - 2 minute. *Arrangement:* 8 tiles & formed as a "U". *Times:* 3 times. *Other items:* None.
	**Exercise 2** *Game:* Colorrace - 1 min. *Arrangement:* 9 tiles & formed as a "U". *Times:* 5 times. *Other items:* The blackboard.
	**Exercise 3** *Game:* Simon Says. *Arrangement:* 5 tiles & formed as a line. *Times:* 5 times. *Other items:* None.

Figure 2. Marie's training session with different physical arrangements of the modular tiles and exercises.

In exercise 1, the 8 tiles have been organized as a "U" and the game "Colorrace - 1 minute" has been inserted. "Colorrace" is a game where the player has to step on the tiles that light up. Mette has chosen this exercise because it gives Marie the opportunity to work with both her balance and her field of vision to the sides. First of all, by playing the game "Colorrace" Marie is forced to move her feet in a high tempo and when she is stepping on the tiles with her one foot she is balancing on the opposite leg. Secondly, because the tiles are arranged as a "U" Marie is forced to pay attention to the sides and not only in front of her.

The second exercise is based on Mette's evaluation of Marie's performance of exercise 1. During exercise 1, Mette observe how Marie's balance and field of vision has improved. Marie is e.g. not overlooking the lightning tiles to the sides as she did at the last training session. The result of the evaluation is that Marie needs to be challenged more. In exercise 2 the tiles are being adjusted to the improvement of Marie's physical development. Mette adjusts the tiles by adding one more tile to the arrangement. The expansion of the tiles forces Marie to work with her balance in a different way because she has to take more steps or have her legs more apart from each other than in exercise 1. To challenge Marie further, Mette introduces the element of counting. At first Mette is the one counting how many tiles Marie manage to step on for one minute and writing the result on the black board. But after a while, this task is put on Marie's shoulder. Adding counting to the exercise is a way of making Marie speed up the tempo because she wants to do better. This is also a way of training Marie's endurance and shared attention because she has to look at the tiles and step on them while she at the same time is counting. According to Mette, Marie is managing the tasks well.

The purpose of exercise 3, which is the last one in this session, is to slow the tempo down and let Marie train her memory. Mette adjusted the tiles to this goal by reducing the 9 tiles to 5 tiles and by exchanging the game "Colorrace" with the memory game "Simon Says". With the game "Simon Says" Marie is forced to slow her tempo down because she has to pay attention to the lightning pattern on the tiles and memorize where the lightning tiles are placed.

Here we have presented a case where we have described how the tiles became part of a training session because the physiotherapist could adjust them to her patient's individual needs. The way the tiles take part in different training session is through a specific adjustment to the patient's individual needs. During our investigation we have found many different combinations of exercises on the tiles.

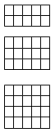
In three tables, we document the different exercises with the tiles used by the therapists for stroke patients, cardiac patients and COLD patients (Figure 3-5). For completeness, we include also the exercises from the home-rehabilitation project to make a more completely overview of the different exercises with the tiles (Figure 5, right). The results are found by the therapists, and expressed in the interviews.

Game	Arrangement	Treatment Area	Time	Participants	Result
Stepper (1 min.)		Fitness & endurance	5 times (5 min.)	One patient	Improved the patient's mobility and condition.
Lunge (½ min.)		Balance, coordination & concentration	6 times (3 min.)	One patient	Improved the patient's reaction.
Colorrace Floor (2 min.)		Fitness, endurance & concentration	3 times (6 min.)	One patient	Improved the patient's physical level.
Colorrace Wall (1 min.)		Concentration, balance & coordination	4 times (4 min.)	One patient	Improved the patient's competences to balance when the body weight is placed differently.

Figure 3. Exercises for patients recovering from cardiac attack.

Game	Arrangement	Treatment Area	Time	Participants	Result
Colorrace Floor (2 min.)		Balance & field of vision	Two times (4 min.)	One patient	Obtained more awareness to the left and the right side.
Colorrace Floor (1 min.)		Divided attention & field of vision	Five times (5 min.)	One patient	Improved the patient's capability to focus on more elements at one time.
Colorrace Floor (1 min.)		Balance	Five times (5 min.)	One patient	Improved the patient's balance on the right leg.
Colorrace Floor (1 min.)		Balance	Five times (5 min.)	One patient	Improved the patient's balance on the left leg.
Colorrace Floor (1 min.)		Balance & endurance	Five times (5 min.)	One patient	Improved the patient's balance and endurance.
Colorrace Floor (1 min.)		Balance & cognition	Five times (5 min.)	One patient	Improved the patient's ability to act on and understand instructions.
Colorrace Floor (1 min.)		Balance, cognition, endurance & divided attention	Three times (3 min.)	One patient & the therapist	Improved the patients speed and endurance.
Colorrace Floor (1 min.)		Balance & cognition	Six times (6 min.)	One patient	Improved the patient's mobility.

