SAARLAND UNIVERSITY

Faculty of Natural Sciences and Technology I
Department of Computer Science
Related Work Summary

Interactive technologie in slackline training

Christian Murlowski

March 2017

Advisor:
Your advisor's name
German Research Center for Artificial Intelligence
Saarland Informatics Campus
Saarbrücken, Germany

Started on 01/01/1970
Handed in on 31/01/1970

Saarland University
Faculty of Natural Sciences and Technology I
Department of Computer Science
Campus - Building E1.1
66123 Saarbrücken
Germany

Contents

While the following examples, arguments, and descriptions apply equally to both genders, for the sake of ease of reading, only the female pronouns are used in this thesis.

1 Introduction

This section presents related work to a slacklining assistance system with an interactive technology approach. It provides exercises and feedback for beginners on a slackline with the Microsoft Kinect v2 as a tracking device. Hence it is necessary to have a good overview about existing systems, approaches and studies that can help to build an appropriate concept and system. First related concepts regarding slacklining show how to build learning techniques for beginners, the efficacy of it in balance training, and areas of application. Next current tracking technologies have to be compared for tracking the human body on the slackline and why the Microsoft Kinect v2 seems like the best tracking device. Lastly the system has to be aware of cognitive load and motivating aspects, which can be challenging with repetitive exercises. Several applications show where problems occur with different feedback and interaction methods. Also design opportunities for guiding the user through the learning process are demonstrated by various approaches.

2 Slackline specific training and effects to the human body

The slacklining assistance system should mainly train and support beginners to walk on the slackline. Beyond that new skill acquisition for further training should be appropriately realised with the system. Therefore it is important to have a concrete baseline about what exercises and tips are useful for very beginners. Further research justifies the applicability for areas like sport medicine and rehabilitation training in which such a system could be embedded. It could be used as an alternative to classical balance training because the slackline itself varies largely in space and the user has to use the whole body to balance her swift on the line [23]. Donath et al. [5] found in his meta-analysis significant improvements in the postural control after slackline training, which justifies the efficacy of this training method on the human body.

2.1 Exercises during slackline training

For beginners it is difficult to walk or even stay with one foot on a slackline. The uncontrollable swift of the narrow line result in unfamiliar movements that cannot be handled at the very beginning. Therefore they should learn to concentrate, build up motoric basics, and trust into the line as well as manage their body behaviour. It is a good advise to learn the fundamentals of standing and walking on the slackline to build up a groundwork. Thoman [33] differentiate two basic methods for the learning process. Teaching without any help due to repetitive exercises or train with external assistance. The investigation of Kroiß [18] shows that providing methodological aid, like human support or physical objects as nordic walking sticks or a bar, can help to improve the learning effect (Figure 1, 2, and 3). Several basic techniques and tips are useful to support her in this way. For example focusing on a specific point, stretching out the arm, raising the hands over the shoulder level, turning the palms to the top, going slightly in the knees, have the feet straight with the line, and so on [18] [17].

Figure 1: Stick support [18]

Figure 2: between bars [18]

Figure 3: Human support [18]

With further progress, the external help should be reduced. The user can now begin to stay and walk on the line on her own. (Figure 4, 5 and 6).

Figure 4: Basic start [18]

Figure 5: One feet [18]

Figure 6: Both feet [18]

Advanced training should be practiced in a more dynamical way [33]. To practice the weaker feet for the starting procedure, a crossover start can be realised (Figure 7). Like seen in several research works [3] [4] [16] [9] [23] this can be from turning on the line, hands on hips or behind the back, walk sidewards or backwards up to catch and pass a pall, kicking a football, bouncing a basketball, or a kneel down on the slackline (Figure 8 and 9).

Figure 7: Crossover start [18]

Figure 8: Hand behind back [18]

Figure 9: Dropknee [18]

Additional cognitive load is caused by unfamiliar exercises and simultaneous balancing on the line. This conjunction can lead to impairments. Even more difficult exercises can be carried out in further sessions like standing up from a sitting position, juggling, two people on the same line, reading a newspaper, closing eyes while balancing, vertical jumps, or rope skipping. Due to the higher difficulty of constraints, it results in a more unstable movement of the line.

Changes directly on the slackline itself like varying the tension and length can also be realised [24] [16] [23]. A short and tight line results in a relatively small vibrating area, where the user has to outbalance short unpredictable movements on point. Given a longer and loose line, it results in a more swinging behaviour that she has to counteract [18].

With those approaches in mind a foundation is set to build helpful exercises for the system. Because the focus relies especially on beginners this information serves as an inspiration for supporting them with effective and efficient methods.

2.2 Slackline specific training effects and application scenarios

Donath et al. [3] elaborated the effects of slackline training on regular balancing, jump performance, and muscle activity with young children in school sport. The slackline specific balance has improved. Also the dynamic sway and muscle activity for the lower limb is reduced. But there were no effects regarding jump performance. The children enjoyed the slackline training. In comparison to classical balance training it can be more fun for the children and at the same time an effective training method.

