SAARLAND UNIVERSITY

Faculty of Natural Sciences and Technology I
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Related Work Summary

DRAFT - Interactive technology in slackline training

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Abstract

The aim of this thesis project is to design and evaluate an interactive slackline learning training system. To evaluate the efficiency of the system the learning progress is measured while training beginners on a slackline.

In the study all participants have to execute predefined exercises that are divided into four training levels. Each exercise attempt, the time, and their confidence will be measured. Exercises will be executed without as well as with the slackline. For safety reasons gymnastic pads are placed beneath and to each side of the slackline.

During the actual exercise study, the participant will be recorded via audio and video. This will only be used for this study to evaluate and validate performance parameters and detect failures of the system. The participant will be interviewed about her experience after the training. During the interview the participant will be recorded via audio for later analyses.

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.

Chapter 1
Introduction

1.1 Motivation

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Chapter 2
Related Work

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 provide instructive teaching methods for beginners. Therefore existing approaches and studies have been elaborated to build an appropriate foundation and point out several application scenarios. Also the user interface should motivate the slacker for the training scenario and lead to a proper user experience.

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 appropriate tracking device. The system has also be aware of the cognitive load and motivating aspects, which can be challenging with repetitive exercises. Several applications show where problems occur with different feedback and interaction methods. Lastly design opportunities for guiding the user through the learning process are demonstrated by various approaches.

2.1 Slackline Specific Training and Effects to the Human Body

As in other sport activities it is important to have a concrete baseline about what exercises and tips are useful for very beginners. Mainly to have a good knowledge of the basics, which results in a faster learning process, but also to prevent injuries from the beginning. In the following several slackline learning techniques will be discussed, which can then be implemented in the assistance system. Prior research indicates the applicability of slackline training for areas like sport medicine and rehabilitation training. It shows why slacklining could be used as an alternative to classical balance training and how the body swift affect these. Donath et al. [11] found in his meta-analysis significant improvements in the postural control after slackline training, which indicates the efficacy of this training method. This subsection shows several application scenarios in which a slackline can be implemented and improve the training effect.

2.1.1 Exercises during slackline training

For beginners it is difficult to walk or even stay 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.

Thoman [47] differentiate two basic methods for the learning process on a slackline. Teaching a slackline beginner, further called slacker, without any help or with systematic external assistance. The investigation of Kroiß [27] resulted in no significant difference between both methods. But there is a trend regarding providing methodological aid, like human support or physical objects as nordic walking sticks or a bar, can help to improve the learning effect (Figure 2.1). Therefore it is a good advise for beginners to learn the fundamentals of standing and walking on the slackline to build up a groundwork. 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 [26, 27].

(a) Stick support (b) Between bars (c) Human support

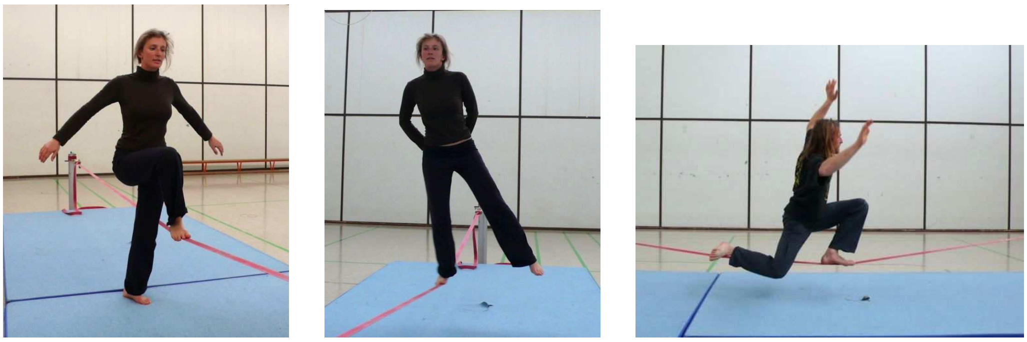
Figure 2.1: Supportive exercises [27]

With further progress, the external help, if given, should be reduced. The slacker can now try to stay and walk on the line on her own. It is recommended to begin with the practice of a basic start, to stay with both feet, and one feet on the slackline since these are basic techniques (Figure 2.2). Staying with both feet seems easier in the beginning but only the hips and hands can be used for balancing. With just one feet on the line, the slacker can use the other one as an additional extremity for balancing purposes.

(a) Basic start (b) One feet (c) Both feet

Figure 2.2: Basic exercises [27]

Advanced training should be practiced in a more dynamical way [47]. Like seen in several research works [9, 10, 17, 25, 36] this can be from crossover start (Figure 2.3a), turning on the line, hands on hips or behind the back (Figure 2.3b), 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 2.3c).



(a) Crossover start (b) Hands behind back (c) Dropknee

Figure 2.3: Advanced techniques [27]

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, have also an influence on the stability of the human body on the line [25, 36, 37]. A short and tight line results in a relatively small vibrating area, where the slacker 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 [27].

The slacklining assistance system should mainly train and support slacker to walk on the slackline. 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. Now is the question, what effect has slackline on the human body and where can it be applied? This is part of the next subsection.

2.1.2 Slackline Specific Training Effects and Application Scenarios

Donath et al. [9] 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.

A further study of Donath et al. [10] 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. [25] 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. [36] 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. [37] 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. [17] 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 [36]. Therefore this study can be seen as an exceptional case.

Those investigations 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 a 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. Interactive technologies can be used to support training in such scenarios. The next section provides an overview about state of the art technologies, compares them, and show several implementations in balance scenarios.

2.2 Interactive Technology

To build a real time feedback assistance system, a tracking device is needed that supports the slacker in an appropriate way and won't interrupt her. 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 motion capture systems, 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.

2.2.1 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 [4, 45]. Gesture recognition is an essential aspect of the slacklining assistance system for giving appropriate feedback regarding the executed exercise. Schlömer et al. [43] analysed 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 [4, 45].

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, like *Xsens MVN* [31] or *OptiTrack* [34], 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 are that 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 [4, 5, 33]. This makes it an inappropriate device for user tracking on a slackline.

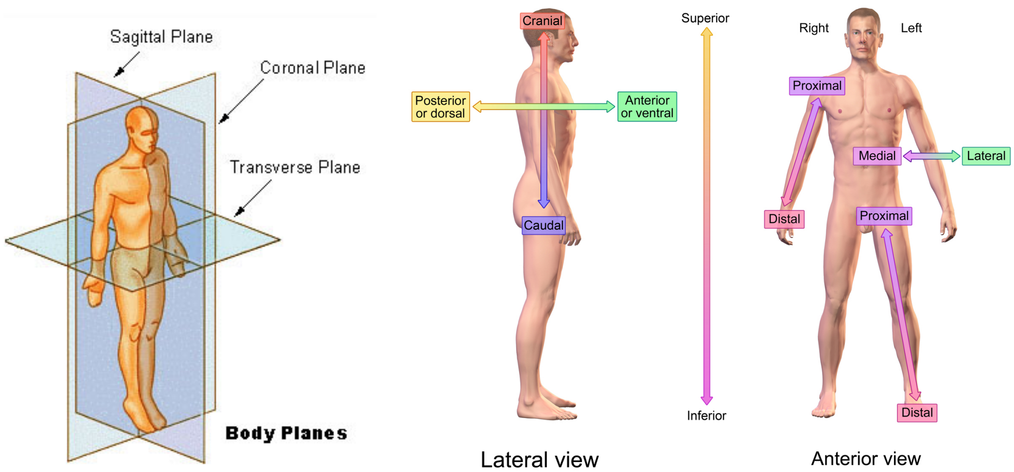
The Microsoft Kinect is a static device that includes a RGB camera and depth sensor. Because the body joints and player position are recognised by these, the user is free in her movement without any further controller. Another advantage is the low price in comparison to the motion control suite, and the low setup time because only the device itself is needed. Problems occur with occlusion of body parts that results in glitches and flawed tracking [23, 46]. To the user they can be hidden, e.g. by only showing the output of the depth cam [21]. This problem can also occur in the slacklining case because of overlaying feet. Therefore a technical feasibility has to be conducted to show if this is a bigger problem or can be neglected.

With this in mind, the Microsoft Kinect v2 seems like the most suitable device. 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.

2.2.2 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. [29] assessed the accuracy of the Kinect with a 3D motion capture system as a reference system. For further understanding please review Figure 2.4 regarding expressions to body planes and anatomical directional references. The participants had to execute balance training with complex aperiodic movements in the body planes (Figure 2.4a). 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 and extensions in the medio-lateral-axis (x-axis) but not on the anterior-posterior-axis (y-axis) and the cranial-caudal-axis (z-axis) (Figure 2.4b). 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 of joint angles in the sagittal and transverse plane is not optimal (Figure 2.4a). 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.



(a) Body Planes (b) Directional References (modified)

Figure 2.4: Anatomical terms of location [51]

Chang et al. [5] 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 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 [59] 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 2.5). 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.

(a) Inaccurate and imprecise system generates random-like measurements

(b) Inaccurate but precise system, where measurements are close to each other but have systematic error

(c) Accurate and precise system generates measurements that are close to the real world

(d) Accurate and suffice precise system generates measurements that are close to each other and are not systematically biased

Figure 2.5: Definition of accuracy and precision [59]

The Microsoft Kinect v2 can indeed be compared with high performance tracking devices. If no detailed analysis is needed, it provides reliable and appropriate data. For the assistance system it should provide sufficient data to track the user and give useful feedback

2.2.3 Implementation in balance training scenarios

Like already stated Chang et al. [5] 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 [59] 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. [29] 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. [49] 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. [38] 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. [39, 40]. The results affirm that the patients improve in balance purposes and motoric movements with this help.

Furthermore Estapa et al. [12] and Freitas et al. [14] 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 et al. [16] 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 that provides sufficient accurate and usable feedback. It can be embedded in a variation of fields as rehabilitation system, home assistance, or preventative technique. The aspect to motivate patients with an exergame approach and enjoyable user interface can also lead to successful exercise execution, which is part of the next section.

2.3 Feedback and Interaction Methods

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. Several studies show why and how the cognitive load should be restricted. 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. Various techniques have been elaborated on how to provide this appropriately.

2.3.1 Restricting cognitive load

As a baseline Paas et al. [35] 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 her 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 patterns or generating new ones in the working memory to enhance a learning process. Regarding this several applications have been evaluated that are also relevant to the slacklining supporting system.

Van der Spek [50] evaluated how to deal with the right complexity in serious games. He describes in his mental model construction (Figure 2.6) 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.

