Influencing body awareness through interactive technology in physical training

A design-oriented research in equestrian vaulting with an excursion into neuromuscular biofeedback

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Abstract

Current research is underdeveloped regarding the application and development of interactive technology in instructed physical training. This includes the lack of training tools and methods targeting body awareness. Underdeveloped body awareness leads to a lack of self-confidence and the lack to relate to oneself emotionally, mentally and/or physically, as well as the inability to relate oneself to the external world. Therefore further research in this area is strongly required.

Accordingly, this thesis deals with the questions of what types of body awareness can be designed for in a physical training context as well as how to influence the identified types through interactive technology. Reducing the thesis’ scope, the applied research concentrated on the physical training of equestrian vaulting. Therefore, a research through design approach was applied in combination with a selection of embodied interaction methods. In total, two epochés, two bodystorming workshops, two experienced prototyping sessions, one expert interview and one pilot study were conducted by focusing on an explorative, qualitative approach while putting high emphasis on the user involvement. Through the iterative development, the effect of neuromuscular biofeedback on body awareness was tested and discussed on a superficial level as one example of how interactive technology could influence body awareness.

Overall, results identified various types of and issues with body awareness that re-occurred throughout different training situations and for which the integration of interactive technology could be beneficial. These results further lead to design implications for and insights about the design of interactive technology aiming at supporting the training of the identified body awareness issues.

Sammanfattning

Aktuell forskning är underutvecklad när det gäller tillämpning och utveckling av interaktiv teknik vid instruerad fysisk träning. Detta inkluderar bristen på träningsredskap och metoder som inriktar sig på kroppsmedvetenhet. Underutvecklad kroppsmedvetenhet leder till brist på självförtroende och till en brist att förhålla sig emotionellt, mentalt och / eller fysiskt, liksom till en oförmåga att förhålla sig till den yttre världen. Därför krävs ytterligare forskning på detta område.

Följaktligen behandlar denna avhandling frågor om vilka typer av kroppsmedvetenhet som kan utformas i en fysisk träningskontext samt hur man påverkar de identifierade typerna genom interaktiv teknik. På grund av begränsning av uppsatsens omfång, koncentrerar den tillämpade forskningen på den fysiska träningen av ryttarevalvning. Därför tillämpades en forskning genom design metod i kombination med ett urval av förkroppsligade interaktionsmetoder. Totalt genomfördes två epokéer, två kroppssstoringsverkstäder, två erfarna prototyper, en expertintervju och en pilotstudie genom att fokusera på ett explorativt, kvalitativt tillvägagångssätt samtidigt som man lagt stor vikt vid användarnas engagemang.

Genom den iterativa utvecklingen testades effekten av neuromuskulär biofeedback på kroppsmedvetenhet och diskuterades på en ytlig nivå som ett exempel på hur interaktiv teknik kan påverka kroppens medvetenhet. Sammantaget identifierade resultaten olika typer av problem med kroppsmedvetenhet som upprepades genom olika träningssituationer och för vilka integrationen av interaktiv teknik skulle kunna vara till nytta. Dessa resultat leder vidare till konstruktionsimplikationer och insikter kring utformningen av interaktiv teknik som syftar till att stödja utbildningen av de identifierade kroppsvårdsproblemen.
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1. Introduction

Today’s technology and standard of living cause people to become more and more inactive because of mainly working in front of computers, watching television or by playing with their mobile phones while moving their fingers only. Thereby, physical movement is highly important for our bodily, emotional and mental health. A lack of it can lead to severe and long-lasting medical conditions as well as decreases a person’s quality of life. We humans experience and feel ourselves as well as the world around us through our senses and hence, through our body. Accordingly, the experience through and with our physical body determines our experience of and interaction with the world.

Sports, or in general, physical training, is an effective countermeasure against the increasing immobility and supports the development of a good body awareness. Body awareness is the key driver that determines how and what we experience as well as defines the level of self-control about one’s own actions. Instead, lacking body awareness leads to a lack of self-confidence, the inability to relate to oneself as well as the inability to relate oneself to the external world. So, while a good body awareness can be developed through physical training, it further enables us to learn and execute courses of movements.

The training of body awareness is already an important topic in the rehabilitation sector. E.g. stroke patients who suffer hemiplegia, exercise to recover their body control and - strength. In such a case, people face the additional problem of not being aware of the paralyzed body side, so that they first need to regain the connection to that other body-half. However, everyone who is familiar with the situation knows that the recovery is a long lasting process that can take up to several years, if ever fully recovered.

In general, to perform a certain movement in the way it is implied to be done, can take years. Therefore, the thesis aims at revealing types of body awareness in a physical training context that could benefit from the integration of interactive technology. Interactive technology offers various possibilities to be applied and integrated into any situation and is already deeply integrated into our daily lifes which makes it an interesting medium to look at. Hence, the second aim of this thesis is to derive design implications that indicate how to design interactive technology for body awareness by scoping the thesis into a specific physical training context.

Equestrian vaulting is thereby selected as the physical training area, as it incorporates various training possibilities regarding its participants. It is a sport that can be done individually, together with one partner or in a group and which includes additionally the training on and with the horse. The different components and possible training situations that the sport offers, enables a very broad basis for exploration which is an important aspect for the identification of body awareness types and how to influence them. With influencing body awareness is meant either to support, change, challenge, enhance, augment or complement it.