Another study of Donath et al. [4] investigated slackline training with seniors from an age between 59 to 69 to measure effects on slackline specific balance and neuromuscular performance. They found significant differences between pre- and posttests during all slackline stance conditions. In addition the trunk and limb muscle activity were reduced after the training phase. With this in mind slacklining can be provided as an alternative balance training method for seniors. Regular balance training can help to reduce the fall risk, which can be an useful therapy for seniors when keeping in mind that 30% of seniors suffer from fall injuries once a year.

Keller et al. [16] examined the improvement of the postural control regarding the Hoffmann-Reflex after slackline training and whether adaptations can be found regarding classical balance training. The H-Reflex (Hoffmann-Reflex) is used to assess and quantify stretch-reflex responses due to electrical stimulation. The measurements show that these were significantly reduced as well as slackline specific balance were improved. Therefore slackline training and classical balance training have at least similar effects on the postural control.

Pfusterschmied et al. [23] found significant effects regarding stable stance after slackline training and even more effects were found for perturbed leg stance. This is because slacklining is a high dynamic movement activity and there is more need of regaining equilibrium as in perturbed stance than for maintaining balance as in a stable leg stance condition. The velocity in medio-lateral and anterior-posterior center of gravity, knee and hip joint is reduced as well as the range motion in knee and hip joint. No changes in medio lateral direction for the stable surface or joint kinematics for both have been found.

Another study of Pfusterschmied et al. [24] shows effects on lower limb joint motion and muscle activation. They found a decrease in platform velocity and improvements in corrective action in the knee joint. Also enhanced activation of the muscle activity in rectus femoris (upper leg) was measured.

Granacher et al. [9] investigated the impact of slackline training for balance and strength promotion and found contradictory results compared with the studies described above. Static and dynamic postural control were analysed as well as the isometric and dynamic muscle strength. There were no effects regarding the postural control, maximal torque, and jumping height. The results can be explained due to the assessment of other recorded variables, usage of different methods for analysing the data, and the relatively short slackline training time than in other studies [23]. Therefore this study can be seen as an exceptional case.

Those studie projects show that slacklining is indeed an effective method for improving the postural control. Hence many application scenarios can be thought of to implement a slacklining assistance system. For example it can be used as an training approach in school sport, preventative activity for seniors, and rehabilitation alternative. Furthermore it can be used as a supportive training method for athletes in sport activities like skiing or skating, that require a good body balance [23].

3 Appropriate tracking device

To build a real time feedback assistance system, a tracking device is needed that won't interrupt the user but supports him in an appropriate way. The Microsoft Kinect v2 seems like a suitable tracking system in this context, because the user don't need any further devices to be tracked. But it should be compared with other tracking technologies like the Nintendo Wii, Playstation Move, and a motion control suit, to justify its usage. In the following advantages and drawbacks of these systems will be discussed. Further several studies show how accurate and precise the Microsoft Kinect v2 is, if it can be applied for balancing purposes, give the user appropriate feedback, or useful analysis data for specialist like therapist.

3.1 Comparison of tracking technologies

The Nintendo Wii consists of a sensor bar with infrared sensors that estimates the position of the Wiimote controller in 3D. Further an accelerometer is integrated in the Wiimote to detect its motion. Thus the user can interact with the console, based on predefined gestures [1] [31]. Gesture recognition is an essential aspect of the slacklining assistance system for giving appropriate feedback regarding the executed exercise. Schlömer et al. [30] analyzed the gesture recognition of the Wii and found an error rate between 5% and 15%.

A similar approach with a handheld controller is followed by the PlayStation Move. It contains an RGB camera called Move Eye that is used for tracking the 3D position of a lighting sphere attached on the handheld device named Move wand. The controller contains an accelerometer, gyro sensor and geomagnetic sensor to track the rotation and also support position tracking. In this way more accurate tracking is possible than with the Nintendo Wii [1] [31].

Both systems are good devices if the controller itself can be replicated as a virtual device like for example in golf or tennis. But they do not track the body movement and the user is bound to her handheld devices to interact with the system. In the slacklining system they could disturb user standing on the slackline. Moreover accurate feedback from the whole body is wanted and thus it should be the actual controlling device. Therefore they seem not to be appropriate devices for the slacklining system.

With a motion capture suit markers have to be attached on the user's body for tracking her body motion and rotational data. This makes it the best device for high accuracy and precision body tracking. Problems with the suite occur with the inaccuracy of the position tracking and mapping into the virtual environment [1] [21]. Also it is very expensive and the setup takes relatively long time because of the marker attachment and the positioning of the tracking cameras. The biggest drawback is the uncomfortable bulky equipment that could interfere the user during the performance [2]. This makes it an inappropriate device for user tracking on a slackline.

The Microsoft Kinect is a static device that includes a RGB camera, depth camera and an infrared sensor. Because the body joints and player position are recognised by these, the user is free in her movement without any further controller. Problems occur with occlusion of body parts that results in glitches and flawed tracking [14] [32]. To the user they can be hidden by only showing the output of the depth cam [11]. This problem can be adapted to slacklining purpose and therefore a feasibility study is realised to show if these failures are a bigger problem or can be neglected. The results can be seen in section **<NUMBER>**. Anyway the recognition of the whole body, freedom of movement, short setup time and relatively low cost makes it the best system out of the stated devices.