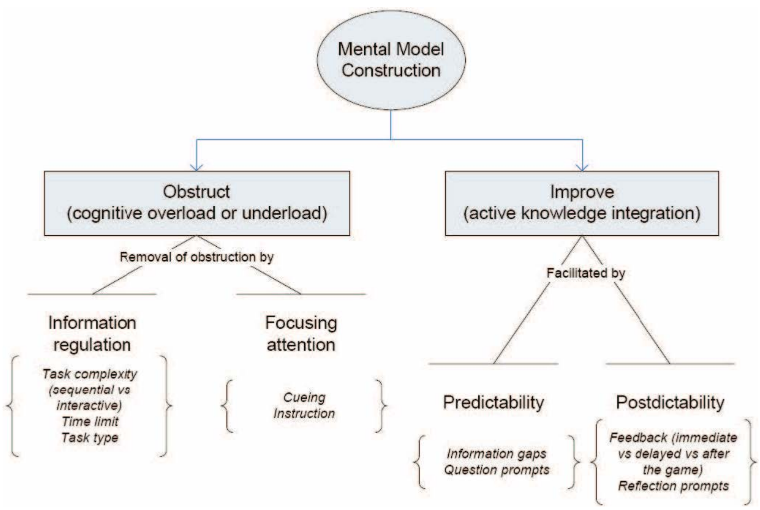


Figure 2.6: Guideline for enhancing the cognitive load [50]

Pisan et al. [38] 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 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 on how to behave in a situation should be provided in an appropriate manner to support the slacker. The system has to be aware of this and restrict the cognitive capability in the right way. Next to cognitive load the system has to ensure that the user stays motivated for the training, which is part of the following subsection.

2.3.2 Motivating factors for skill acquisition

Several rehabilitation and sport training programs can be elaborated for motivating facotrs because the skill acquisition in slacklining resemble with them. The training procedure 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. [41, 42] 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 behaviour. 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. [22] 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. [38] 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. [49] 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. [14] 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. [12] 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 [23] 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 a 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. Another part of the system should also provide useful feedback to the slacker. What methods can be used for this will be discussed in the following.

2.3.3 Approaches and techniques for providing feedback

Several technological advances like video feedback, virtual environments, and auditive information can be applied for providing feedback in sport activities. Liebermann et al. [28] 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 video. Training in 3D virtual environments can help to improve or to familiarize with a real world skill acquisition. The user can pre-practice a skill in simulated unknown conditions like pilots in a simulated airplane. Providing appropriate auditive information can also have a relatively high impact on performance enhancement.

Also the Microsoft HCI-Guidelines state that implementing audio is a good way if the user need to be notified, and to indicate states of changing behaviour [7]. For example in balance training a warning signal can indicate that the current pose is not the desired one. If the user corrects his posture in the right way, the signal should then transform into an more comfortable signal. All of these allow qualitative and meaningful feedback in their application context. The user can review the execution, pre practice in a virtual environment, or be supported by audio warning signals. With this 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 [20, 58]. Therefore it should be easy to understand for enhancing the learning process.

Hämäläinen [19] 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. Both consists of four commands to record, play, stop and delay the recording. The user test ranked the automation 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 mentioned that the gesture approach were more intuitive and natural, which could be a good compromise out of the three approaches.

Holsti et al. [21] 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 [23] project graphics on an artificial climbing wall. A feasibility study showed that graphic information is best located near holds where the focus of the climber goes naturally. This can be adapted to slacklining since the slacker has to focus usually a specific point in front of her.It would be 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 has to be avoided. User state 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. [24] 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.

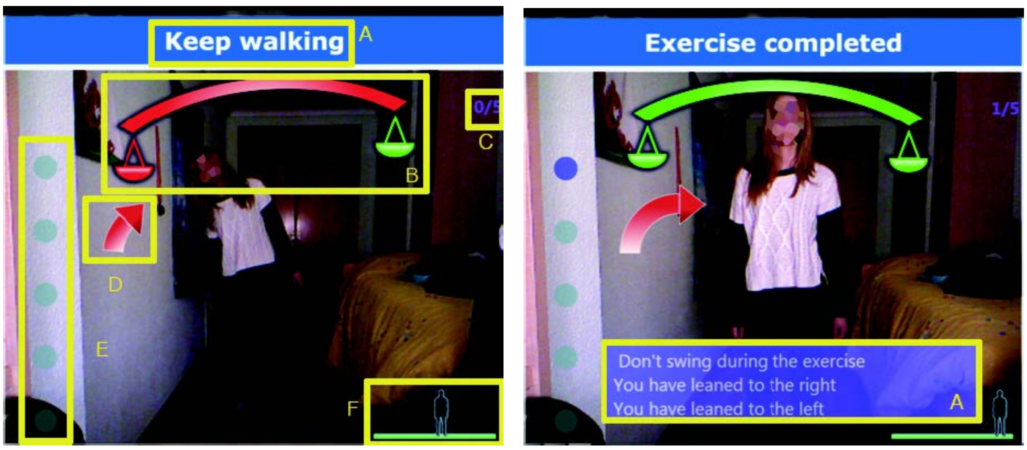
Like seen a delayed video feedback is a good approach to learn new skills. Combining this with a gaming approach can simultaneously lead to a joyful experience with training aspects. Also adding audio signals can further improve this experience for the user as well as for spectators. A well suited interaction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

2.4 User Interface Design

The user interacts with the system through the provided interface. This should contain all relevant information, which are necessary to achieve a specific goal and support her on the way to reach this goal. General user interface approaches from exergame like related work approaches should be compared. Therefore the subsection *User interface design for appropriate feedback* gives an overview on which elements can be used for guiding the user through the system and how feedback can be visualized properly. After that in subsection *Kinect for Windows - Human Interface Guidelines* shows how to enhance the user experience on a kinect application with guidelines provided by Microsoft.

2.4.1 User interface design for appropriate feedback

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 et al. [16] in Figure 2.7a. Additional informations like



(a) Surrounding elements in the interface (b) Completed exercise feedback summary

Figure 2.7: Interface of a rehabilitation training application [16]

the current exercise and the state can be displayed outside of the focus space. They should be designed to not distract the user. A feedback summary after the execution can give an useful recap about the exercise for reflection (Figure 2.7b).

Another method is to show the user itself or an avatar that demonstrates the correct performance of the current exercises like in Figure 2.8 and 2.9. Holsti et al. [21] implemented such a user integration and in user testing they endorse to see themself performing in real time.

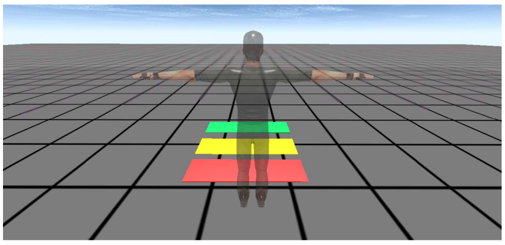


Figure 2.8: 3D Model as avatar [12]

Figure 2.9: Rail-time user representation [21]

The task about the execution has to be clarified. Chang et al. [5] 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 2.10). If she performs something wrong during the performance e.g. in the slacklining case corresponding body parts could be highlighted.

(a) Instruction to the game

(b) Green indicator for correct performance

Figure 2.10: User interface of a rehabilitational application [5]

2.4.2 Kinect for Windows - Human Interface Guidelines

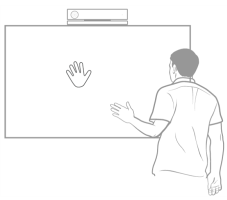
Microsoft itself offers Human-Interface-Guidelines (HIG) for developer and designer that describes several techniques of certain areas for developing a kinect application [7]. It provides a quick introduction into the Kinect itself, design principles for interactions regarding gesture and voice, techniques on teaching complex gestures, and how to visualize appropriate feedback. Also which interactions should be used for a specific action. Therefore developer may follow this general standard to support their end-user. In the following general principles of the guideline will be discussed on which the interactive slackline system will rely on to enhance the user experience.

Basic design principles

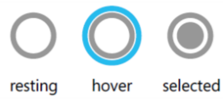
Context-awareness delivers the best user experience e.g. controls should be placed where user would expect them to be and interactions should be appropriate for the environment. It is important that the user feel confident by designing interactions simple and easy to learn. User will choose an input that take the least effort for the given goal. Therefore the input method should match its purpose, be reliable, consistent, and convenient. Conducting user test helps to improve the system. Not each person will use the system the same way and minor adjustments can make a huge difference in the understanding of the usage.

Visual and audio feedback

Giving the user constant feedback helps her to know what is happening. In general appropriate feedback should show if the sensor is ready, she is visible and engaging with the Kinect, and so on (Figure 2.11a). Regarding this a combination of visual as well as audio feedback results in a better experience, e.g. clicking a button changes its visual state and provides an audio signal (Figure 2.11b).



(a) Hand cursor visualizes the engagement and readiness of the system



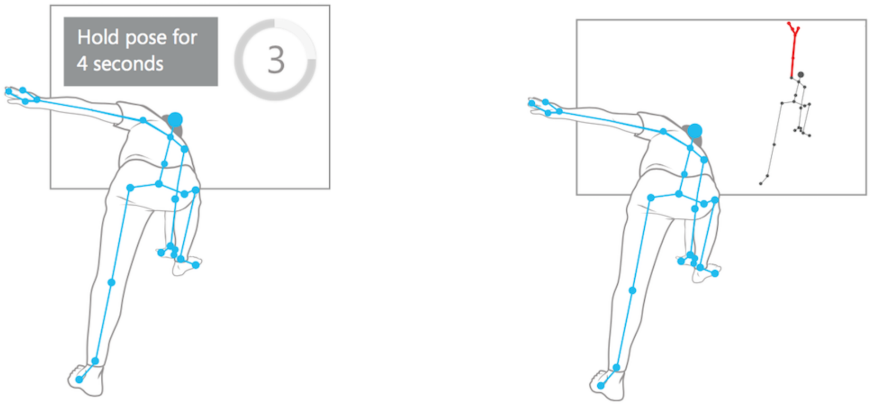
(b) Different states of UI controls

Figure 2.11: Feedback methods [7]

The most important part for complex gestures is the progress indicator described in this guideline. It supports the user if she has to hold a position, as well as if an amount of frequent repetitions have to be performed. Clear and prominent visuals should be used to show the entire progression (Figure 2.12a). If a user has to copy a specific movement an avatar or animation can be shown, before or during the movement, like in Figure 2.12b.

Clarification

The user may interpret interactions with the system differently from others. Therefore the system should explain clearly what the user has to do, e.g. *"Raise*



(a) Repetition and time length indicators

(b) Avatar that shows correct movement and wrong body parts are highlighted

Figure 2.12: Feedback indicator and movement visualization as an avatar [7]

one hand above your head" instead of just *"Raise your hand"*. The cognitive load of the user should be kept low and not exceed a number of six gestures, such that she easily remembers the actions. The system has a set of three basic interaction techniques, which fits in this range.

User viewer

A small scene viewer shows the range in which the user can move and is recognized by the Kinect. It displays a mirror like view in which the user can see a silhouette of herself and the constraints of the Kinect device, like in figure 2.13.