1.1. Problem Statement and Research Question

Lacking body awareness leads to great issues in our daily lifes. It includes the issues of not being able to control or trigger certain body parts as well as not being able to identify oneself with the own body. Physical training supports the development of body awareness, but requires a certain level of body awareness at the same time to even conduct a movement. As reaching the required level of body awareness to perform an implied movement can take up to several years, this thesis explores
possibilities for interactive technology to support the training process of body awareness by framing the broad topic into the context of the physical training of equestrian vaulting and by concentrating on the two following research questions:

1. What aspects of body awareness are important in a physical training and can be supported by interactive technology?

2. How can interactive technology influence body awareness in the physical training for equestrian vaulting?

**1.2. Objectives**

The thesis main objective is to reveal design areas and potential design solutions based on interactive technology to influence body awareness in the physical training context of equestrian vaulting while identifying facets of body awareness that interactive technology can be designed for. Deriving from this, the more abstract aim is to enrich current research within HCI about the knowledge of the role of body awareness on the design process of training artefacts that are supported by or built of interactive technology.

**1.3. Development**

At the beginning of this study, the scope was on the potential integration of interactive technology in physical training overall. By framing the topic to equestrian vaulting, the topic was narrowed down, while a clearly identified problem was still outstanding. Through an iterative approach, the thesis focused soon afterwards on body awareness and how to design for its training. By reducing the scope even further, one design example was iterated through prototyping which was based on body awareness by neuromuscular biofeedback.

**1.4. Structure**

The thesis’ structure clearly presents the argumentation of and for the various made (design-) decisions throughout the progress and how each applied method influenced the following. In the next sections, the thesis introduces its design domain as well as current research within the fields of HCI, rehabilitation and engineering. It follows some term definitions including body awareness, the human senses and biofeedback which are necessary to analyze and discuss the gathered results. Afterwards, an introduction of the conducted methodology and methods is presented, including the reasons for conducting them.

Thereby, considering the high influence that each method result had on the following, the thesis structures the progress and results of each method in one own chapter. For a better overview, the analyzed results are summarized in the following analysis chapter and further discussed in the discussion chapter. Lastly, the thesis concludes with a summary of the conducted approach and gathered results.
2. Background

The following chapter introduces embodied interaction design as the domain in which the thesis is situated and provides an overview of ongoing research in HCI about interactive technology in a physical training context. Furthermore, ongoing research using interactive technology targeting body awareness as well as neuromuscular biofeedback is presented. Lastly, equestrian vaulting is introduced as this thesis’ application area of the physical training. The presented research provided an overall understanding about the current research status as well as implementation and usage of interactive technology in the context of physical training, of the training of body awareness as well as its role for body awareness by neuromuscular biofeedback.

2.1. Embodied Interaction

This thesis’ work is situated in the domain of embodied interaction which aims towards the understanding of how meaning is created and conveyed through embodiment as well as how we can make use of our way of interacting and perceiving the world in the design process of interactive technology (Dourish, 2004). Thereby, body awareness is an essential medium through which embodiment as well as the process of meaning-making is possible.

Embodied interaction is, according to Dourish (2004), the social and bodily interaction which makes us experience and interpret the world and ourselves within it in an immediate experience. The foundation of embodied interaction is influenced by phenomenology, a philosophical movement which discusses that perception and meaning making of the world is a subjective process depending on the experiences each individual makes. One of the movement’s philosophers, Merleau-Ponty’s, influenced Dourish’s definition of embodied interaction essentially, as shown by Svanaes (2013). The concept of perception and the lived body by Merleau-Ponty emphasizes, among other aspects, that the human body is not an object through which we perceive the world, which would consequently mean that mind and body are separated, but that both are one (Merleau-Ponty, 2012). It includes that the meaning-making and the understanding of the world are based on the interaction with our physical and social environment and experienced through our body, including its senses, hormones and physiological processes. Thereby, it shows quite well why an embodied interaction approach makes sense to consider in the design process for interactive technology that targets a physical training application area.

Another core aspect of embodied interaction is the consideration of the space in which the interaction takes place. Also thereby, the physical as well as the social conditions of a space are mentioned to influence a person’s experience (Dourish, 2004). Hence, the space in which an activity or an interaction takes place needs to be taken into account in the research and design process, so that the influence a space has on an interaction can be experienced under real, or at least simulated, conditions. Further, also objects within the interaction space are of interest. Each object is identified with a certain affordance by our perception and interpretation. This identification process triggers our (re-)actions and our understanding of the object for what, why and in which situations we could make use of it. Consequently, the way we perceive artefacts in space completes our perception and meaning-making of the world.

The presented details about embodied interaction shall provide a better understanding as well as argumentation basis for the selected methods, which are mainly based on the prominent role of the physical interaction that embodied interaction represents and its high emphasize of the contextual conditions, such as space and physical artefacts.
2.2. Interactive Technology in a Physical Training Context

As the thesis begun by framing the topic into the area of physical training, the following background section introduces ongoing and to the topic related research conducted and discussed within HCI. The goal is thereby to receive an overall understanding of the current status, so that the thesis’ results can be compared to – or build upon it.