3.2 Accuracy of the Microsoft Kinect

In the field of balance training it is necessary to give appropriate feedback for the patient that reveals errors in the performance and support a proper execution. With this in mind user tracking should be good enough to fulfil this criteria. Since Microsoft Kinect is used as the tracking device the accuracy and precision should be assessed.

Lim et al. [20] assessed the accuracy of the Kinect with a 3D motion capture system as a reference system. For further understanding please review Figure 10 and 11 regarding planes, front, and side view of the human body. The participants had to execute balance training with complex aperiodic movements in the basal plane. Similar characterization of movements are provided by the Kinect in comparison to the 3D motion capture system. The correlation analysis showed that the Kinect and the 3D motion capture system are highly correlated for the flexion-extension in the medio-lateral axis (x) but not on the anterior-posterior-axis (y-axis) and the cranial-caudal-axis (z-axis) (Figure 11). This is because the Kinect determine joint locations based on the depth image data and the data input is limited to the depth camera view. Therefore recognition in the sagittal and transverse plane is not optimal (Figure 10). Also the primary goal of the Kinect is to measure the dynamic movements in the coronal (frontal) plane for gaming reasons. It is indeed an effective system to characterize changes in center of mass and movements in the frontal plane during balance training. But it would not be suitable in balance training that require in-depth analyses of joint motions, which is not needed with the slackline assistance.

Chang et al. [2] focuses mainly on the tracking performance of the Microsoft Kinect as a rehabilitation device in comparison with a high fidelity motion capture system called OptiTrack. In their application the user has to move objects from one side of the screen to the other. Five correct and incorrect movements have been realised and both systems successfully identified them. In trajectory comparison the results of the hand and elbow by the Kinect are very close to the OptiTrack system. Tracking of the shoulder movements are moderate because

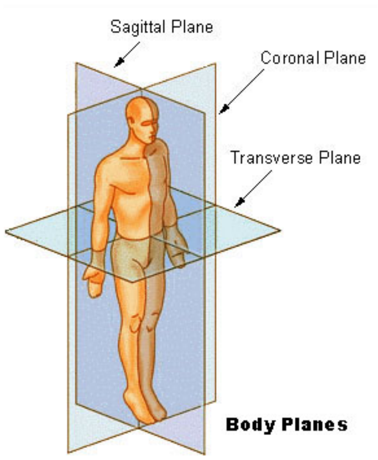

Figure 10: Body Planes [36]

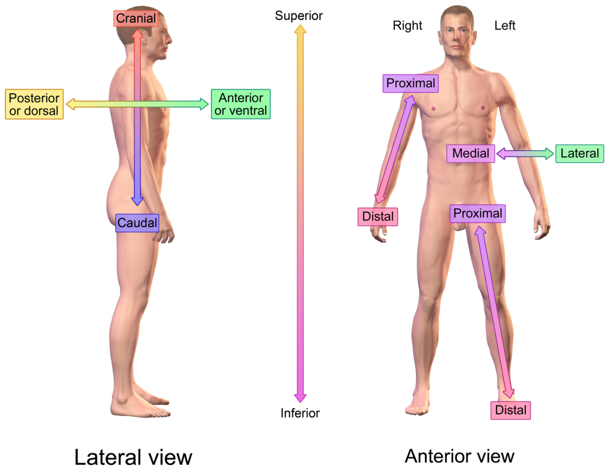

Figure 11: Directional References [36]

it involves rotation that the device does not recognizes well. The timing performance comparison shows that the OptiTrack system is negligible faster than the Kinect.

Woolford [38] compared the accuracy and precision of the Kinect v2 with the Qualisys motion capture system for the usage in healthcare applications. He describes that accuracy is the amount of how close a measured quantity to the actual value is. Precision is the similarity of repeated measurements (Figure 12, 13, 14, and 15). For example the Kinect skeleton tracking methods are accurate because the average joint position data is very close to the actual physical position. Regarding his definition of precision, the joint position data is not always precise because the data spreads in its position of the frame. The results show that the Kinect V2 is accurate but imprecise for body parts whose center of mass cannot be easily identified like the shoulder. For smaller body parts as well as between two body parts such as elbow or wrist the accuracy and precision is very high.

Figure 12: Inaccurate and imprecise system generates random-like measurements [38]

Figure 13: Inaccurate but precise system, where measurements are close to each other but have systematic error [38]

Figure 14: Accurate and precise system generates measurements that are close to the real world [38]

Figure 15: Accurate and suffice precise system generates measurements that are close to each other and are not systematically biased [38]

3.3 Implementation in balance training scenarios

Like already stated Chang et al. [2] not only assessed the accuracy of the Microsoft Kinect but also if it could fit as an alternative training device in rehabilitation training. The results show that it provides enough usable feedback to the therapists to be an appropriate device for medical uses. Woolford [38] state that the Microsoft kinect is a useful device for monitoring such exercises. The set-up is relatively easy and the tracking is appropriate for exercises in a healthcare environment. Lim et al. [20] investigated the usage of Microsoft Kinect in the field of falling risk. They tracked characterizing movements and found that it is an useful device for balance training. Ustinova et al. [34] used the kinect to improve the postural control as well as coordination deficits from chronic traumatic brain injury patients. It resulted in improvements of postural stability, movement performance and motoric coordination. The participants were also very satisfied whereas normal exercises have been stated as boring. Pisan et al. [25] used the device to investigate the prediction of the loss of balance for elderly users with a step training program. The user preferred doing exercises with the system and the tests matched also the expectation of the researcher. An integration in promoting the postural control for parkinson disease with

Kinect games were elaborated by Pompeu et al. [26] [27]. The results affirm that the patients improve in balance purposes and motoric movements with this help.