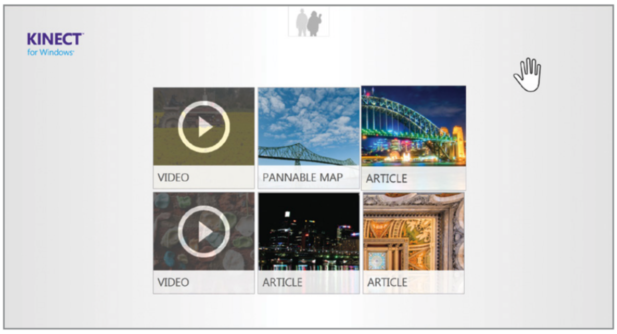


Figure 2.13: User Viewer on top [7]

Learning interaction methods

The application should teach the user how to proper interact with it right from the beginning with an introduction tutorial. An interaction itself should rely on the real world, which can help the user to be more familiar with the product, than learning unknown gestures (Figure 2.14). Also biliteral interaction support should be applied to cover both possibilities for left- and right-handed people.

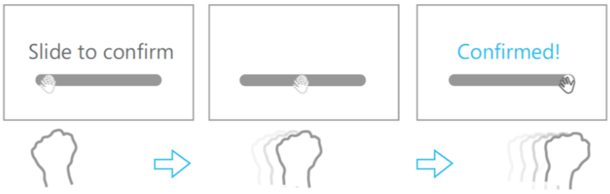


Figure 2.14: Direct manipulation of a slider with intuitive interaction [7]

Teaching complex gestures / exercises

Executing gestures is a core functionality in the slacklining assistance system. For new gestures, especially complex ones, the application should provide a tutorial that teaches and shows the user on how to execute or accomplish the gesture properly. When performing the gesture a visual indicator (a hint, animation, or notification) should acknowledge if the gesture is executed and when it is completed. (Figure 2.15).

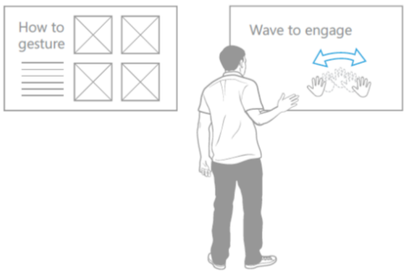


Figure 2.15: Teaching new gestures [7]

Element sizing

The system will rely on the guidelines and match the button sizing regarding the screen resolution to keep reliability on interaction. This is a size of 208 by 208px in a resolution of 1920x1080 pixel. As recommended a tile button style will be used which are a good baseline where the user can hit them accurately and read the button text.

Physical interaction zone

This zone ensures that the user is able to reach anything in a comfortable range. In the application it is constrained by the joints of the shoulders to the hips of the opposite site of the interaction hand. It is designed like seen in figure 2.16 to have a better understanding.

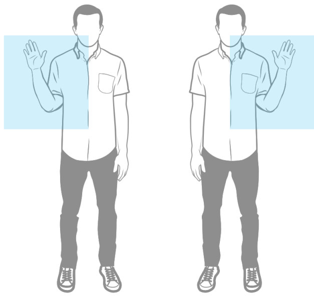


Figure 2.16: Physical interaction zone [7]

Summarizing the user interface should not distract the slacker but support him. Only necessary and useful information have to be displayed during the exercise. Providing an introduction and useful tips can help to give an understanding of the exercise. An avatar or animation is a good alternative to make clear how to perform an exercise. The system should also rely on Microsoft human interface guidelines, which provides design tips and serves as a reference to build user friendly applications.

2.5 Conclusion

With the stated related work a foundation is given to build a slacklining assistance system. For teaching beginners on a slackline it is important get familiar with it. The assistance system should provide the given exercises and tips for beginners which build a foundation for further training. Several application scenarios show that slacklining can replace balance training in rehabilitation environment, as prevention system, in school sport or as an home assistance. This can be combined with interactive technology, which helps patients to fulfil their exercises and provide the medical stuff with sufficient analysis data.

As interaction device the Microsoft Kinect v2 seems like the best choice out of the available technologies. It provides sufficient useful and accurate data analysis, if no in-depth analysis is needed. More advantages are the low cost, short setup time and the freedom of the movements for the user. Several studies indicate also that the Kinect can be embedded in balance training scenarios and increases the training efficacy while motivate patients.

A problem that occurs with more complexity in the exercises is the raising cognitive load. The system should therefore provide appropriate feedback and be aware of the cognitive load of the slacker. Motivating the slacker for further exercise execution can be done with a well defined interaction mechanism, an enjoyable but challenging virtual training environment, and an user friendly interface. This can be realised especially with the help of human interface guidelines provided by Microsoft, which include several design tips for developing a Kinect application.

Chapter 3
Slacklining and Slacklining Learning Techniques

The following section *Introduction into Slacklining* gives an understanding of the evolution, philosophy, and basics of this sport. Further an overview about the diversity of slacklining and application scenarios can be found in section *Slacklining Variations and Categorizations*. The last section *Slackline learning techniques* elaborates teaching methods and exercises, which will be used as a basis for designing the concept and will be integrated into the system.

3.1 Introduction into Slacklining

The term *slackline* has its origin in the 1980's. In contrast to the existing balance activity tightrope, where you balance on a steel rope, some climbers balanced on a tubular webbing. Therefore they used the term *slack wire* that later transformed into *slackline*, which means loose line [60, 2, 30].

Hence slacklining comes from the climbing sport and can be compared with ropedancing in a broader sense [26]. The line itself is made out of a nylon ribbon. Unlike in ropedancing the ribbons width is between 2.5 and 5 cm and very flat. It has to be tensed between two stable fixation points like trees, stable pillars, fixation systems on the ground, so called *A-Frames*, or on a rock with a bolt hanger and carabiner. Mostly this is done with a tension device, which is in general a ratchet or pulleys depending on the fix points [26]. Because of the nylon texture the line will expand under pressure once someone stands on it. Given this elasticity makes it very dynamic and the slacker has to outbalance every sway [27]. To be in control of her body behaviour she has to act very calm, which makes slacklining in general a quiet and meditative sport activity. Besides walking one can also e.g. bounce, bob, or swing on the line. As a result various fields of application arose from this variability, which is further described seen in the next section.

3.2 Slacklining Variations and Categorizations

Several slackline variations originated from combining and modifying the core components of a slackline, which are the height, length, and tension [26, 30, 48]. Regarding the height of the slackline fixation one can differentiate between a *lowline* (Figure 3.1a) and a *highline* (Figure 3.1b). A lowline describes a height in which a person can safely jump off the line. On a highline this is not possible. Here the slacker has to make safety precautions like e.g. a seperate rope above or under the regular line in which the person can hook herself into [26]. Hence, the majority of the lines are categorised as a lowline.

(a) Common lowline

(b) Highline between mountains [53]

Figure 3.1: Main categories of slacklines

The following terms describe some fine granular variations as well as categorizations of the slackline in different application scenarios. They are not strict, which means they can differ in its scenario or can be combined with each other. A common slackline is also named *trickline* (Figure 3.2a). It is tensioned a bit loose in about the height of the knees and has a length up to 30 m. A *jumpline* (Figure 3.2b) is stronger tensioned to simplify jumps on the line. It has a length of 8 - 14 m and is a bit higher than the trickline. With a *rodeoline* the line is more slacked and has the highest amplitude, like seen in figure 3.2c. It is a relatively short line with a length of 5 - 8 m and the fixation points are in about 2 m such that if a person stays in the middle of the line it is just above the ground and she can swing on it sideways. Slacklines beyond 30 m are called *longline* (Figure 3.2d). The goal here is to walk as far as possible without falling off the line.

Beside these there exist some terms that describe a categorization or environment where a slackline can be applied. For example a *waterline* is a line set up over a pool, sea, or a river like in figure 3.3a. *Urbanlining* can be found, like already implied in its naming, in urban areas. Manmade buildings or structures are then used to tension the line in between, like in figure 3.3b.

(a) Handstand on a trickline [54]

(b) Backflip on a jumpline [26]

(c) Rodeoline [55]

(d) Longline [52]

Figure 3.2: Slackline variations

(a) Waterlining over a river [56]

(b) Urbanlining in the city [57]

Figure 3.3: Categorization of slacklining

The disadvantage of these lines is the inevitable usage of static fixation points. In the case of the SLS this would result in a constraint of variability regarding developing, testing, and study purposes. Since the focus of this thesis is mainly on beginners the slackline must not be very long. Therefore the choice felt on a mobile slackline device, which provides the needed mobility and is further described in section *Hardware*.

3.3 Slackline learning techniques

Section *Exercises during slackline training* of chapter 2 showed that systematic help is not essentially necessary to learn slacklining. The user of the interactive learning system should be able to learn it by herself without any further external help. In the following section *Methods for slackline skill acquisition* differentiates between two learning concepts, the methodical routine and differential methodic, on which the interactive learning system relies. Further, section *Levels and Exercises of Learning Slacklining* describes the categorization of specific slackline exercises in the system that are used for structuring the learning flow of the user.

3.3.1 Methods for slackline skill acquisition

Thomann [47] designed two learning procedures for slackline skill acquisition. One approach is the *methodical routine* which follows a more strict procedure and guides the trainee through more and more difficult stages. The second approach is the *differential methodic*. It follows a more dynamical model where big stimulus differences are given to the trainee. In the following both methods are discussed in more detail.

Methodical routine

A methodical routine can be integrated in almost every sport activity. It consists of a series of exercises, whose difficulty increases with further practice. The selected exercises should base on methodical principles that can be scaled by e.g. easy to difficult, known to unknown, or simple to complex [13]. Größing [18] describes the general procedure as follows: at the beginning of a methodical routine the trainee will perform warm up exercises. This is useful to prepare her for the training. After that preliminary exercises will be provided, which are more specific regarding the actual exercises. With this she will learn the general motoric basics and train the movements that are needed to perform the activity. Further, it ensures a smooth transition to the main exercises.

The methodical routine by Thomann [47] is specifically designed for slackline skill acquisition. It contains various approaches with different elements to reach the goal of learning slacklining. However the integration of these elements are more strict to guide the trainee through a constructive exercise procedure (Figure 3.4). The routine starts with an introduction and preliminary exercises. This is followed by material and security where the lines' dynamic, how to jump off, and controlling of the line is covered. Further, the learning of the oscillation behaviour should be implemented with or without methodical help, e.g. human support. Afterwards the user can decide to execute balance training either with help and therefore directly balance on the line, or without any further help, with which she can decide to first sit, step, or balance on the line independently. The trainee can then decide if she wants to train static or dynamic balance, which follows by the option for more variable exercise execution like walking forwards on the line, walking backwards, with eyes closed, and so on. After this the trainee must first learn to stay with her feet orthogonal on the line. It is a necessary prerequisite for learning tricks, which can be found at the very end of the routine, and has to be learned beforehand.