Figure 4. Exercises for patients recovering from thrombosis.

Game	Arrangement	Treatment Area	Time	Participants	Result
Colorrace Floor (2 min.)		Fitness, Condition, tempo & divided attention	From one to ten times. (2-20 min.)	Two or more patients. Or a combination of patients, relatives and the therapist.	Improved the patient's physical and mental condition because the patients are being physical active while they are having fun. This combination can make the patient forget about their fear for exercising due to their illness.

Game	Arrangement	Treatment Area	Time	Participants	Result
Colorrace Floor (2 min.)		Endurance & balance	3 times (6 min.)	One patient	Improve the patient's balance and physical level in their own environment.
Colorrace Floor (1 min.)		Cognition & endurance	5 times (5 min.)	One patient	Improve the patient's mobility.

Figure 5. Left: Exercises for patients with chronic obstructive pulmonary disease (COLD). Right: Home-exercises for discharged patients.

Figure 6 shows an example of how the therapists used the tiles in training sessions where exercises on the tiles have been included in order for the patients and the therapist to reach their goal. As an exercise-equipment, the modular tiles are used by the therapists in training sessions in a combination with other exercises and equipment.

Game	Arrangement	Treatment Area	Time	Participants	Result
Colorrace Floor (1 min.)		Balance, cognition, endurance & divided attention	Five times (5 min.)	A patient who has a high physical level but damages on the cognition and balance due to a stroke.	Improved the patient's ability to act on and understand instructions. Speed and endurance
Colorrace Floor (2 min.)			Three times (6 min.)		
Step (1½ min.)		Fitness & balance	One time (1½ min.)		
Table tennis		Cognition	One time (5 min.)		
Walk the stairs (Down & Up)		Fitness	One time (6 min.)		

Figure 6. A training session with focus on the patient's fitness, cognition and balance.

The list of exercises shows that the tiles are being adjusted to the patients' need when they are part of the rehabilitation praxis. The different parameters such as: the amount of tiles, the arrangement of the tiles, the games and the amount of time are parameters which the physiotherapist can fine-tune and thereby make them to some useful tools for their patients.

In interviews with the therapists, they also expressed the need for rearrangement and adjustment of exercise equipment to the individual stroke patients:

- "It is not more complicated to work with the tiles compared to other exercise-tools we use. We are used to re-arrange the set up all the time because we have to vary the exercises."
- "It is possible to adjust the tiles to the specific patient by re-arranging and shaping the tiles in different ways. This possibly is a necessity for the exercise-tool to be part of the equipment in the physiotherapy."
- "It is possible to work on more components, such as e.g. endurance, balance, view, memory and concentration, at the same time."
- "It is possible to evaluate the improvement on the patients' physical and mental level while they are interacting with the tiles."

Also, the interviews along with previous studies (Lund, 2009) suggest that most patients find exercising on the modular tiles motivational, since it is fun to compete against yourself and others.

Related Work and Discussion

There are many challenges to prevention and rehabilitation of elderly. For instance, fall incidence rates currently pose a serious health problem for older adults. In the United States, about 40% of the population age ≥65 living at home will fall at least once each year, and the rates are much higher for persons aged >75 years and persons living in long-term care institutions (Rubinstein, 2006).

Decreased balance is attributable to an age-related decline in multiple physiological systems that contributes to decreased muscle flexibility and strength, reduced central processing of sensory information, and slowed motor responses (American Geriatrics Society, British Geriatrics Society, and American Academy of Orthopedic Surgeon Panel on Falls Prevention, 2001). In addition to an increased risk of falls, diminished balance and mobility may limit activities of daily living or participation in leisure-time activities. Accordingly, it is essential that balance exercises be incorporated into the physical activity programs of older adults. Indeed, the Panel on Prevention of Falls in Older Persons of American Geriatrics Society and British Geriatrics Society concludes: "Because a large body of evidence supports the recommendation that exercise, in the form of resistance (strength) training and balance, gait, and coordination training, is effective in reducing falls, the panel concluded that exercise, in the form of strength training and balance, gait, and coordination training, should be included as part of a multifactorial or multicomponent intervention to prevent falls in older persons and may be considered as a single intervention." (Panel on Prevention of Falls in Older Persons, American Geriatrics Society and British Geriatrics Society, 2011, pp. 151).