Furthermore Estapa et al. [6] and Freitas et al. [7] collected data of execution from patients for medical reviews. Both developed a motor rehabilitation game. It is used to support therapeutic exercises and evaluate biomechanics of the patients. This allows subsequent analysis of the performance data for the therapist.

This approach of data analysis was also integrated by Garrido Navarro et al. [8] but in addition they elaborate if the Kinect can serve as a rehabilitation home assistance. Many patients are thrown out of their daily life environment for accessing traditional rehabilitation training in a medical center. Here the patient incorporate the system into their daily life and avoid such trips. The medical stuff gets all relevant parameters due to the transmission of the recordings from the exercises to the medical center. Beside this they get more time because nobody has to observe the training.

Keeping the stated results in mind shows that the Microsoft Kinect is a promising system for balance exercises in a variation of fields. Sufficient accurate and usable feedback is given by the device to be an appropriate tool.

4 Feedback and interaction methods for the user

Cognitive load plays an important role if skill acquisition is a major factor. In slacklining the user has to focus on multiple things simultaneously that increases the mental pressure. The system has to be aware of this to restrict it in the right way, which results in useful feedback for the user. Another important fact is that repetitive exercises can lead to a boring and demotivating user experience. For that reason several methods, systems and game approaches can be used as an inspiration to build a system with a motivating and joyful environment. At last the integration and visualisation of feedback and interaction methods should be well thought out. Several techniques have been elaborated on how to provide this appropriately.

4.1 Restricting cognitive load

As a baseline Paas et al. [22] describes that the acquisition of new skills is in conjunction with cognitive load. By adjusting this the learning effect can be easened or hardened. Three types of cognitive loads exists that handle the working memory of a person regarding the learning process. Intrinsic load is the inherent complexity that is caused by the topic itself. It is also important in which manner information is given to the user. If this is unnecessary, repetitive or interferes him it is called an extraneous cognitive load and increases the burden of the user. The last type is germane cognitive load, which describes also how information is given to the user but by supporting the him in that way. This is brought by activating and automating already existing schemas or generating new schemas in the working memory to enhance a learning process. Regarding this several application have been evaluated that are also relevant to the slacklining supporting system.

Van der Spek [35] evaluated how to deal with the right complexity in serious games. He describes in his mental model construction (Figure 16) that interference can be avoided by information regulation and focus attention. Improving is encouraged by predictability and reflection of the tasks. The attention of the user should be focused to relevant material by regulating the information given to him. Since a serious game like approach should be developed this is an important reference for building an effective learning process to the user.

Pisan et al. [25] evaluates the user risk of falling with cognitive loading exercises. They executed two stroop tests, where the participant had to name the correct color of the word. High and low cognitive load can be measured by differentiating the meaning and color of a word. In the next challenge she has to answer different maths problems provided by the system. The results show that the reaction time due to cognitive load is much larger with users that have a higher risk of falling than for users that have a lower risk. This could be explainable due to the fact that user with higher falling risk are not that good in terms of switching

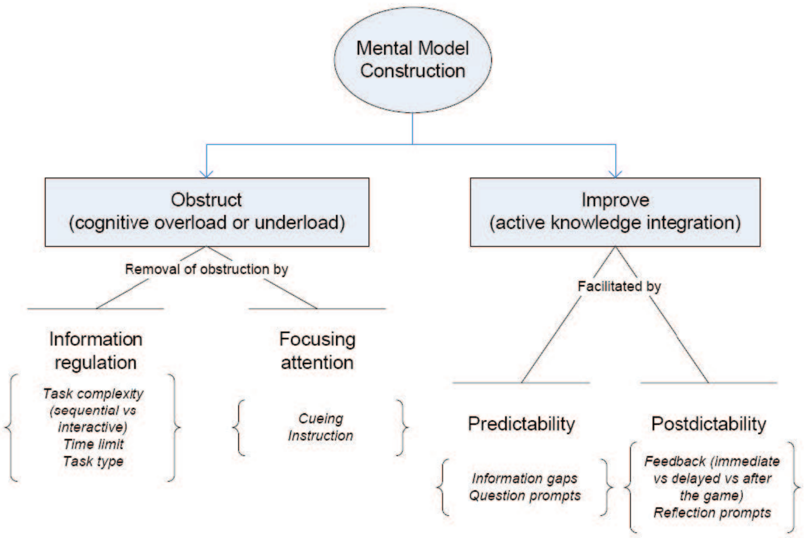

Figure 16: Guideline for enhancing the cognitive load [35]

the cognitive focus from the balancing action into other actions. Training on a slackline provides cognitive load to the user because of several simultaneously things she has to be aware of. Hence feedback given by the system on how to behave in a situation should be provided in an appropriate manner to support and restrict the cognitive capability.