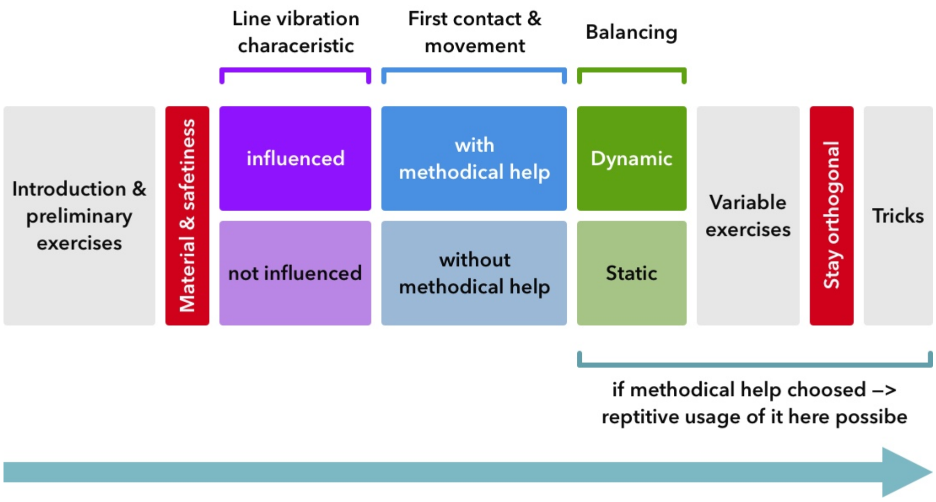


Figure 3.4: Methodical routine [47]

Differential method

The differential or dynamic method follows another approach. It is in coherence with an open learning situation [47]. This means it depends on several factors, which in slacklining would be line type and length, tension, environment, etc. Considering the interplay of these factors each trainee can construct her own training set. A dynamic method is a practical usage for this [3, 44]. This inherits the model of stepping stones. In general it describes that many ways can lead to the same goal. Each potential way has therefore its own level of difficulty. This results in a more modular way to reach a specific goal. In comparison to the methodical routine it leads to bigger differences in stimulus and provides more variability in the movement execution, like compared in Figure 3.5.

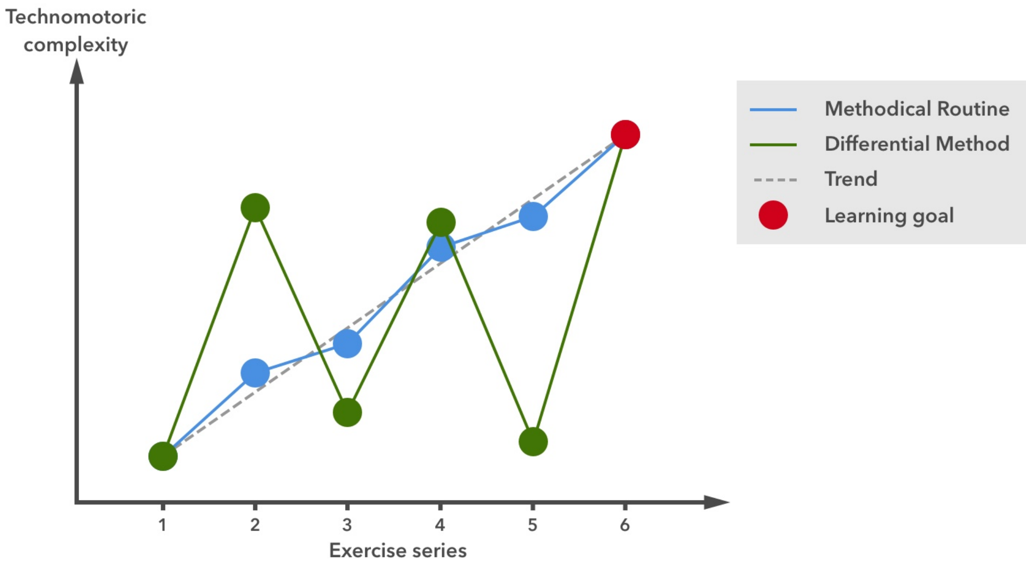


Figure 3.5: Comparison methodical routine vs. differential method [47]

To make use of the differential learning method, the trainee can follow a methodical principle like seen in the methodical routine. If she reaches a certain skill level, more dynamic procedures can then be involved in the actual learning process.

The usage in slacklining can be integrated like described and visualized by Thomann [47] (Figure 3.6). He divided exercises regarding to five learning stages and their coordinative demands and complexity. The main goal is to master controlled and complex movements on the line. The trainee has to choose an amount of various exercise of all stages. More complex exercises can either be supported by methodical help or the trainee can return to the lower stage to learn the movement for the specific exercise. Each trainee can therefore create her individual training path. Modification and integration of more useful exercises are allowed. Structured examples can be seen in Figure 3.6. The purple arrows visualize a way for more skilled people that are more coordinative, more venturesome, or have background knowledge. In contrast the green arrows visualize a path for more novice people that are less coordinate, less venturesome, or have no background knowledge in slacklining.

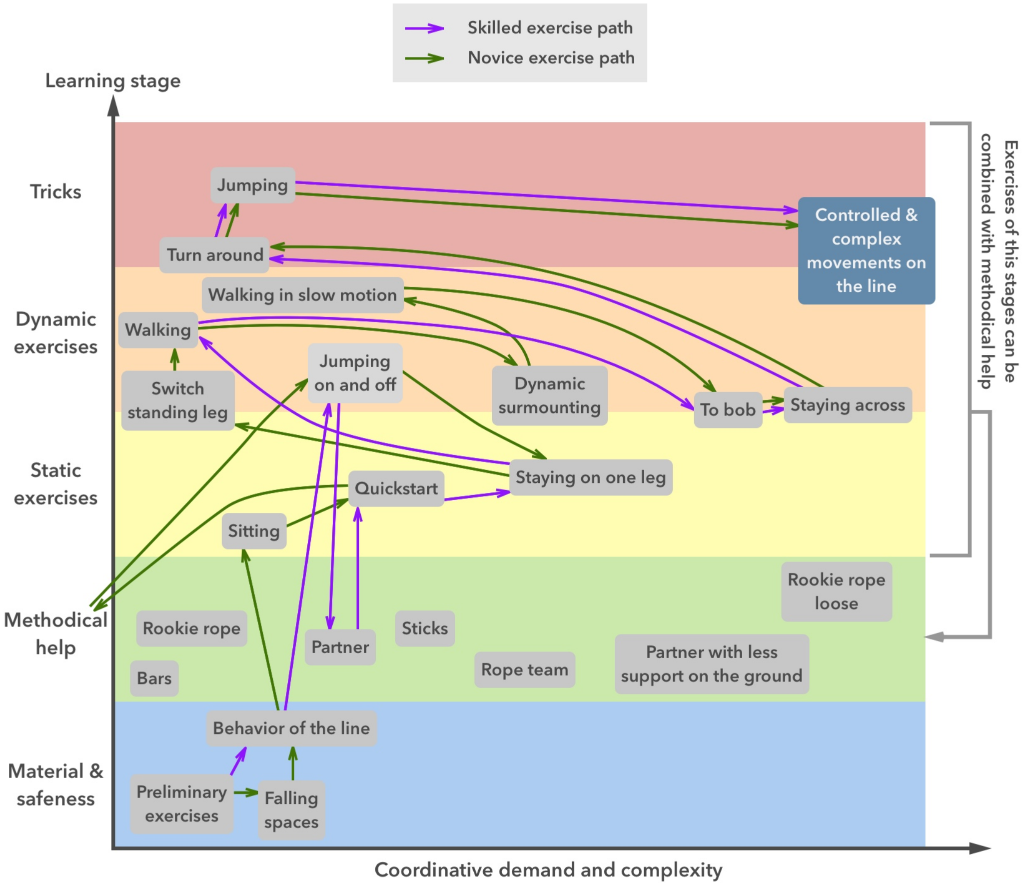


Figure 3.6: Dynamic methodic in slacklining [47]

For proper training with the system the trainee should follow a clear workflow. Therefore the methodical routine is the better choice as a learning concept in this interactive learning system. She learns right from the beginning essential aspects of slacklining that are relevant and build up on each other. Because it follows a strict linear sequence, stages and exercises can be designed as levels and the implementation is more simple as a first approach of such a learning system. The next subsection *Levels and Exercises of Learning Slacklining* will cover a clear workflow integration of exercises for this learning system.

3.3.2 Levels and Exercises of Learning Slacklining

Repetitive trials are one approach of learning to walk on the line. However, this could result in dangerous situations and frustration for the slacker because of her missing skills. Therefore, a set of slacklining exercise can teach and guide the trainee appropriately. It pursues the goal to balance in a controlled manner on the line, stand on it for a few seconds, and be able to walk a few steps.

In general, three core skills have to be acquired to achieve this goal [27]. At first, the slacker should be able to stay on one foot. This is essential because most of the time one foot serves as standing foot on the line and the other one as balance element. Second, balancing on a narrow surface is important since the slackline exists of a limited width. Lastly, she should manage the height due to the fact that a slackline is tensioned around the height of the knee and above.

Kroiß [27] defined a useful execise set for slackline skill acquisition, which will be used as groundwork within the SLS. He elicited learning exercises for beginners on a slackline within a school class, which gives a structured basis on the exercise integration. Further, several other works [2, 9, 10, 17, 25, 26, 36, 47] integrated similar exercises for their slackline training approach. The exercises implemented in this thesis have been categorized into four levels, which represent the fundamental basis of the exercise routines. In the following, each level is introduced, its goal clarified, and the learning aspects described:

Level for Slacklining Skill Acquisition

The first level serves as a preparation for the subsequent levels. Preliminary exercises will be executed on the ground and thus no slackline is needed. With this the users' overall physical balance will be strengthened. The trainee learns how to use her arms as a balance function, set a focus point to calm the visual sense, and to execute exercises slowly and controlled to prevent and handle unpredictable body behaviour.

Mastering the preliminary exercises leads the slacker to her first experience with the slackline. The goal is to get a feeling for the slackline, to be able to get up on the line, as well as to hold herself for a short amount of time on the line. This can be achieved by becoming familiar with the line, feeling the imbalance and how her body behaves, and getting a better feeling for counterbalancing unpredictable movements.

After finishing the second level the slacker is familiar with the line and able to get up the line. The goal of the third level is to make her more confident with standing and prepare her for walking on the line. All prior learned techniques prepared the trainee to this goal and have to be directly applied. Hereby she has to make more usage of the balancing leg, which servers as an additional balancing parameter beside the arms.

More dynamical exercises are part of the last level. The slacker should now be able to stand confidently on the line with one foot as well as with both feet. Its goal is to teach how to make first steps as a result for walking on the line. In general several static exercises, like getting up, balancing with one foot, and standing with both feet on the line have to be applied together.