Interactive technology in a physical training context is discussed and explored from different perspectives within HCI, from either a more practical point of view focused on physical exercises or a more aesthetic point of view focusing on the embodied sensation of an experience. As a common factor of the following presented research approaches serves the concept of embodied interaction design which focuses on and emphasizes the role of embodiment during an interaction and hence, how we create meaning of the world and our surroundings.

In general, research from embodied interaction design enjoys increasing popularity for the last 15-20 years. Especially in the context of more artistic related sports like dance (Moen and Jin, 2005; Mullis, 2013; Ribeiro, dos Anjos and Fernandes, 2017), in physical training (Mueller et al., 2007; Isbister and Mueller, 2015) or by focusing a holistic embodied interaction design approach by emphasizing the role of emotional or cognitive aspects (He and Schiphorst, 2009; Schiphorst and Thecla, 2009; Schick and Malmborg, 2010; Loke, Khut and Kocaballi, 2012; Beuthel and Wilde, 2017).

Beginning with research focusing on a practical point of view, e.g. Mueller et al. (2007), looked into the benefit of computer supported collaborative sport, also abbreviated as CSCS, to enable people over long distance to do physical activities together. One of the research’s core aspects was the role of sport as a social event and how benefitting physical activities are not only for the body fitness, but also for the mental health and well-being. Additionally, as there are very few established guidelines and principles for the design process of interactive technology in this context, Isbister and Mueller (2015) introduced a first collection which was generated based on experience of a pool of researchers and designers. These guidelines and principles focus on how to design for movement-based games. Nonetheless, many aspects can be used as orientation for the design of interactive technology in the physical training context too and hence, for the later prototyping. Both presented references show as well as mention that the current research state is still on a beginning level, requiring much more research to be conducted from an HCI perspective in the context of physical training.

One of the first sports that researchers started to look into and use from an HCI perspective was contemporary dance (Moen and Jin, 2005; Mullis, 2013; Ribeiro, dos Anjos and Fernandes, 2017). The reason for this sport was that it conveys and emits through physical movement emotions and aesthetic properties which are perceived by the dancer and the observer. Hence, contemporary dance requires to really embody the movement by nature, instead of a pure mechanical execution as it might occur in other sports. Further, Moen and Jin (2005) points out that two of the aspects that researchers have to learn is how movement is perceived, which requires a good body awareness as well as the reason for why humans move. Understanding the intrinsic motivation of and for movement reveals many insights about how, why and when we embody a situation. Ribeiro et al. (2017) and Mullis (2013), emphasize further the role of interactive technology in contemporary dance which triggers a change of performer’s and observer’s perception of the performance. Additionally, interactive technology provides a platform to share movement, the meaning of it and hence, the experience behind it for further collaboration and social interaction. Thereby, researchers used different technology to achieve
the shared platform, such as “Composition in Real Time”, 3D capturing (Ribeiro, dos Anjos and Fernandes, 2017) and sharing of performances or the Chunky Move’s Glow as in McNeilly (2014). In each example, the applied technology supported the revelation of body functionalities, including emotional ones, by leaving space for (re-)interpretation and subjectivity. Another reason to focus on dance is to understand the meaning of aesthetics and aesthetic movements which is still in the process of being researched. As equestrian vaulting requires embodied performances during freestyle including a well-developed aesthetic and charismatic expression, the presented research in dance could allow to draw comparisons between both sports in the later process.

The emotional and cognitive aspects of embodied interaction are further researched in either more open conducted research or more concentrated studies focusing on a certain embodied aspect. Tomico and Wilde (2016) as well as Beuthel and Wilde (2017)) made, as example, use of soft wearables which are textiles including smart technology and soft electronic interfaces, to convey a person’s feelings and emotions. In comparison, Höök draws from somaesthetics, which is a cross-disciplinary field that deals with the topic of how to increase the understanding for our body as well as how to improve the usage of it. This field was introduced by Shusterman in e.g. (1997). Thereby, Höök (2009) describes the embodied interaction between a system and a human as “affective loop experience”. She emphasizes with this term the importance and the effect of a system’s reaction to a user input on the user’s interpretation of the world and one’s own behavior, while the user would alternate the behavior based on the system’s response. Also hereby, she points out that the system would make the user reflect and become more aware of the own body functions and the emotional involvement. Another study by Höök (2010) focused on the somaesthetics experience of horseback riding and how that sport increased and challenged one’s own body perception and control. Even though the study relinquished the use of interactive technology, it showed the effect that a second living entity can have with its own movement on one’s own movement and perception, especially if the goal is to synchronize and collaborate with the animal. By introducing the aforementioned research in the thesis’ context, the current role of interactive technology from an HCI perspective becomes clear in the context of physical training. It might be used as a tool to express emotional sensations or other aspects, as presented by Tomico and Wilde (2016) but it also changes the user’s perception and meaning-making as mentioned by Höök (2009).

As the thesis focuses in the following progressively on body awareness, the following part reveals what kind of technology is currently used in, at least, research to change a person’s body awareness as well as the meaning of body awareness in a more overall design context.

### 2.3. Interactive Technology in The Context of Body Awareness

This chapter extends the consideration of ongoing research beyond the field of HCI by narrowing the focus on body awareness. Both changes in scope are based on the thesis development from physical training to body awareness. As body awareness is barely discussed within HCI, other research areas are consulted for a better understanding of the current status.