4.2 Motivating factors for skill acquisition

Several rehabilitation and sport training programs can be elaborated because the skill acquisition in slacklining resemble with them. It is a process of repetitive exercise execution. For mastering new skills and extend himself a user must have the willingness and commitment for practicing, which can be described as motivation. The self-determination theory by Ryan et al. [28] [29] describes several types of motivational factors. First the intrinsic motivation, which is caused by interest to an action and satisfies the own psychological needs for self-determined behavior. This is the fundamental stimulus for high valuable learning and practicing. Second the extrinsic motivation that is performing an activity because of an external output. The user can hereby feel externally propelled due to compliance with external regulations or she can be self-endorsed due to willingness and acceptance by the value of the practice.

Johnson et al. [13] stated regarding rehabilitation training that if exercises and the user himself provide negative factors like boredom, repetition or long execution time it results in a discouragement. Enhancing the interaction with this trainings can lead to effective training. Pisan et al. [25] says that video games can help to motivate the patients through their physical training. The participants in his user tests found the games that he developed engaging. They preferred doing the exercises with the system.

Several researchers involved the motivational aspect of video games in their system. Ustinova et al. [34] developed four custom virtual video games to elaborate the efficacy for postural deficits. First a virtual teacher where the subject has to copy its movements strictly. Second a virtual challenger that is divided into a skateboard, courtyard and an octopus game with specific exercises in which the movements of the user are more flexible. Successfully completed performance will be rewarded with a number of points. Overall the user were strongly satisfied with the gaming part of the therapy and moderate with the virtual teacher part.

Freitas et al. [7] focused on user centred development of a physiotherapeutic game that supports motor rehabilitation exercises. A plane represented the user and she has to fly through rings in the air and avoid obstacles. The patients were strongly satisfied with the game. An important factor here is the good user interface that affects the user motivation, visually presented scenario and playing technique in a positive way.

Estepa et al. [6] evaluates three developed exergames involving different psychophysical rehabilitation exercises. A virtual avatar represents the patient and orders are giving via an auditive or visual stimuli. The first two games are a series of coming balls placed at desired angles that the patient has to avoid with her trunk or, in the second game, with her feet. In the third exercise she has to step forward to a colored line between starting and goal position. All games were easy to understand and provide necessary feedback. The patients had a considerable interest to use the system.

Kajastila and Hämäläinen [14] encourages monotonous parts of climbing training by adding goals and supporting the social collaboration of the participants. Hence they are making it overall more enjoyable. Six prototypes were developed. Prototypes that rely more on a training part are an easy route builder, automatic route generator and instant video feedback. For the user those were the most useful ones. The exercises that consists of a more playful part, such as a chasing animated saw that the climber has to avoid, shifted the focus away from the training part.

With this in mind an useful training device should be considered that includes an enjoyable virtual environment. A good balance between these both is the key for successful and motivating skill acquisition.

4.3 Approaches and techniques for providing feedback

Several useful technological advances like video feedback, virtual environments and auditive information can be applied for providing feedback in sport activities. Liebermann et al. [19] evaluated those regarding their field of application. With video information costs are relatively low, it is easy accessible, and portable. It can be repetitively replayed in real-time or superposition of two footages. Training in 3D virtual environments can help to improve or to familiarize with a real world skill acquisition. This is because the user can pre-practice a skill in simulated unknown conditions like pilots in a simulated airplane. Providing appropriate auditive information can have a relatively high impact on performance enhancement too. E.g. defining a high- and low-pitch tone in balance training can be use as a warning signal to correct the position of the user. If her center of pressure distinguishes too far from the initial body location she can be warned with a high pitch tone. If both are relatively close it can represented with a lower pitched signal. All of these allow qualitative and meaningful feedback in their application context. The performer can review the execution, pre practice in a virtual environment, or be supported with audio warning signals. Therefore she can discover failure in her performance.

Feedback has to be provided in an appropriate manner for improving new motor skill acquisition. Especially for starting to learn a new technique it is important to have immediate feedback sources on which the user can rely on [10] [37]. Therefore it should be easy to understand for enhancing the learning process.

Hämäläinen [12] developed applications for a camera output in front of the user. An automated motion controlled approach starts and stops the recording if the motion exceeds a certain threshold. Second a speech and last a gesture control prototype that consists of four commands to record, play, stop and delay the recording. The user test ranked the automatisation the worst because it reacted to unintentional motions, which ends in unwanted command recognition. The speech system ranked the best but only worked well if the participant speaks near the microphone. Some participants mentioned that the gesture approach were more intuitive and natural, which could be a good compromise out of the three approaches.

Holsti et al. [11] investigated delayed video feedback and a platform jumping game in trampoline sport. The former records the performance execution and shows it repetitive to the user. In the second the player has to jump back- and forwards on virtual platforms. They tested it with athletes and beginner. The delayed video feedback was ranked useful for nearly all athletes. Overall the platform jumping game was ranked the best.