3.4 Conclusion

Slacklining can be compared with ropedancing but with a wider and flater ribbon. It is a sport that claims a certain amount of balancing skills. Therefore, two learning techniques have been discussed for skill acquisition, which are the methodical routine and dynamic method. The SLS presented in this work will focus on the methodical routine. This technique follows a clear workflow and its structured routine can be easily implemented into the system as a prototype. Lastly a set of exercises have been designed that fit in this routine and train beginners appropriately.

Chapter 4
Concept

This chapter describes the conceptual analysis of an interactive slackline learning system (SLS) with real-time feedback. The idea of the SLS is to provide helpful information, structured exercises, and appropriate feedback to the user for learning slacklining with the given application. One main feature is the autonomous interaction with the system. This gives the opportunity to be independent of any controlling device or external support like human help. Therefore the SLS can only be controlled by the currently interacting user. Further, it responds to the actions of the user and provides several feedback indicators to help her with the exercise execution.

In the following a conceptual analysis will be elaborated. Section *Basic Principles* describes basic design principles and system related requirements. This is followed by the more specific sections *Interaction*, *Stages*, and *Exercises* that describe how to interact with the system and how exercises are structured. Another main component is to provide adequate feedback to the user, which is part of section *Feedback system*. Lastly section **??** gives a good overview about the workflow of the specific components.

4.1 Basic Principles

In general, the SLS should be easy to learn, understand, and to interact. Appropriate user experience helps to achieve these characteristics. Usability heuristics created to identify or prevent problems in a system. Therefore the SLS will acknowledge the interaction design principles by Nielsen [32] described in section *Ten Heuristic Principles for Interaction Design*. Beside this, certain tasks have to be considered that are more related to this system. An overview about these can be found in section *System Specific Basics*.

4.1.1 Ten Heuristic Principles for Interaction Design

Nielsen designed his ten heuristics by comparing several sets of usability heuristics with existing usability problems from certain projects [32]. He was able to determine which heuristics identify usability problems the best and therefore creating a set of them. They can also be used as a guideline for designing and developing a user friendly system to prevent usability problems. The SLS will respect these interaction design principles described in the following:

Visibility of System Status
The system should always keep the user informed about the current state through appropriate feedback in an adequate time.

Match between System and the Real World
The system should provide the user with familiar terms and information. Using technical terms with which she is not familiar can lead to confusion. Therefore proper information should be natural and in a meaningful order.

User Control and Freedom
If the user clicks accidently on something she should be able to leave this state without any troubles.

Consistency and Standards
It should follow a clear design standard and provide consistency. The user should not be confused whether different terms or elements mean the same.

Error Prevention
Conditions and actions that could easily result in errors should be prevented. Another option is to inform the user about the consequences that the action may have and which she has to actively confirm.

Recognition rather than Recall
The users memory load has to be minimized. She should not remember every action or information. Elements, actions, and options should be visible and instructions about the usage must be easy to retrieve.

Flexibility and Efficiency of Use
Providing quick options and allowing to skip certain steps can speed up the interaction for more familiar users. Hence the system should take care of both novice and experienced users.

Aesthetic and Minimalistic Design
Information should just contain aspects that are relevant to the user and that she

really needs. Every irrelevant data decreases the intelligibility.

Help Users Recognize, Diagnose, and Recover from Errors
Error messages should accurately indicate the ongoing problem such that the user knows what is wrong. Providing a constructive solution helps the user to solve the problem.

Help and Documentation
Optimally the system can be used without any further documentation. If it cannot be circumvented the provided help and documentation should be easy to find and clearly show the relevant steps.

4.1.2 System Specific Basics

One person at a time should be able to interact with the SLS. This is because mostly just one person can stay on the slackline especially for beginners. However, it should provide the ability to have multiple user profiles. Several people can thereby have her own profile in the same application. For proper user training the system should follow a clear workflow. Therefore two methods have been discussed in section *Methods for slackline skill acquisition*. A methodical routine will be used with which stages and exercises can be designed as levels. These should be locked at the beginning and the user can unlock them by successfully executing the prior exercises. Another important part is the user tracking. The SLS should be able to track the user in an adequate accuracy and precision such that it can match the users' movement with the actual exercise. This is in correlation with properly providing real-time feedback, which is further discussed in section *Feedback system*. All relevant recorded data should be immediately saved when it is needed, e.g. when successfully accomplishing an exercise.

4.2 Interaction

The interaction can be seen as a bigger part of the system since it is independent of any external controlling devices. The user should be able to navigate through the system by herself with her hands as input for the interaction. A cursor should always be visualized to navigate through the systems interface. If the user initially starts the system, there should be an engagement gesture to convey that the system initially recognises and responds to a user action. Furthermore a small tutorial should be given in which the user will be trained on how to use the interaction possibilities with the system (*cf. Recognition rather than recall*). To make her familiar with these, she should directly apply these techniques in the tutorial. The current state of the interaction is clearly visualized, such that the user knows if she triggers an action regarding an element (*cf .Visibility of system* *status*). To be able to interact with elements and start the exercise execution the user should stay in a predefined initial position. The SLS then recognises if a user is ready to start. Interaction will also play a role in exercise execution. During the execution she interacts with the SLS by trying to match the predefined exercise. The user should then get appropriate feedback, which is further explained in section *Feedback system*.

4.3 Stages

The system covers predefined exercises, which are subdivided in stages that have been elaborated in section *Levels and Exercises of Learning Slacklining*. These are designed as levels, which the user has to unlock. With this an exergame like approach is followed to motivate the user for unlocking the next level. Therefore a menu should exist for all available stages as well as for all exercises within a stage. The very first stage and exercise should be unlocked and interactable to give the user a starting point. She can then unlock the next stage by accomplishing all exercises in the current one. In this way it can be ensured that the user is able to encounter with more difficult exercises in the next stage. An introduction into each stage should inform the user about the purpose and goals of it, as well as general information about the exercise within that stage. Lastly a summary gives an overview of her performance for the entire stage.

4.4 Exercises

Each exercise is part of one stage. An exercise consists of two body sides, which are further divided into several repetitions (Figure 4.1). Every exercise is locked except the first one to provide a starting point, like seen in the last section Stages. The next exercise should be unlocked by accomplishing both sides of the current one. Similarly, a side will be completed if all repetitions have been finished. As for the stage, each exercise should be instructed for the user such that she can successfully perform it. The SLS will also recognise if the user is ready to start with the exercise. During the execution she gets real time feedback about her current performance. An exercise summary should then show the performance of the execution with several performance parameters regarding the given exercise.

4.5 Feedback system

Feedback is the main and most powerful component of the SLS. Since the user should interact on her own with it one has to assume that no other person interferes with her and the system. With this in mind the feedback of the system should be designed in a way, that the user knows at any time what she has to do or has done (cf. *Aesthetic and minimalistic design*). In general audio and visual

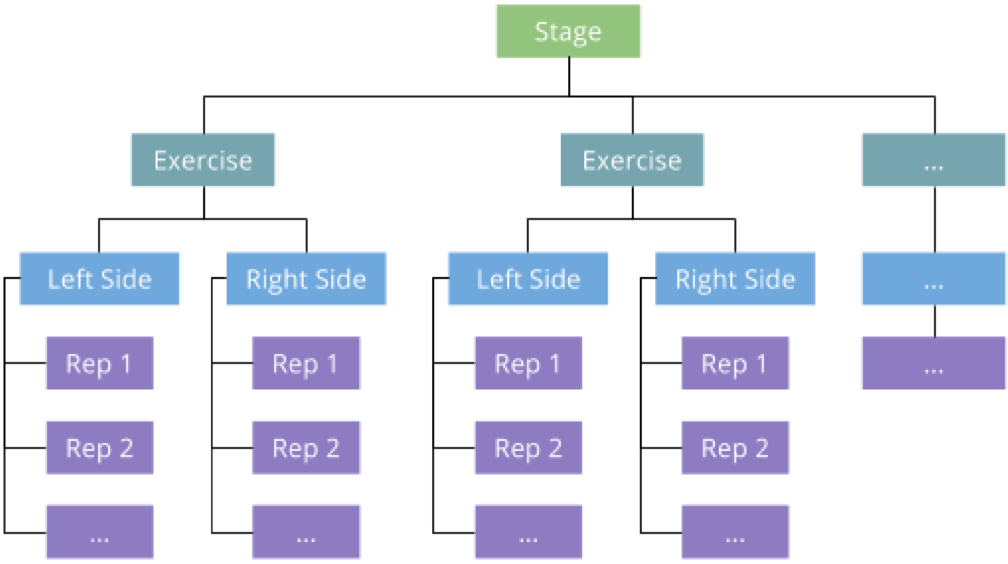


Figure 4.1: Exercise structure

feedback will be provided to the user. Regarding the interaction with the system, e.g. clicking a button, the system should respond with an audio signal as well as changing the elements' visual state accordingly.

Real-time feedback supports the trainee during her performance and improves the learning effect when given in an appropriate manner [20, 28, 58]. The SLS should therefore respond to the user with immediate helpful information during the training to improve the exercise execution. This can be seen in several other sport applications like *EA SPORTS Active 2*[1] or *Nike +*[2]. The provided feedback should mainly indicate whether the current execution is performed correctly or not, visualize the the performance of the user regarding the predefined exercises, and show the execution progress. The user should also see herself mirrored in an appropriate environment to see her current execution and if she is in detection range of the tracking device. With this, a baseline is built for appropriate real time feedback.

4.6 Conclusion

The interactive slackline learning system should be able to teach and support users how to slackline with predefined exercises. For proper realization the SLS has to consider several aspects. It should comprise an appropriate amount of user experience. By following and respecting Nielsens ten usability heuristics it provides an overall standard of usability. Further, some system specific ground-

[1] `https://www.ea.com/de-de/news/ea-sports-active-2-bringt-fitnessfans-in-die-form-ihres-lebens`

[2] `https://news.nike.com/news/introducing-nike-kinect-training`

work should be integrated. This involves, for example, autonomous interaction, adequate user tracking, and supportive real-time feedback. More specifically, the stages and exercises should be designed as a levels that can be unlocked by successfully completing exercises. Each of these exercises should be introduced to the user to give her an understanding of the correct execution. Lastly, the feedback system is one of the biggest components. It involves audiovisual real-time feedback for the user interaction as well as exercise execution, and general feedback for rating her performance regarding an exercise or the entire stage. The next chapter *System implementation* relies on this concept and discusses the development process.

Chapter 5
System implementation

The following chapter discusses the implementation of an interactive slackline learning system with real-time feedback based on the prior conceptual elaboration. Like already discussed in section *Comparison of tracking technologies* the low-cost tracking camera Microsoft Kinect v2 will be used as tracking device. Before going into detail with the actual implementation, section *Hardware* discusses the tracking performance of the Kinect with persons on a slackline. Currently each exercise has to be created by the developer such that the SLS can match and compare the movement performance of a trainee with the actual exercise. The workflow of constructing such exercises is described in section *Exercise Integration*. After that, section *System architecture* explains the general relationship of each system component, which includes for example the interplay of the Kinect SDK with Unity3D as game engine, and more specific topics like e.g. real-time feedback integration. Lastly section *User Interface* covers the design process of the application with scribbles, mock-ups, and the final interface.