An area where interactive technology with a focus on body awareness is often used is in physiotherapy in the context of rehabilitation. Nonetheless, among others, Christou et al. (2011) as well as Levisohn and Schiphorst (2011) emphasize the role of body awareness for the design and implementation of interactive technology from an HCI perspective. Both papers point out clearly the increased quality of an interaction experience by including and considering body awareness in the design and implementation process which further emphasizes the importance of the thesis’ topic. Christou et al.
(2011) introduce further a framework, which emphasizes that for the design of interactive technology it is important to consider the user’s former experiences and expectations that are based not only on the contextual side of the design, but also the physical movement-related interactions.

Nunez-Pacheco and Loke (2014)’s work provides another perspective on how and why interactive technology can be used to increase body awareness. Body awareness is intertwined with the perception of ourselves and the world around us as well as with the actions we perform within this world. The argument by Nunez-Pacheco and Loke (2014) is that the better developed a person’s body awareness is, the more power the individual has over its perception and its actions. In other words, the better our body awareness, the more we can control and influence also our user experience. However, for developing body awareness, there is a need of learning tools and methods. Interactive technology can at least partly provide these tools, especially as it is deeply integrated in our daily lives already. Wilde, Cassinelli and Zerroug (2012) made an attempt by applying light arrays to visualize the range of as well as the occupied space of movements and the body. They conclude that the application of light, in various forms, can be used as learning tool to become more aware of the effects of a body movement in space which influences a person’s body awareness.

Warren, Matkin and Antle (2016) emphasize the differences between the subjective, personal body awareness and the outer image perceived by others, which they call “objective reality”. Interactive technology can be applied to close this gap and to, first of all, reveal the difference between internal image and external scheme, and second, to align both. This includes altering a person’s body awareness over short- as well as long-term. Thereby, it reveals that time and timing are important aspects in this research field, especially as movement is always a temporal process. In this regard, Warren, Matkin and Antle (2016) further discussed the timing of applying interactive technology which is, in this case, mainly based on pressure and vibrations sensors. The timing of giving the planned input is key for understanding how body position and movement are related. In the current example, the input is required in real time, in other words directly when a wrong body posture appears.

In the context of body awareness, the outer perspective by e.g. a second person on oneself or during an interaction can also be used to develop the change of it. The method of using a second person perspective to increase one’s own body awareness is related to the relationship between coach and athlete, so that the quality of the coach’s feedback and perception needs to be taken into consideration in the further process, as well. Research focusing on the social interaction is summarized by, among others, Schick and Malmborg (2010). In their example, changes on a person’s skin were shared with others through wearable technology. Their setup allowed not only other people to understand one’s own body reactions better, but also supported, due to reflection, to understand the own body functionalities better as well as a potentially increased the level of empathy in other persons due to the shared experience. However, nothing was mentioned about the (after-)effect that the shared experience caused in and for participants. Nonetheless, the presented research shows the importance of considering the perception by other persons on the own body awareness, which influences the further approach regarding the different user perspectives that are taken into account.

By considering examples of the area of rehabilitation, training towards an, e.g., improved body postures or balance (Wang et al., 2017) is one discussed focus. Other research used the training in a virtual environment to train balance abilities (Chen et al., 2012; Grewal et al., 2015). Results showed that the virtual environment and representation improved balance abilities and trained the vestibular system which further practices a person’s body awareness.
Other applied technology that aims toward an increased self-awareness deals with making interoceptive information and functionalities, the information about the physiological state of the body including emotion processing (Forkmann et al., 2016), transparent to the concerned person (Filippetti and Tsakiris, 2017; Françoise et al., 2017). Neumark and Khut (2007) used, as example, mandalas based on video projection and real time sonification to visualize participants’ heartbeats which included a certain aesthetic aspect. Khut and Poonkhin (2016) further used visual and audio output to convey the autonomous nervous system outside the body, so that body functions were extended in the outside projection, allowing the user to experience oneself from a different perspective and to get to know one’s inner-self better.

Overall, the presented research shows that interactive design lacks design implications or an overall design process for training tools to develop and train a person’s body awareness. Instead, more research has been conducted towards single body sensations, that all contribute to body awareness, and how to practice these, especially in a rehabilitation context. It supports the thesis’ statement about the current research gap in this direction.

As the thesis conducts an exploration of applying neuromuscular biofeedback and its influence on body awareness in the physical training context, the following presents a short overview of current research in this field.

2.4. Interactive Technology Considering Neuromuscular Biofeedback

The following presented research should provide a short overview of current application areas of and problems in the interaction with neuromuscular biofeedback which can be further considered or related to in the later progress.

Interactive technology considering neuromuscular biofeedback is mainly applied in medical, rehabilitation and sport contexts. Barbero, Merletti, and Rainoldi (2012), Fjellman-Wiklund et al. (2004), Giggins et al. (2013), Harvey, McPhetridge, and Thorne (2012) as well as Kropp and Niederberger (2010), as example, researched the effect of visible muscle tension on dyponesis which is a chronically occurring muscle tension, aiming towards a conscious activation and deactivation of muscles and muscle groups. Their results showed that an increased awareness about one’s own muscle tension state can help to reduce varying issues depending on which muscle the technology is applied to, such as headache, neck pain etc. Further, a conscious control over one’s muscle tension would also improve performances as well as body positions while reducing unnecessary or conflicting tension (Barbero, Merletti and Rainoldi, 2012; Harvey, McPhetridge and Thorne, 2012; Peper et al., 2014; Jehu, Thibault and Lajoie, 2016), a topic also relevant in physical training.