Kajastila and Hämäläinen [14] project graphics onto an artificial climbing wall. A feasibility study showed that the graphic information is best located near holds where the focus of the climber goes naturally. This can be adapted to the slacklining system since the focus is usually set onto a specific point in front of the user. It would be therefore useful to provide information in the peripheral view. Next to other prototypes he has implemented an instant delayed video feedback. This is rated as one of the most useful ones because the user can immediately analyse her performance. Also a gaming approach is developed as an animated saw that chases the climber and which she has to avoid. User testing resulted that it moves the focus away from the training, but it could be an enjoyable alternative to kids for getting them used to the sport.

Based on the results of the last paper Kajastila et al. [15] developed two games and a route creation application. User emphasize the versatility and excitement of the games. They also forget the fear of heights due to time limits and forcing them to focus and achieve a goal. User stated that playing and spectating is also more fun due to implemented sound and visual effects.

A well defined interaction mechanism and a good looking environment can help to create an effective system and motivate the user for training purposes. A delayed video feedback is a good approach to learn new skills. Combining this with a gaming approach can simultaneously lead to a joyful experience with training aspects. Also adding audio signals can further improve this experience for the user as well as for spectators.

4.4 User interface

Important feedback information during the exercise should be placed surrounding the focus point in the peripheral view of the user. Directing the user for correcting her movement can be done in several ways. Basic information about the execution should be given prior to the user for exercise preparation. Surrounding objects can be displayed as arrows, flashing notifications or weighting scale like seen by Garrido Navarro et al. [8] in Figure 17. Additional informations like current exercise and the state can be displayed outside of the focus space. But they should be designed to not distract the user. If they do so it should be able to just show the feedback visualisations. A feedback summary after the execution can give an useful resume about the exercise as an reflection like in Figure 18.

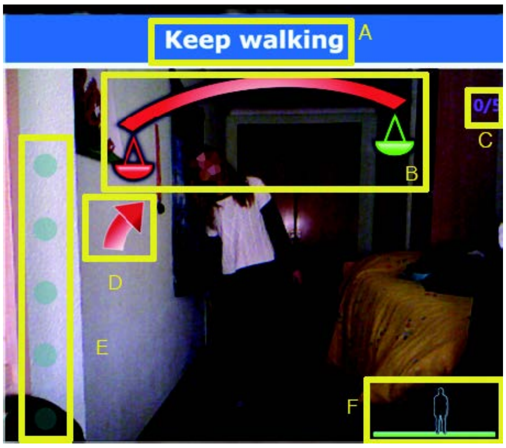

Figure 17: Surrounding objects in the UI [8]

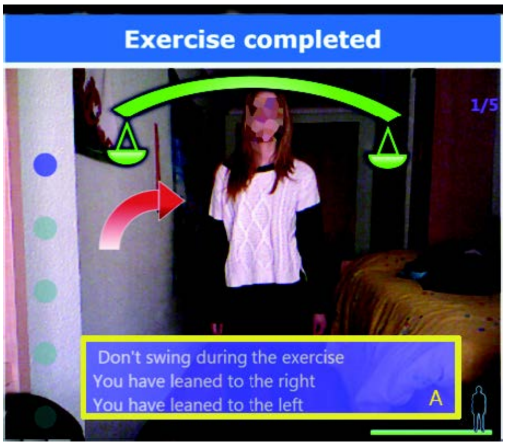

Figure 18: Completed exercise feedback summary [8]

Another method is to show the user itself or an avatar that demonstrates the correct performance of the current exercises like in Figure 19 and 20. Holsti et al. [11] implemented such a user integration and in user testing they endorse to see themself performing in real time.

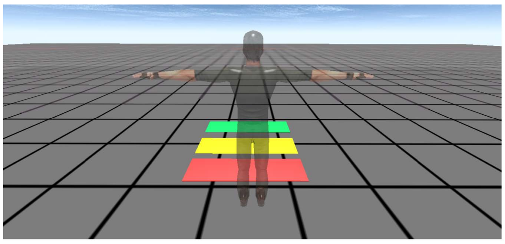

Figure 19: 3D Model as avatar [6]

Figure 20: Rail-time user representation [11]

The task about the execution has to be clarified. Chang et al. [2] provides real time feedback on the performance quality due to a visualised path. If the performance is correct the path will turn green. But if she moves outside the range the path turns red and an arrows guides him into the correct position. Instructions and highlighting objects can help to complete an exercise successfully (Figure 21 and 22). If she performs something wrong during the performance e.g. in the slacklining case corresponding body parts could be highlighted.

Figure 21: Instruction to the game [2]

Figure 22: Green indicator for correct performance [2]

Displaying an avatar can be further implemented by a conjunction or overlapping with an instructor on the screen **(Figure 8)**. With this she can see wrong performance execution in real time. After the exercise she should be able to review her performance. At the same time the system has to be aware of not distracting the user too much during the performance.

References

[1] Bogdanovych, Anton and Stanton, Christopher. A novel approach to sports oriented video games with real-time motion streaming. In *Proceedings of the 7th ACM SIGCHI Symposium on Engineering Interactive Computing Systems - EICS '15* (2015).