5.1 Hardware

5.1.1 Physical setup

- hier noch iwo PC + Beamer + screen Setup erklären

Tracking a person on a slackline with the Kinect is very different from a common situation. The combination of the slackline range, vibration of the line itself, and unpredictable movements of the user and her balancing actions could lead to imprecise and inaccurate tracking data. Furthermore, there exists no comparable work about how to track user properly on a slackine with the Kinect.

The major point is to compare different slackline positions regarding multiple angles and heights of the Kinect. At first this will clarify how good a person can be tracked on a slackline. Furthermore, which is the best combination of the slackline and Kinect positioning for user tracking on an entire slackline as well as for study purposes of this thesis.

For feasibility reasons and since the focus of this thesis lies mainly on beginners the slackline does not have to be very long. Therefore the choice felt on a mobile slackline device namely *alpidex POWER-WAVE 2.0*[3]. It provides the needed mobility and independency due to its comparatively short length of three meters. The included slackline is tensed around brackets at both ends of the device. The middle rail is divided into two parts and needs to be put together. Hence it is possible to set it up indoors as well as move it in different positions with a minimum of effort 5.1.

Figure 5.1: Mobile slackline *alpidex POWER-WAVE 2.0* [1]

Limitations of the Kinect

A considerable role plays the angle and tracking range of the Kinects' depth sensor regarding the length of the slackline. The sensors' angle of vision covers in horizontal 70 degrees and in vertical 60 degrees (Figure 5.2a). Hence, the users' height could result into tracking problems because the slackline is about 30 cm off the ground. In combination with a person on a slackline several body parts could be cropped. The total tracking range of the sensor lies between 0.5 and 4.5 meters, whereas the sweet spot area lies between 1 up to 4 meters [7] (Figure 5.2b).

mobile slackline device sollte hier schon erklärt sein.

Since the mobile slackline device has a length of three meters, it would fit entirely into the sweet spot. But the Kinects' depth range is not sufficient to track user for

[3] http://www.alpidex.com/fitness/slacklines/slackline-gestell-in-2-laengen-power-wave-2-0-inklusive-slackline/a-10288/

further training on a longer slackline. This could be solved by using more than one Kinect device to enlarge the range.

(a) Angle of vision (b) Kinect tracking range

Figure 5.2: Sensor constraints of the Kinect v2 [7]

Testing scenario

The slackline is placed in three positions to the Kinect: frontal (0 Degree), diagonal (45 Degree) and sideways (90 Degree) **(Figure X - 1)**. Each of this positions is tested regarding three different height level of the Kinect: 80 cm, 160 cm, and 240 cm. Therefore it was attached on a tripod or traverse system (**Figure X - 2**). At the end nine different combinations are covered to track a user on a slackline, which gives a general overview of the Kinect height to the slackline. The testing person was recorded via *KinectStudio* [4], a tool for recording clips out of the streaming data of the Kinect. In the following the results discuss the feasibility and appropriate tracking positions.

Best positioning for study purposes

With a slackline positioned sideways in 90 Degrees rotated to the Kinect, the advantage is that the whole body on the slackline is in a constant line within the tracking area. No interference regarding the limits of the tracking range can happen. However, the Kinect had problems to detect the body joints with appropriate accuracy and precision, because of overlapping body parts (**Figure X**).

Better results have been achieved by placing the slackline diagonal in 45 Degrees to the Kinect. This is because several body parts will not overlap in this positioning. But it occurs that joints of the arms interfere with other body joints, especially at the end of the line. Also both legs occlude while stepping forwards **(Figure X)**.

Positioning the slackline frontal towards the Kinect resulted in the best user tracking. The Kinect can see the full body and track the joints without any

[4] `https://developer.microsoft.com/de-de/windows/kinect/tools`

problems. However, tracking failures occurred at the starting position of the slackline. This is because the slackline utilises the entire tracking range and therefore the user stands closer to the outermost limit of this range. **(Figure X)**.

Beginning with a height of 2.40 meters the Kinect has a very steep view angle to track the slackers' body on the full range of the slackline. Because of this the depth range shifts into the front like seen in **Figure X**. Therefore, if the slacker begins at the starting position on the slackline, she immediately reaches the end of the tracking area which causes detection problems. Also the closer she walks towards the Kinect the more the joints overlap due to the angle view of the Kinect.

With a height between 1.60 and 0.80 meters the body is fully visible in the entire tracking range. The Kinect has a relatively flat view angle. This results in a more homogeneous depth range (**Figure X**). If the height of the Kinect lays about 0.80 m the slackline must be positioned further away from the Kinect to prevent cropped body parts like the head or arms.

table

Kinect Height (m)	Slackline Positioning (m)						
	Frontal		Diagonal		Sideways		
	Front	Back	Front	Back	Front	Back	Mid
2,40	1.30	4.30	1.90	3.80	3.00	3.00	2.70
1.60	1.70	4.70	2.10	4.00	3.00	3.00	2.70
0.80	1.30	4.30	1.90	3.80	2.60	2.60	2.10
0.80 - 1.60	0.00	4.00	-	-	-	-	-

Table 5.1: Demographic data and physical activity table

The best combination resulted placing the slackline frontal and having a Kinect height of 0.80 up to 1.60 meters. The Kinect can track the entire body with nearly no joint overlap. Since the focus of the study in this thesis lies mainly on beginners, the starting position of the slackline plays an important role. Hence, it is better to move the slackline closer to the camera because the very end of the line is not important for the study. With this a higher tracking confidence is possible at the starting position, which is more important in this case **(Figure X)**.

5.2 Exercise Integration

The SLS leads the trainee through predefined exercises for slacklining. In development it is important to know that the exercises are defined as *gestures*. The *Kinect for Windows Human Interface Guidelines* describe the term gesture as follows: "*[...] we use the term gesture broadly to mean any form of movement that can be used as an input or interaction to control or influence an application.*" [7].

Two approaches exist to create custom gestures. The first one is heuristics, which means to manually track the position of each joint of the user. Conditions can then be defined according to the action that should happen e.g. if a joint exceed a certain threshold or is in a defined range. This can be easily used for simple gestures like raising the hand over the head. For more complex gestures, the developer must have a good understanding about the movement and behaviour of the human body. Furthermore, environmental factors, like an inappropriate mounting of the Kinect, could exacerbate managing and maintaining the code. Usually a common developer has not the appropriate expertise of the human body behaviour. Hence, it is recommended to use the Visual gesture builder (VGB) provided by Microsoft for this case. It uses machine learning to build a database out of pre-recorded clips by the developer. Afterwards the database can be implemented in an application to track the desired gesture. The cons of this are the huge file size of the recorded clips that can take very much disk space. Also tagging keyframes for recorded clips, which should be detected by the application is time consuming. On the other hand the tool is simple to use and constructing complex gestures can be easy like described in the next subsection.

5.2.1 Workflow for Building Gestures

The workflow for creating a gesture follows a general routine (Figure 5.3). At first the gesture has to be recorded via *KinectStudio*. This is a tool provided by Microsoft for monitoring and recording clips of the Kinect streams. Before inserting the clip into the VGB a new project has to be created. Therefore the developer first selects the body parts that are necessary for the gesture. After that an indicator has to be defined, i.e. if it is a discrete or continuous gesture. Discrete gestures underlay a conditional check in which the application determines if a certain gesture is currently performed or not. It provides a confidence value that compares the correctness of the persons execution regarding the gestures in the database. This is the majority usage for gesture tracking like e.g. raising the hand or lifting a leg. A continuous gesture however means that its progress can be measured instead of the confidence. Usually multiple small gestures are combined to an entire gesture, for which the progress is essential. This could be for example a golf swing or switching the standing leg [8].

After the project creation the recordings can be inserted as training data. The developer has to describe a starting as well as an end point of the gesture by tagging the clips. When finished, a gesture database file can be built. For testing reasons it can be analysed via a live preview or with other recorded clips in a separate analysis area. If the testing results are not satisfying, the developer can record and add more clips or adjust the tags of existing clips. Lastly, after the testing phase the gesture database file can be implemented in the application for gesture detection.

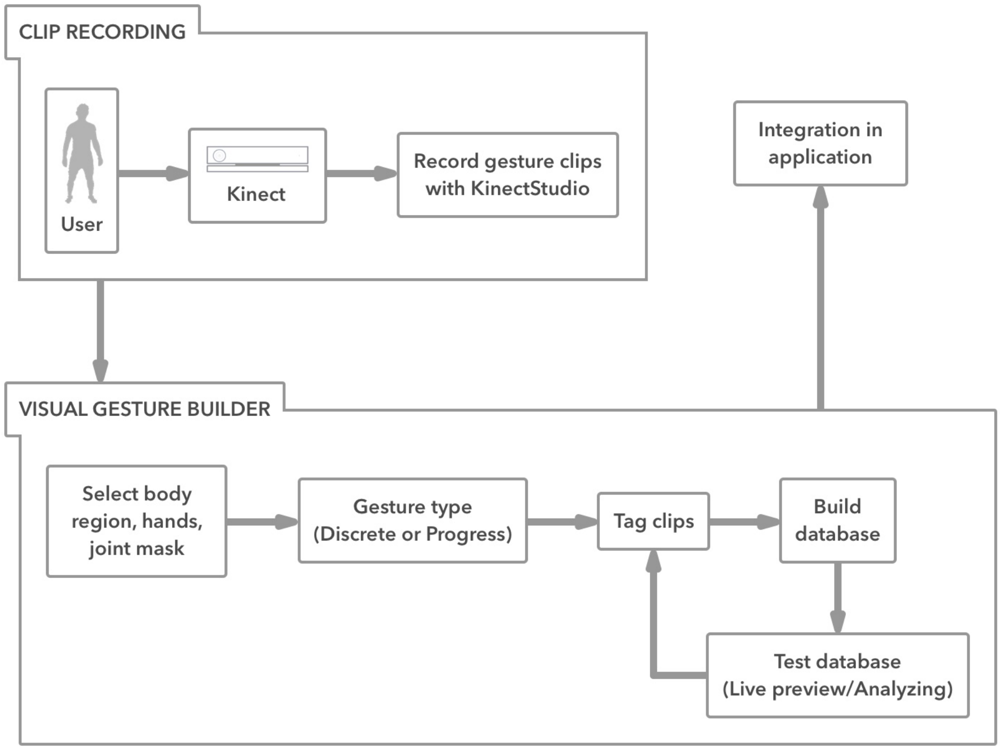


Figure 5.3: Workflow of creating a gesture database

5.3 System architecture

In the following several components of the general system architecture will be described that are necessary for the functionality of the interactive learning system with real-time feedback and for the study afterwards. An overview can be seen in figure 5.4.