An essential part of the interactive technology in this context is the possibility to move body-internal functions outside the body and convert it in a way that it is understandable and hence, creates meaning for a person. Apparently, a combination of a graphical output on a screen-based user-interface with an audio pitch are the most common form of conveying biofeedback, especially in a therapeutic context (Kropp and Niederberger, 2010; Harvey, McPhetridge and Thorne, 2012; Jehu, Thibault and Lajoie, 2016). In comparison, research by e.g. Verschueren et al. (2003) and Cimadoro et al. (2013) showed the application of a pure haptic feedback in either a muscle enhancement exercise or in balance training. In general, neuromuscular biofeedback provides various application areas that relate to interoception and is effective for training the vestibular system as well as for conscious muscle control.
In sports, e.g. research by Ekblom and Eriksson (2012) and Xu, Li, and Hong, (2003) shows the correlation of physical training on muscle tension measurements and the other way around. It appears that either way, the extended awareness of the neuromuscular function increases the physical fitness and abilities as well as provide another kind of comparability between performances which can be reviewed via the graphical output based on the measured data. However, focusing on the user experience while interacting with muscle tension measuring technology had not been discussed much. Peerdeman et al. (2011) point out this problem in their research while investigating the user experience of a forearm prosthesis. Other research focuses rather on the kind of output that should be provided to communicate the measurements. According to Afzal et al. (2016) multimodal biofeedback, for which in that study visual and haptic feedback was combined, had the greatest training effect. Multimodality is defined to be the most natural way of communication for humans (Dumas, Lalanne and Oviatt, 2009; Wechsung, 2013) and hence, the modality that offers the greatest accessibility for the broadest range of users.

However, research on interactive systems integrating muscle tension measurements focuses mainly on the mechanical and practical implementation, so that the development towards a more user-centered approach provides still opportunities to grow. Accordingly, neuromuscular biofeedback is proven to have an influencing effect on body awareness, but still requires a lot more research regarding its implementation. Hence, the thesis applies this knowledge and explores the application of neuromuscular biofeedback in a new context, considering former presented research results about e.g. multimodality.

2.5. Equestrian Vaulting

Since the thesis deals with body awareness in a physical training context, the scope was reduced to one particular physical training area which is equestrian vaulting. The limitation to one sport was to allow more in-depth explorations and testing as well as it provides concrete physical training situations as references for the later analysis and discussion. In the following, a short introduction is given about the sport to get a general idea in which application area the thesis took place.

Equestrian vaulting is a sport which requires a good body perception and control as well as which encourages social interaction and responsibility through the interaction with the horses, the coach and other participants. It is used and practiced in varying contexts and for different reasons. First of all, it is a sport including competitions on national or international levels (Vereinigung, 2013). Secondly, it serves as preparation for horse riding due to its safe and soft entry to the interaction with horses and their movements (Rieder, 2002). Further, it is also used in therapy in which the horse serves either as disciplinarian (Carlsson, 2017) for, especially, younger children, or as mediator (Scott and Evans, 2005) between therapist and patient. And lastly, it is also used in events as entertaining performance in various shows (Seidensticker, Reisß and Kehler, 2016; Kaiser, 2017).

Christian Peiler and Dennis Peiler (Peiler and Peiler, 2014) describe in their book a huge set of trainings exercises which includes official definitions and requirements by the FEI (Fédération equestre international) (King and Building, 2013), the international leading organization in equestrian sports, as well as root causes for mistakes in the execution of exercises. A general rule in the competitive sport is that each group or individual needs to show a compulsory as well as a freestyle which includes grading criteria like execution, composition and level of difficulty. Thereby, performances in the freestyle can include up to three vaulters on the horse at the same time. The
composition of the freestyle includes aspects like the design of the vaulting suit or the selected music. Hence, it incorporates and requires a certain charismatic expression of the vaulter.

Peiler and Peiler (2014) further summarize the skill set of a vaulter whom they attest a good body perception and control. The skills set is thereby structured into three categories, motor skills, psychological skills and pedagogical skills as seen in the following table.

| Motor skills | • Conditional abilities: endurance and strength lead to speed  
|             | • Coordinative abilities: interoperability, differentiation, balance, orientation, rhythm, reaction and adaptation lead to agility |
| Psychological skills | • Mental abilities lead to improvement of the physical performance, the technical learning process and solves other psychological issues influencing the performance |
| Pedagogical skills | • Mental training leads to challenging one's own performance more, team spirit, experiencing one's own body abilities and capacities through sensual perception of auditory, visual and haptic information, improved expressions of compositions (artistic expression), taking more controllable risks and an improved health consciousness |

Table I Promoted skill set in equestrian vaulting acc. to Peiler and Peiler, 2014

As the thesis deals with physical activities in equestrian vaulting, it is important to understand the terminology as well as the training goals within the sport. Considering the three categories, it shows a good overview of the as-is training goals as well as the promoted skill set of a vaulter.