[2] Chang, Chien-Yen; Lange, Belinda; Zhang, Mi; Koenig, Sebastian; Requejo, Phil; Somboon, Noom; Sawchuk, Alexander and Rizzo, Albert. Towards Pervasive Physical Rehabilitation Using Microsoft Kinect. In *Proceedings of the 6th International Conference on Pervasive Computing Technologies for Healthcare* (2012).

[3] Donath, L; Roth, R; Rueegge, A; Groppa, M; Zahner, L and Faude, O. Effects of slackline training on balance, jump performance & muscle activity in young children. *Int. J. Sports Med. 34*, 12 (Dec. 2013), pp. 1093–1098.

[4] Donath, L; Roth, R; Zahner, L and Faude, O. Slackline training and neuromuscular performance in seniors: A randomized controlled trial. *Scand. J. Med. Sci. Sports 26*, 3 (Mar. 2016), pp. 275–283.

[5] Donath, Lars; Roth, Ralf; Zahner, Lukas and Faude, Oliver. Slackline Training (Balancing Over Narrow Nylon Ribbons) and Balance Performance: A Meta-Analytical Review. *Sports Med.* (4 Oct. 2016).

[6] Estepa, A; Sponton Piriz, S; Albornoz, E and Martínez, C. Development of a Kinect-based exergaming system for motor rehabilitation in neurological disorders. *J. Phys. Conf. Ser. 705* (2016), p. 012060.

[7] Freitas, Daniel Q.; Gama, Alana E. F. Da; Figueiredo, Lucas; Chaves, Thiago M.; Marques-Oliveira, Déborah; Teichrieb, Veronica and Araújo, Cristiano. Development and Evaluation of a Kinect Based Motor Rehabilitation Game. In *Brazilian Symposium on Conputer, Games and Digital Entertainment (SBGames 2012)* (2012).

[8] Garrido, Juan Enrique; Marset, Irma; Penichet, Víctor M. R. and Lozano, María D. Balance Disorder Rehabilitation Through Movement Interaction. In *Proceedings of the 7th International Conference on Pervasive Computing Technologies for Healthcare* (ICST, Brussels, Belgium, Belgium, 2013), PervasiveHealth '13, ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering), pp. 319–322.

[9] Granacher, U; Iten, N; Roth, R and Gollhofer, A. Slackline training for balance and strength promotion. *Int. J. Sports Med. 31*, 10 (Oct. 2010), pp. 717–723.

[10] HODGES, NICOLA J AND FRANKS, IAN M. Modelling coaching practice: the role of instruction and demonstration. *J. Sports Sci. 20*, 10 (Oct. 2002), pp. 793–811.

[11] HOLSTI, LEO; TAKALA, TUUKKA; MARTIKAINEN, AKI; KAJASTILA, RAINE AND HÄMÄLÄINEN, PERTTU. Body-controlled trampoline training games based on computer vision. In *CHI '13 Extended Abstracts on Human Factors in Computing Systems on - CHI EA '13* (2013).

[12] HÄMÄLÄINEN, PERTTU. Interactive video mirrors for sports training. In *Proceedings of the third Nordic conference on Human-computer interaction - NordiCHI '04* (2004).

[13] JOHNSON, D A; ROSE, F D; RUSHTON, S; PENTLAND, B AND ATTREE, E A. Virtual reality: a new prosthesis for brain injury rehabilitation. *Scott. Med. J. 43*, 3 (June 1998), pp. 81–83.

[14] KAJASTILA, RAINE AND HÄMÄLÄINEN, PERTTU. Augmented climbing: interacting with projected graphics on a climbing wall. In *Proceedings of the extended abstracts of the 32nd annual ACM conference on Human factors in computing systems - CHI EA '14* (New York, New York, USA, 2014), ACM Press, pp. 1279–1284.

[15] KAJASTILA, RAINE; HOLSTI, LEO AND HÄMÄLÄINEN, PERTTU. The Augmented Climbing Wall: High-Exertion Proximity Interaction on a Wall-Sized Interactive Surface. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems - CHI '16* (New York, New York, USA, 2016), ACM Press, pp. 758–769.

[16] KELLER, M; PFUSTERSCHMIED, J; BUCHECKER, M; MÜLLER, E AND TAUBE, W. Improved postural control after slackline training is accompanied by reduced H-reflexes. *Scand. J. Med. Sci. Sports 22*, 4 (Aug. 2012), pp. 471–477.

[17] KLEINDL, REINHARD. *Slackline: Die Kunst des modernen Seiltanzens*. Meyer & Meyer, 1 Jan. 2011.

[18] KROISS, ANDREAS. Der Trendsport Slackline und seine Anwendungsmöglichkeiten im Schulsport. Master's thesis, TU München, 2007.

[19] LIEBERMANN, DARIO G; KATZ, LARRY; HUGHES, MIKE D; BARTLETT, ROGER M; MCCLEMENTS, JIM AND FRANKS, IAN M. Advances in the application of information technology to sport performance. *J. Sports Sci. 20*, 10 (Oct. 2002), pp. 755–769.