Research shows that only single-task activities fail to place the client in an environmental condition similar to that experienced prior to and during a fall (Silsupadol et al., 2009). Hence, an exercise program should feature concurrent performance of balance exercises and additional tasks. For example, in addition to performing a physical balancing exercise, the person may simultaneously be asked to complete a cognitive task, or the dual-component training may involve combining a balance exercise with another form of physical activity, so that the multi-task balance training more closely replicates the activities of daily living in which a client's balance performance is most likely to be challenged by a disturbance. Indeed, the literature shows that an integrated exercise-training approach has been found to be effective (de Bruin and Murer, 2007). Also, researchers find that "regardless of which techniques are utilized,

altering the sensory cues available to a client is an important consideration when preparing the overall balance-training program", and that "in addition to gradually increasing the difficulty of a balance exercise, it is paramount to continuously seek novel and fun balance exercises for clients." (Dalleck, 2010).

The modular interactive tiles games therefore enforce activities that combine physical training with sensory tasks and cognitive tasks. Some of the games are consequently designed to promote unpredictable, sudden movements, and the games allow a gradual increase of difficulty.

Related to the use of technology for elderly training, the following evidence of effect can be mentioned. Nitz et al. (2009) found that utilizing interactive video games may be an effective strategy to employ with designing balance activities for elderly, and progressively incorporating interactive video games into training can increase motivation and improve balance performance (Betker et al., 2006).

Sveistrup et al. (2004) showed that the impact of virtual reality exercise participation of different groups ranged from improvements in clinical measures of functional balance and mobility, time on task, as well as participant and care provider perceptions of enjoyment, independence and confidence. It suggests that even simple applications of virtual reality have significant impacts on physical and psychosocial variables.

Sveistrup (2004) finds that technology can be of crucial importance when it integrates the means to modulate the level of difficulty, since improving the functional abilities of patients is commonly achieved by using tasks of increasing difficulty in combination with physical and/or verbal guidance of the patient's movements or actions, and concludes that the ability to change the virtual environment relatively easily, to grade task difficulty and to adapt it according to the patient's capabilities are important advantages of VR, since these features are essential to cognitive and motor remediation (Rizzo et al., 1999). The modular interactive tiles were designed to easily allow such adaptation to the individual patient's capabilities, and the training sessions show how the therapists are taking full advantage of this opportunity with the tiles.

Shigematsu et al. (2008) made important findings with the square stepping exercises. Square stepping exercise is performed on a thin mat (100*250 cm) that is partitioned into 40 squares (25 cm each, compared to the 30cm of the tiles). Patients perform different walking exercises of gradually higher difficulty level on the squares, including corrective steps in certain directions, as indicated by the instructor/therapist. Indeed, there is a whole scheme of step patterns going from elementary levels over intermediate levels to advanced levels. In all cases, the instructor/therapist needs to instruct the patient(s) on how to perform these step patterns on the thin mat.

Shigematsu et al. made numerous larger studies with control groups to investigate the effect of such square stepping exercises. In one study, they had a group of elderly to perform the square stepping exercises and a control group of elderly to perform normal walking. The statistical tests showed that the functional fitness of the lower extremities (one of the most common risk factors for falls) was improved to a greater extent in the square stepping exercise group than in the walking group. Furthermore, the perceived health status was improved in the square stepping exercise group. Hence, they conclude that the study "provides new evidence that square stepping exercise is a more useful exercise program than regular walking for older adults; thus, it may serve as a new form of exercise to prevent falls" (Shigematsu et al., 2008, p. 80-81).

This supports the therapeutic findings with the modular interactive tiles. As an important addition to the square stepping exercises, the tiles are by themselves lighting up in the pattern needed to be performed by the patient, and the tiles are providing immediate feedback to the patient on the correct/incorrect performance. Hence, the tiles are automatically instructing the patient and automatically giving feedback on the performance. This quality of the tiles is labour saving, it ensures correct movements, and it motivates patients. Further, the features of the modular interactive tiles allow for a combination of physical and cognitive training of elderly.

Conclusion

The observations of therapeutic practices with the modular interactive tiles for a variety of patient groups (cardiac patients, stroke patients and COLD patients) suggest that therapists do indeed take advantage of the flexibility that the modular system provides, as was the hypothesized reason for utilizing inspiration from modern artificial intelligence and modular robotics in the design of the system. The therapists create the activities for the patients modulating exercises and levels by changing the physical set-ups with the modular tiles system. This is indeed important in the daily therapeutic practice, which is characterized by the treatment of patients with many different, individual needs. A system should therefore provide flexibility to adjust to treatment area, activity, patient level, and patient fatigue. The observations of therapeutic use in this paper suggest that the modularity gained from the inspiration from modular robotics is one solution to provide such flexibility. At the same time, the modularity provides an ease of use, possibility of use anywhere, and robustness through distributed processing.