Lastly, looking into the training material, interactive technology is only integrated in form of training- and music apps on mobile phones or (i)pads. The biggest change in that direction made a moving barrel horse which is used for training times without the horse. A moving barrel horse copies the gallop movement of a real horse in different speeds. But as vaulting is, in general a low-cost sport as mainly targeted for children and teenagers and as the moving barrel horse was still in the testing phase for the previous years, such a barrel horse is mostly only found in clubs with professional competitors (Galoppierendes Holzpfard ‘Movie’ | Voltgierservice, 2013). Hence, the attempt to introduce interactive technology into equestrian vaulting is still at its beginning.
3. Theory

The following part introduces concepts and definitions which are essential for the further design process. An emphasize is put on body awareness and its contributing factors. Further, an introduction about a selection of senses is presented to give the reader a better understanding of the presented design solutions and argumentation in the later process.

3.1. Body Awareness

As the thesis focuses on the core object body awareness, this chapter clarifies what it actually is per definition and what characteristics are important to further consider.

Body awareness is mainly based on the perception of interoceptive, proprioceptive and exteroceptive sensations. Also, it is the perceived embodiment of one’s self (Tsur, Berkovitz and Ginzburg, 2015; Cebolla et al., 2016). In this context, embodiment means the merge of the physical body with the mind which substantiates and concretes the definition given at the embodied interaction section. It is further assumed that body awareness is also based on perceiving and copying other humans’ body movements and structures (Berlucchi and Aglioti, 2010). The orientation on and experiencing other humans’ body movements entails a cultural as well as social component, which influences the understanding and meaning making of the individual’s body awareness. Body awareness is also essential to execute movements, as e.g. presented in Turmo Vidal et al. (2018) which provide a direct relation to physical training. Thereby, it can be stated that physical training supports the development of body awareness as well as is highly influenced by it.

Interoception is the sensation of body internal conditions such as thirst, hunger, temperature etc. and which are always related to emotions (Craig, 2003; Calì et al., 2015). Additionally, Singer et al. (Singer, Critchley and Preuschoff, 2009) recapitulate body signals as the foundation of “conscious and emotional experiences”. Looking at a heartbeat, as example, that skips for a second; this kind of body signal incorporates a certain meaning due to the emotional experience we make in the moment the heartbeat skips. In this case it could be that we are afraid of- or that we are surprised by something and react accordingly. Hence, interoceptive awareness influences and guides our behavior, emotions and decision-making. It creates the basis of a subjective, somatic perception, as a feeling for and of ourselves and hence, is essential for our self-identification. However, it is still unclear how emotional experiences and interoceptive sensation are exactly intertwined.

Proprioceptors are somatic senses (Britannica Academic, 2009) that give feedback about our body position, angles in which joints and limbs are positioned to each other etc. and which allow further to locate the own body position in space (Landy, Yang and Badde, 2016). Sensory hairs as well as receptors based in, e.g., the skin or some muscle parts forward the position information to the brain. The body position in space derives from connecting somatic sensory information with other sensory information, such as e.g. proprioceptors, visual and audio input (Azañ, Ae and Soto-Faraco, 2007; Limanowski and Blankenburg, 2016).

In comparison, exteroceptive awareness comprises any perceived sensory stimulation from outside the body on the body (Durlik, Cardini and Tsakiris, 2014; Colman, 2015). It includes any sensory input from the five senses as well as kinesthetic. As any input by interactive technology is received and perceived by exteroceptions, these senses play a much bigger role in the context of the second research question about how body awareness can be influenced by interactive technology.
Other linked concepts to body awareness are self-consciousness and mindfulness. Self-consciousness is hereby defined in dependence on Hutchinson and Skinner (2007) and Costantini (2014), as the outer image-as well as the understanding of and identification with one’s self. Thereby, it can be considered from two perspectives. First, self-consciousness depends on one’s own image in society, so in dependency of others. Second, it is about the conscious perception of personal feelings, emotions and thoughts. It relates to some of the research presented in the background section about the shared understanding and perception of movements. At the same time, both kinds of self-consciousness include the body in the process of self-identification (Costantini, 2014) as all to self-consciousness contributing aspects are perceived through our body and the “the integration of [the] motor efference” (Apps and Tsakiris, 2014). Yet, the concept of self-consciousness contributes mainly to the emotional and mental components of body awareness. It influences the awareness by personal and conscious reflection of oneself in a social, cultural context.

In comparison, mindfulness contributes to body awareness in the form of “knowing the mind” (Kabat-Zinn, 2015) and hence, introduces possibilities to shape and influence it. Further, mindfulness is the intentionally directed attention on the embodied, present moment (Cebolla et al., 2016). The process of being mindful requires body awareness, whereas controlling one’s body requires mindfulness. As one goal of this thesis is to change body awareness in the training for equestrian vaulting, it is important to understand which aspects can be targeted to achieve this. Hence, the concept of mindfulness serves as a framework for a further approach. Both, mindfulness and self-consciousness contribute to the understanding about how humans make meaning of and interpret themselves and the world around them. In each concept the interaction of the physical body and the mind are core aspects.

Other research emphasizes the importance of body awareness and discuss reasons of its effect on various life areas. Similar to the role of body awareness in self-identification and self-consciousness, (Mayer et al., 2008; Backåberg et al., 2015; Ambolt, Gard and Sjödahl Hammarlund, 2017) discussed body awareness in a motor control and therapy context, approaching it from different perspectives by which each research revealed different argumentation for the importance of body awareness. A common statement, however, was shared through all four chosen examples in which body awareness is essential for executing and controlling movement as it enables us to relate body parts to each other as well as to the external world which directly links body awareness to the overall physical training context.