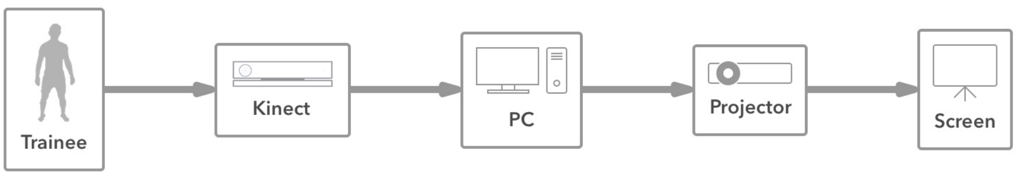


Figure 5.4: System overview

5.3.1 Hardware and Software Components

As slackline the mobile *alpidex POWER-WAVE 2.0* is used. It is placed in front of the *Microsoft Kinect v2*, which is used as tracking device. The Kinect itself is attached on a modell tripod with a height of about height, hüfthöhe?. A *Steambox*

PC footnote specs served as development device that fulfilled the recommended specs of the Kinect: *Windows 8, 4 GB Memory, Physical dual-core processor with 3.1 GHz or faster, USB 3.0 Gen-2 controller, Graphics card supporting DirectX 11*. A projector modell with a resolution of 1920x1080 was attached on a traverse system to give the user a more immersive feeling. The image is visualised on a projection screen with a size of 2x3m.

For software realization the cross-platform game engine *Unity3D* by *Unity Technologies* is used. It is widely known for developing games but manufacturer of several interaction devices (e.g. *HTC Vive*, *Oculus Rift*, *Leap Motion*) provide compatibility packages to make use of them in Unity. Applications can be deployed for several platforms on desktop, mobile, web, console, TV, VR, and AR (e.g. Windows, macOS, Android, iOS, Oculus Rift, Windows Mixed Reality and so on).

To access the data stream of the Kinect the *Microsoft Kinect SDK v2.0* [5] has to be installed on the PC. Microsoft offers also a *Kinect for Windows Unity package*[5], which provides all required scripts in Unity for creating a Kinect based unity application. Since *Unity 5* it can be used with the free personal edition of Unity, whereas before it could be only used with the pro version. Also the *Kinect v2 Examples with MS-SDK* [6] by Rumen Filkov was used to make data access and interaction implementation more simple as well as getting an idea on how to handle incoming data from the Kinect.

hier evtl UI design chapter rein

5.3.2 Software Implementation

The software development process consists of the interplay of two system components (Figure 5.5). First Unity itself, which is used to create the virtual environment, interface, and manage actions by the user. Second the Kinect SDK plugin for accessing input data of the user recognized by the Kinect device like e.g. joint position, gesture detection, and user actions. In the following the data structure and management, interaction integration, and feedback implementation of the system are further described.

Data Management

All relevant user and exercise data will be stored in JSON files, which is more human-readable and makes accessing and updating data simple in Unity via the JSON serialization feature [7]. Each user should have the same basement regarding the exercises. Therefore a default exercise JSON file serves as reference for all registered users in the system. An internal editor for exercises and users was

[5] `https://developer.microsoft.com/de-de/windows/kinect/tools`
[6] `https://www.assetstore.unity3d.com/en/#!/content/18708`
[7] `https://docs.unity3d.com/Manual/JSONSerialization.html`

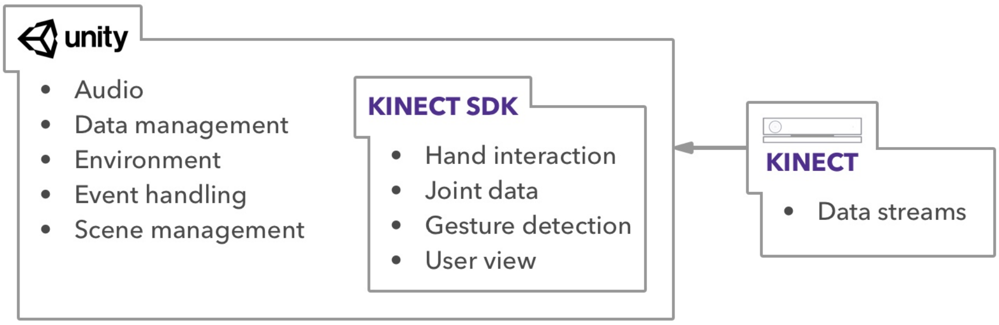


Figure 5.5: Unity and Kinect architecture

created for proper data management and to adjust the data files more easily for testing purposes. The overall data structure can be seen in figure img ref data structure.

image of data structure

Engagement gesture

The engagement gesture is the very first user interaction with the system. She has to raise her hand over the head whereupon the system conveys that it recognises specific user actions.

A code example on how to this gesture is implemented can be seen in listing 5.1. First the developer has to assure that the Kinect is initialized, a user has been detected, and the relating joints are recognized. A condition checks if the current vertical position of the right hand is above the head joint (*Listin 5.1 line 13*). If this is the case, the next scene can be loaded.

Listing 5.1: C♯ example code for tracking a raising hand

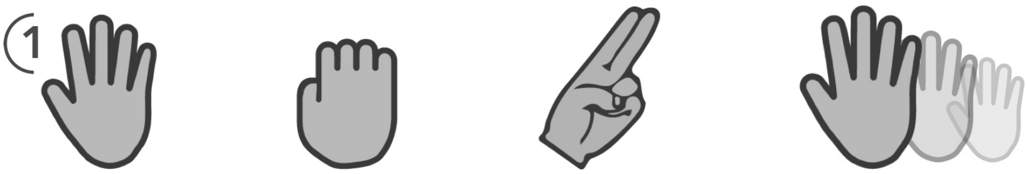
```
1  if (_kinectManager.IsInitialized() && _kinectManager.IsUserDetected())
2  {
3    long uId = _kinectManager.GetPrimaryUserID();

5    if ((_kinectManager.IsJointTracked(uId, (int) _jointHandRight) &&
6         _kinectManager.IsJointTracked(uId, (int) _jointHead))
7    {
8      Vector3 jointHandRightPosition =
9        _kinectManager.GetJointKinectPosition(uId, (int) _jointHandRight);
10     Vector3 jointHeadPosition =
11       _kinectManager.GetJointKinectPosition(uId, (int) _jointHead);

13     if (jointHandRightPosition.y > jointHeadPosition.y)
14       SceneManager.LoadScene("Tutorial");
15   }
16 }
```

Hand cursor interaction

To provide the possibility of an autonomous interaction the user has to navigate on her own with the system. Her hands serve as input for interacting with interface elements. The current position on the screen is visualised by a virtual cursor. Therefore she is in constant interaction with the system and becomes more familiar to it.

Four different approaches were tested as interaction gesture. First hovering with the hand over elements (Figure 5.6a). It is a good approach if small elements should be selectable. However relatively big and many interaction elements exists in the system, which resulted in accidental and unwanted misclicks. The second one is interacting by closing the hand to a fist or grab gesture and releasing it(Figure 5.6b). This resulted also in unwanted misclicks because of the anatomical behaviour and tracking distance. The hand of the testing users closes automatically a little bit during system interaction, which is sufficient to trigger a click (Figure comparison default & target). A better interaction gesture is the *V-sign*. The user makes simply a pointing gesture with the index as well as the middle finger. The click event triggers when the user releases her hand into the default state (Figure 5.6c). The last interaction gesture is pushing the hand towards the Kinect. It is related to the real world like pushing a button down and therefore the most intuitive and natural gesture behaviour (Figure 5.6d).

Therefore as main interaction serves the hand push gesture. The V-sign servers as fallback interaction if something wents wrong with the push gesture.



(a) Hover and wait (b) Grab (c) Lasso (d) Pushing towards Kinect

Figure 5.6: Several tried hand interaction techniques of the Kinect

Starting position

After engaging with the system the user is introduced on how to stay in a proper starting position. She has to stand with both feet parallel and in front to the Kinect like in figure ref illustration. This is required by some actions like just before starting the exercise execution. It ensures the readiness of the user and is needed to get the initial foot joint positions (cf. section Feedback integration). This is mainly to verify that the user stays, in the slackline exercises, on the line and not on the ground, since the Kinect cannot cover this condition.

illustration feets parallel

User selection

The system can have multiple user profiles. Hereby more than one user can train with the system separately. When the trainee selects her profile the system checks if the JSON file has any data. If no data is available, which means it is a new user, the default exercise JSON file will be copied into the profile. Then all exercise data are loaded into the system for data adjustment and management.

Tier & exercise menu

The tier and exercise menus are designed as levels. Like a common level system all levels are locked but the first one to provide a starting position. They can be unlocked by executing each exercise of the previous one. The structure already seen in section *4.4* is adapted to store the corresponding information for the tier, exercise, side, and repetition.

Exercise execution, providing feedback

The exercise execution consists of the biggest functionality implementation. Feedback indicators provide the user with necessary information about the current exercise in real time. This should help to enhance the performance in her execution and for successfully accomplishing the exercise. In the slackline system the following feedback indicators are integrated:

- Correct performance of an exercise
- How good the exercise is currently performed, namely the confidence
- Elapsed time the user is performing the exercise
- When the repetition was successful (i.e. minimum time has been reached)
- When a repetition attempt was not successful
- Amount of repetitions in general, finished, and left
- Checklist about key elements of an exercise (hands up, foot stretched, etc.)

After each successful exercise execution the user is lead to a summary screen. Here she gets an overview about her performance. It shows parameters about the execution time, attempts, and the confidence for each repetition as well as an average value for the accomplished side. A similar summary screen exists also for the entire level with the same parameters but only the average value for the entire exercises.

5.4 User Interface

The user starts with an engagement gesture which is implemented as raising her hand over the head. After that a tutorial about interaction techniques of the system will be given. Now that she's confident with the system interaction she can select her profile in the user menu. This loads the profile which leads further to the level selection menu. In here she can select a level, whereas initially the first one is can be selected. Selecting a level leads to the exercise menu. In here she has to read initially the stage introduction to become a basic understanding about the exercises within. After reading this, it unlocks the first exercise. Selecting an exercise leads to the side selection, where the user has to choose the side she wants to train. This is followed by an introduction of the exercise, in which is explained how to perform it correctly. If the user is ready, she should stay in a starting position to be able to start the exercise execution. Then she find herself in the exercise execution scene. It provides indicators to correctly execute the exercise, like the time, repetitions, confidence and a checklist. After finishing with the exercise, a summary is shown which summarizes the user performance. Then she can return to the main menu or directly try the next exercise. At the end of each stage an overall summary gives an overview about all exercises with average performance parameters.

The user should be introduced to the stage. In here the purpose, goal, and helpful techniques should be given, such that the user becomes an overview about the exercises. At last a summary scene shows several performance parameter for the exercises in this stage.