Having used the qualitative research methodology (Flick, 2009) in the present work, we were able to obtain knowledge on the therapeutic practice with the novel tool. Future work should focus also on quantitative research providing knowledge on the potential effect, though we acknowledge that such studies are complicated when dealing with patients with highly individual differences, such as is the case with stroke patients.

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References

American Geriatrics Society, British Geriatrics Society, and American Academy of Orthopedic Surgeon Panel on Falls Prevention. (2001) Guideline for the prevention of falls. *Journal of the American Geriatrics Society, 49,* 5, 664-672.

Betker, A. L., Szturm, T., Moussavi, Z. K., and Nett, C. (2006) Video game-based exercises for balance rehabilitation: A single-subject design. *Archives of Physical Medicine & Rehabilitation, 87*, 8, 1141–1149.

Dalleck, L. (2010) Designing Balance Exercise Programs for Older Adult, *American Council on Exercise*, June 2010.

de Bruin, E. D. and Murer, K. (2007) "Effect of additional functional exercises on balance in elderly people". *Clinical Rehabilitation*, 21, 2, 112–121.

Derakhshan, A., Hammer, F. and Lund, H. H. (2006) Adapting Playgrounds for Children's Play Using Ambient Playware. In *Proc. of IEEE Intelligent Robots and Systems (IROS'06)*, IEEE Press.

Flick, U. (2009) *An Introduction to Qualitative Research*, 4. edition, Sage Publications

Lund, H. H., Klitbo, T. and Jessen, C. (2005). Playware Technology for Physically Activating Play", *Artificial Life and Robotics Journal, 9:4*, 165-174.

Lund, H. H., Pedersen, M. D., and Beck, R. (2008) Modular Robotic Tiles – Experiments for Children with Autism. In *Proceedings of 13th International Symposium on Artificial Life and Robotics (AROB'13)*, ISAROB, Oita.

Lund, H. H. (2009) Modular Robotics for Playful Physiotherapy, in *Proceedings of IEEE International Conference on Rehabilitation Robotics*, IEEE Press, 571-575.

Lund, H. H. and Marti, P. (2009) Designing Modular Robotic Playware. In *Proc. of 18th IEEE International Symposium on Robot and Human Interactive Communication (Ro-Man 2009)*, IEEE Press, 115-121.

Nitz, J. C., Kuys, S., Isles, R., and Fu, S. (2009) Is the Wii Fit a new-generation tool for improving balance, health and well-being? A pilot study. *Climacteric*, Nov 12.

Panel on Prevention of Falls in Older Persons, American Geriatrics Society and British Geriatrics Society (2011), Summary of the Updated American Geriatrics Society/British Geriatrics Society Clinical Practice Guideline for Prevention of Falls in Older Persons. *Journal of the American Geriatrics Society, 59*: 148–157.

Rizzo, A. A., Buckwalkter, J. G., Neumann, U. (1997) Virtual reality and cognitive rehabilitation: a brief review of the future. *J Head Trauma Rehabil 12:*1-15.

Rubinstein, L. Z. (2006) Falls in older people: epidemiology, risk factors and strategies for prevention. *Age and Ageing 2006; 35-S2*: ii37–ii41.

Shigematsu, R., Okura, T., Nakagaichi, M., Tanaka, K., Sakai, T., Kitazumi, S., Rantanen, T. (2008) Sqaure-Stepping Exercise and Fall Risk Factors in Older Adults: A Single-Blind, Randomized Controlled Trial*, Journal of Gerontology*, *63A:1*, 76-82.

Silsupadol, P. et al. (2009) Effects of single-task versus dual-task training on balance performance in older adults: A double-blind, randomized controlled trial. *Archives of Physical Medicine & Rehabilitation*, *90*, 3, 381–387.

Sveistrup, H., Thornton, M., Bryanton, C., McComas, J., Marshall, S., Finestone, H., McCormick, A., McLean, J., Brien, M., Lajoie, Y., and Bisson, E. (2004) Outcomes of intervention programs using flatscreen virtual reality, *Engineering in Medicine and Biology Society, IEMBS '04. 26th Annual International Conference of the IEEE*.

Sveistrup, H. (2004) Motor rehabilitation using virtual reality, *Journal of NeuroEngineering and Rehabilitation, 1:10*.