Altogether, the thesis defines body awareness as the conscious perception and understanding of as well as attention to internal and external body sensations. Hence, it incorporates the concept of embodiment on a social and physical level by including and emphasizing the role of emotional awareness and the psychological self-identification.

In the following, the concepts of perception and attention are presented as perception is the overall process through which body awareness is created and attention the process through which perceived stimuli are prioritized and interpreted.

### 3.1.1. Perception

Relating perception to Dourish’s definition of perception which he defined as subjective information processing of the world (Dourish, 2004) to enable meaning-making, perception can be defined as the process of receiving and processing information from the outside world for creating our understanding and image of it. It illustrates the meaning perception has for body awareness. Thereby, it relates to the concept of consciousness, in which humans actively perceive and interpret themselves and the world
Attention is thereby the key driver for conscious perception in which humans react to the sensory input received from either interoception, proprioception or exteroception. However, perception is further a constant process which happens also unconsciously (Blake and Ramsey, 1951; Carello and Turvey, 2004). An example for unconscious perception provide kinesthetic sensors that react to externally induced mechanical pressure which results in reflexes.

Perception, like attention, depends further on the spatial, time and social conditions of a situation as well as on the individual fitness in which sensory input is perceived and processed. Due to our limited physical and mental capacities, we perceive more if we are stimulated on either a multisensory level, or on a unisensory level in which the stimuli occur at the same time and the same location (Costantini, 2014) repeatedly. This insight is not only important in understanding the concept of perception, but also in the further process of this thesis, to decide about the kind of sensory stimulation, the timing and the location of it that should be considered in the further design process and decisions.

3.1.2. Attention

Already mentioned as key driver of conscious perception, attention is a mechanism that functions as selection process of received stimuli (Montemayor and Haladjian, 2015). Hence, it is the trigger that directs conscious perception. It is, however, not always a controlled process. Instead, attention tends to constantly shift our perception towards appearing stimuli, voluntarily or not (Kantor, 1924). This kind of instability deriving from the shifting attention is an important insight for the later design process as well as the analysis of the various applied design suggestions.

There are various classifications of attention (Montemayor and Haladjian, 2015), such as, e.g., focused attention in which only one single input is processed at a time and divided attention in which various input is processed at the same time (Eysenck and Keane, 2000). Divided attention includes the concept of peripheral attention (Bakker, van den Hoven and Eggen, 2010) which deals with the simultaneously performed actions that do not take place in the center of attention, such as walking, listening to music etc. Another classification derives from the processing direction which can either be bottom-up or top-down, whereas bottom-up corresponds to willfully directed attention and top-down to the attentional reaction to external stimuli. Understanding the different types of attention allows to group information that should be provided to the user during the physical training under the consideration of different representation modes which depend on the required attention for each.

Attention capacities further allow multitasking depending on the complexity and difficulty of a task. Lien, Ruthruff and Johnston (2006) explain the ability to parallel processing (multitasking) by introducing a bottleneck which refers to central, focused processing, in comparison to bypass processing which provides the possibility to ignore the central unit processing and to process sensory stimuli via other channels. Discussing the topic of multitasking from a slightly different angle, Enns and Liu (2009) emphasize the interaction of conscious and unconscious processing in parallel, such as visual-motor interactions. As attention is also defined as the mechanism triggering the selective process of stimuli, their findings open the discussion to what unconscious processing is and if attention should always be related to awareness or not. Also unconscious processing triggers a body reaction, so that somehow our attention is divided into conscious processing of which we are aware of and unconscious processing conducted automatically by our body.

In later design suggestions, the possibilities and limitation of attention have to be considered to avoid to overcharge the user, but also trigger the user’s full potential by making e.g. use of bottom-up directed attention. Another topic for discussion in this context provides the question about triggering
multi-tasking and hence, make use of the peripheral attention concept, as example, for a potential design solution or rather focus fully on one aspect.

3.1.3. Joint Attention and Joint Action

Another related topic to the individual attention is joint attention which is the phenomenon which occurs when at least two individuals coordinate their attention towards the same object at the same time aiming for a shared experience (Mundy and Newell, 2007; Böckler and Sebanz, 2013; Fiebich and Gallagher, 2013). The concept is important in regard to the relationship between coach and vaulter and considered in the further design process. Most research defines joint attention as comprising one individual directing the attention and, at least, one other following the signals of the “initiator”. The communication between the individuals is thereby mainly based on eye gazing and gestures (Mundy and Newell, 2007; Bayliss et al., 2013). However, the phenomenon has mainly been observed in the behavior of infants yet.

Nonetheless, joint attention can be used as a tool to direct the attention and perception of another person which also allows to moderate the created social relationship by wordless communication. Research by Böckler and Sebanz (2013) and Fiebich and Gallagher (2013) relate joint attention to joint action. Joint action is understood as the coordination of actions between at least two individuals in dependency of space and time aiming towards changing the environment (Sebanz, Bekkering and Knoblich, 2006; Fiebich and Gallagher, 2013).