[20] LIM, DOHYUNG; KIM, CHOONGYEON; JUNG, HOHYUN; JUNG, DUKYOUNG AND CHUN, KEYOUNG JIN. Use of the Microsoft Kinect system to characterize balance ability during balance training. *Clin. Interv. Aging 10* (30 June 2015), pp. 1077–1083.

[21] NUSMAN, DAAN. Real-time full-body motion capture in virtual worlds. Master's thesis, University of Twente, June 2006.

[22] PAAS, FRED; RENKL, ALEXANDER AND SWELLER, JOHN. Cognitive Load Theory and Instructional Design: Recent Developments. *Educ. Psychol. 38*, 1 (Mar. 2003), pp. 1–4.

[23] PFUSTERSCHMIED, JÜRGEN; BUCHECKER, MICHAEL; KELLER, MARTIN; WAGNER, HERBERT; TAUBE, WOLFGANG AND MÜLLER, ERICH. Supervised slackline training improves postural stability. *EJSS 13*, 1 (2013), pp. 49–57.

[24] PFUSTERSCHMIED, JÜRGEN; STÖGGL, THOMAS; BUCHECKER, MICHAEL; LINDINGER, STEFAN; WAGNER, HERBERT AND MÜLLER, ERICH. Effects of 4-week slackline training on lower limb joint motion and muscle activation. *J. Sci. Med. Sport 16*, 6 (Nov. 2013), pp. 562–566.

[25] PISAN, YUSUF; MARIN, JAIME GARCIA AND NAVARRO, KARLA FELIX. Improving lives: using Microsoft Kinect to predict the loss of balance for elderly users under cognitive load. In *Proceedings of The 9th Australasian Conference on Interactive Entertainment Matters of Life and Death - IE '13* (New York, New York, USA, 2013), ACM Press, pp. 1–4.

[26] POMPEU, J E; ARDUINI, L A; BOTELHO, A R; FONSECA, M B F; POMPEU, S M A A; TORRIANI-PASIN, C AND DEUTSCH, J E. Feasibility, safety and outcomes of playing Kinect Adventures!™ for people with Parkinson's disease: a pilot study. *Physiotherapy 100*, 2 (June 2014), pp. 162–168.

[27] POMPEU, JOSÉ EDUARDO; TORRIANI-PASIN, CAMILA; DONÁ, FLÁVIA; GANANÇA, FERNANDO FREITAS; DA SILVA, KEYTE GUEDES AND FERRAZ, HENRIQUE BALLALAI. Effect of Kinect games on postural control of patients with Parkinson's disease. In *Proceedings of the 3rd 2015 Workshop on ICTs for improving Patients Rehabilitation Research Techniques - REHAB '15* (2015).

[28] RYAN, R M AND DECI, E L. Intrinsic and Extrinsic Motivations: Classic Definitions and New Directions. *Contemp. Educ. Psychol. 25*, 1 (Jan. 2000), pp. 54–67.

[29] RYAN, R M AND DECI, E L. Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *Am. Psychol. 55*, 1 (Jan. 2000), pp. 68–78.

[30] SCHLÖMER, THOMAS; POPPINGA, BENJAMIN; HENZE, NIELS AND BOLL, SUSANNE. Gesture recognition with a Wii controller. In *Proceedings of the 2nd international conference on Tangible and embedded interaction - TEI '08* (2008).

[31] TANAKA, KAZUMOTO; PARKER, JIM; BARADOY, GRAHAM; SHEEHAN, DWAYNE; HOLASH, JOHN R. AND KATZ, LARRY. A Comparison of Exergaming Interfaces for Use in Rehabilitation Programs and Research.

[32] TANG, RICHARD; YANG, XING-DONG; BATEMAN, SCOTT; JORGE, JOAQUIM AND TANG, ANTHONY. Physio@Home: Exploring Visual Guidance and Feedback Techniques for Physiotherapy Exercises. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems - CHI '15* (New York, New York, USA, 2015), ACM Press, pp. 4123–4132.

[33] THOMANN, ANDREAS. Methodik im Slacklinesport - Wie geht guter Slacklineunterricht?, 2013.

[34] USTINOVA, K I; PERKINS, J; LEONARD, W A AND HAUSBECK, C J. Virtual reality game-based therapy for treatment of postural and co-ordination abnormalities secondary to TBI: a pilot study. *Brain Inj. 28*, 4 (4 Apr. 2014), pp. 486–495.

[35] VAN DER SPEK, ERIK D. COgnition-based DEsign Rules Enhancing Decision-making TRaining In A Game Environment (Code Red Triage). In *Proceedings of the 28th Annual European Conference on Cognitive Ergonomics - ECCE '10* (2010).

[36] WIKIPEDIA. Anatomical terms of location — Wikipedia, The Free Encyclopedia, 2017. [Online; accessed 12-March-2017].

[37] WINSTEIN, CAROLEE J AND SCHMIDT, RICHARD A. Reduced frequency of knowledge of results enhances motor skill learning. *J. Exp. Psychol. Learn. Mem. Cogn. 16*, 4 (1990), pp. 677–691.

[38] WOOLFORD, KIRK. Defining accuracy in the use of Kinect v2 for exercise monitoring. In *Proceedings of the 2nd International Workshop on Movement and Computing - MOCO '15* (2015).