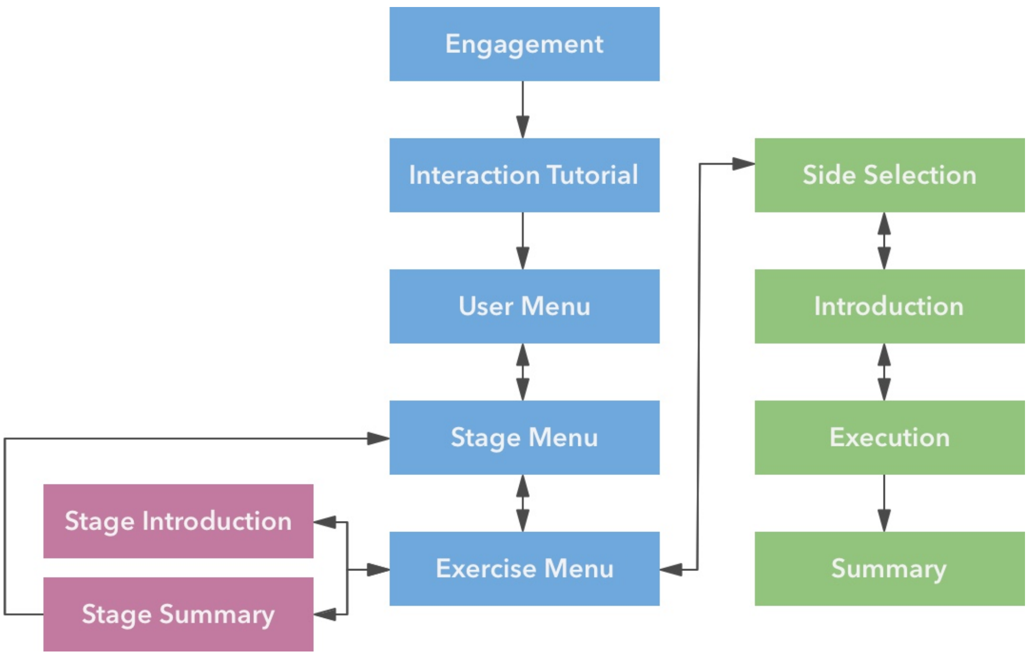


Figure 5.7: Scenario workflow

Chapter 6
Study

This chapter describes the study idea and procedure in detail. At first section research questions discusses the hypothesis and purpose of the study. After that section participants provides information about the users that have participated in the study. Further section set up shows how the tested methods are constructed. The procedure of the study consists of several parts, like the briefing, measurements, experiment itself, and an interview. This is discussed in detail within section structure. Along with that the results will be elaborated and analysed in section results. At last the discussion in section discussion will answer the research questions based on the analysis section.

6.1 Introduction and Goals

The idea is to measure and evaluate the learning progress of beginners with different training methods. Like stated in Section section a human trainer is the common way of learning slacklining. Therefore the SLS will be compared against this method to show if it can compete. It is a *think aloud* study, so that the participant has to share her thoughts and the way she thinks when making an action. Several research question arise regarding the SLS that have to be analysed and discussed, which are the following:

- The SLS has some statistically relevant influence regarding the performance of teaching beginners compared to other common training methods (personal trainer)
- The SLS will support the user in fast changing balancing exercises
- It motivates the user to learn new skills and techniques

- Such a system is usable for the field of sport slacklining
- The exercises provided by the system are challenging but provide a good sense of training for beginners

6.2 Participants

A total amount of number participants were recruited from campus/friends/etc. They were divided into a human trainer (HTG) and interactive system group (ISG), each with number participants. Among them X were males and X females. The age ranged from min age to max range (mean, avg, SD), the body height from min height to max height (mean, avg, SD), and the weight from from min weight to max weight (mean, avg, SD). All participant agreed to train without shoes but with socks to provide a consistent training condition per participant. In the ISG condition, X participants had prior experience with an interactive device whereas X participants had few experience and X had no experience. Regarding prior slackline experience some stood either one up to three times on a slackline or never. All participants had no contact with a slackline in the last two years. No participant had experienced prior knowledge in balance activities.

The physical activity level was determined with the *Physical Activity, Exercise and Sport Questionnaire (Bewegungs- und Sportaktivität Fragebogen - BSA-F)* by Fuchs et. al [15]. The activity level in their job and spare time as well as sport activity, ranged from very low active up to highly active (Table table). The preference of any body side was determined with a *Lateral Preference Inventory Questionnaire* by Coren [6]. Each participant had a strong preference to be right sided.

All participants were briefed and gave their consent for taking part on the study and agreed with audiovisual data recording. The present study was approved by the local ethic commission.

- Table participant information and Table physical activity & lateral preference

- m hoch 2, linien grid

	HTG (n=6)	SLS (n=6)	Total (n=12)
Gender [f/m]	3/3	3/3	6/6
Age [years]	21	22	21.5
Weight [kg]	80	85	82.5
Height [m]	1.70	1.75	1.725
BMI [kg/m2̂]	22	23	22.5
PA-Spare Time [min/week]	1.70	1.75	1.725
PA-Sport Activity [min/week]	1.70	1.75	1.725

Table 6.1: Demographic data and physical activity table

6.3 Method

6.3.1 Conditions of Slackline Training

Interactive Slackline System Group

Like seen in chapter 5 the participant has to interact at her own with the system. It teaches the user how to interact with it and guides her through predefined exercises. Therefore it explains on her own how to execute the exercises, how many repetitions to make, and in which time to accomplish each repetition. It provides real-time feedback about the performance. The participant could ask to skip the exercise if it were too difficult to accomplish or not recognisable by the system. The experiment leader had no influence about questions regarding the exercise execution to ensure the autonomy of the user with the system.

Human Trainer Group

The participant has been instructed by a human trainer. At first an introduction about the current level is given. Then the specific exercise is instructed by how to execute an exercise, how many repetitions to do, and the minimum time she had to hold the pose. After that the trainer demonstrates the execution of the exercise for the trainee. The trainer himself had an exercise description sheet to provide the trainee with the same information as in the SLS condition.

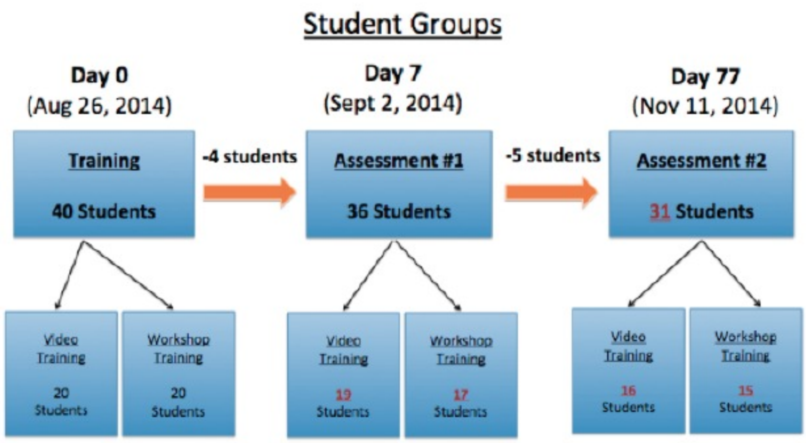


Figure 6.1: Study groups example

Apparatus

The setup can be seen in Figure [figure]. The Kinect was attached on a tripod with a height of 90 cm. It was placed in front of the screen with the camera faced in the direction of the slackline. A beamer was mounted on the ceiling of the room to project the interface on the screen in front of it. The slackline stood, like discussed in Section 5.1, directly in front of the Kinect. A marker was attached on the slackline to provide a starting point for the participant for getting up the line. The set up for the human trainer group was the same, but without the screen. The video camera for recording was placed behind the slacker in a more diagonal way to have her actions as well as the interface interaction recorded. The set up was not changed during the study to have the same condition for every participant.

insert mobile slackline device

Like seen in section *Slacklining Variations and Categorizations* a mobile slackline device is the best solution for the learning system. This makes it easy to vary its position and rotate it accordingly.

[Figure]

6.3.2 Design

6.3.3 Procedure

At first the participant was welcomed and then briefed about the idea as well as what she can expect from the study. Further an introduction about the training method in which she participates was given. After that she had to fill out a questionnaire for collecting demographic data and her prior experience with slacklining. The ISG had to answer one more question about the prior experience with interactive devices (e.g. Kinect, Wii, PlayStation Move, etc.). The physical activity level as well as the lateral preference was determined like stated above. Lastly she had to confirm a form consent.

pre-measurement eher allgemein halten und in 6.4.3 ausarbeiten oder testprozedere hier näher erläutern (attempts, wie lange maximal, marker an der slackline, etc.)?

After that the participant had to stand on the ground as well as on a towel to obtain her general balance ability. Further a pre-measurement was conducted to the slackline balance ability and the steps the participant is able to go on a slackline were measured for comparison.

The participant had to stay on a marked position, which gives the starting position of all exercises. Similarly a marker on the slackline visualises the starting position on the line for the participant. She had to execute all exercises either provided by the system or the trainer. These are divided into four levels with 6, 4, 6, and 3 exercises. Between each exercises the participant could take a break if desired.

After each accomplished exercise execution the participant was asked to rank the exercise regarding its difficulty. The ranking ranged from 1, very easy, to 5, very difficult. Therefore the assumption of the participant can be compared with the logged performance data. Further, it can be shown if the difficulty of the exercise set in each level is increasing and match the integrated exercise routine.

sollte die erklärung eher in Independent and dependent variables?

post-measurement eher allgemein halten und in 6.4.3 ausarbeiten oder test-prozedere hier näher erläutern (attempts, wie lange maximal, marker an der slackline, etc.)?

When finished with the training a post-measurement was conducted with the same procedure, like seen above in the pre-measurement.

Finally the participant had to answer questions a semi-structured interview to obtain her opinion on the general method and application scenarios for exactly this method with the slackline and other sport activities that could fit this method. Additionally the ISG were also interviewed about the user interface of the SLS and their experience with the interaction. The specific questions can be seen in Appendix.

6.3.4 Independent and dependent variables

The general balance ability of the participant was measured before training by how long she can stand on the ground and a towel. Comparing the results of the training method were conducted by standing on a slackline before and after the training. All measurements involves the left, right, and both feet and were counted in seconds.

Furthermore, the participant had to made as many steps as she can on the slackline with the left and right foot as starting point. Hereby the steps were counted as comparison parameter. Additionally the distance on the slackline was measured by dividing the device into five areas, each with a distance of 60 cm. Three attempts per side and method were executed and the best taken / the average calculated to compare the results.

- exercise difficulty ranking, Interview questions?

Dependent variables –>

- Time stood on line with left, right, both feet
- As many steps as possible on the line (+ distance with markers on the line) left, right feet
- Accomplished exercises

Independent variables –> training method

level?

- Interactive Slackline System
- Human Trainer Group

Confounding variable

- Experience with general balance training
- Experience with slacklining
- General physical activity

6.4 Results and analysis

6.5 Discussion

Chapter 7
Conclusion and Outlook

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