Both, joint attention and joint action, are part of a social interaction that allows to keep each individual autonomously acting, while sharing and working towards a common goal. As the individuals cannot perceive the object of attention from the same location, the common understanding is challenged by aligning the varying perceptions. Another challenge is to coordinate the time variables which include, to a certain extent, to predict the other individual’s actions and react accordingly to cognitive prediction.

Considering the social interaction and relationship between coach and vaulter, the concepts of joint attention and joint action provide mechanisms as well as practices to create a more common and shared understanding which again, could improve the coach-vaulter communication.

3.2. Senses and Motor Processing

Taking a step back from concepts contributing to body awareness, the following sections present details about those body senses that are considered in the later design decision and suggested solutions. Thereby, each sense triggers a perception process by itself, but also in combination with other senses and hence, contributes to our body awareness. A focus is put on proprioception as neuromuscular biofeedback, as the chosen example which is explored more in-depth in the thesis context, is integrated in this sensation category.

Not mentioned before, but also very important for our orientation and navigation abilities is the vestibular system, which is also responsible for our balance in rest or in motion. It enables us to be aware of where an object is placed independently from our position to it or, more in general, it allows us to consciously perceive our surroundings in motion (Lackner and DiZio, 2005), also without vision (Seemungal, 2015). This process includes taking countermeasures to external physical forces, such as speed, rotations or distance through an according motor coordination (Angelaki and Cullen, 2008). As the vestibular sensors are located in the brain, the triggered output depends on the orientation of the
head. In Fitzpatrick, Butler and Day (2006), researchers identified two effects of different head positions. The vertical position of a head in relation to the ground influences balance abilities which, whereas the horizontal position of a head in relation to the ground influences the spatial navigation process. In general, the position of our head induces and influences essentially the whole body movement direction and control, at least when being in motion as well as that the vestibular system plays an important part in perceiving, processing and reacting to motions. Accordingly, body awareness by balance or by placing one’s own body in space can be influenced through training the vestibular system. As a vaulter is highly effected by the horse’s movement, as also shown later in the conducted methods, the here presented insights influence the discussion of potential design solutions in the context of physical training.

A focus in the further approach was put on biofeedback in form of muscle tension (neuromuscular biofeedback), vision, audition and sound as well as somatosensation for which the following parts cover a short introduction about each sense in particular. Other senses, such as gustation and olfaction, are not further included in the scope of the thesis as these are not further considered in the prototyping or analysis of the conducted methods.

### 3.2.1. Somatosensation and Proprioceptors

Sensors of the somatosensation cover all stimuli perceived by any body tissue (‘Somatosensory’, 2013), including skin, joints, muscles etc. Hence, kinesthetic (as part of proprioception) and the joint position sense contribute to the overall somatosensation of which both together include the perception of position, vibration, temperature, pressure, touch and pain. Sensors of somatosensation contribute to the perception and awareness of, among other things, one’s body position. Important receptors that convey and forward the received information in muscles are the muscle spindle and the Golgi Tendon organ. The muscle spindle senses and indicates the stretch and speed level of a muscle movement while the Golgi Tendon organ measures the muscle tension intensity (Prochazka, 2015). Research by Kistemaker et al. (2013) show that the combination of both, muscle spindle and Golgi Tendon organ, are necessary for detecting and controlling the body’s position and body movements. Hence, the Golgi Tendon organ represents, among other functions, the human body’s internal EMG sensor, to facilitate the function on a very high level. As the thesis is limited in its scope, the information about the existence and rough function of the Golgi Tendon organ should be sufficient at this point. Nonetheless, in potential future work in which the muscle activity in relation to body position in dynamic exercise might be of interest, the information about the correlation and cooperation of Golgi Tendon organ and muscle spindle could be of high importance.

The way measured muscle tension is presented to a user is done by applying biofeedback. Instead, the measurements are conducted by electromyography which is applied in the thesis context in form of sEMG (surface electromyography). As both areas, biofeedback and electromyography might be rather unfamiliar for the reader, this section includes a short overview about each in the following.

**Biofeedback**

Biofeedback is an umbrella term for any body-internal, physiological functions, such as heart beat, force, body posture, respiratory, movement, cardiovascular and neuromuscular feedback (Giggins, Persson and Caulfield, 2013) that is used to increase a person’s ability to control and perceive oneself (Peper and Shaffer, 2010; Khazan, 2013) and of which a person would be barely aware of without the biofeedback bringing these functions to the surface (Giggins, Persson and Caulfield, 2013).
Accordingly, biofeedback plays an important role in the context of body awareness as it support the creation of awareness towards the body internal senses.

Measurements of muscle tension belong to the neuromuscular biofeedback. The goal of biofeedback is to increase one’s health by either an immediate relief or by a long-term improvement by consistent training of the conscious control over one’s own body. Thereby, physiological functions influence and are closely intertwined with a person’s cognitive and mental state. Work by e.g. Gholami Tahsini et al. (2017) as well as Parsinejad and Sipahi (2017), discuss the usage of biofeedback to overcome stress and anxiety in different situations, such as cognitive overload or other aspects that cause vulnerability. One example for the potential application of interactive technology in this context was introduced by Gholami Tahsini et al. (2017) in car driving situations. Measuring the biofeedback of a driver and adapting car settings according to the result has the potential of preventing incidents and accidents. Biofeedback has been discussed a lot in medical and rehabilitation research, however not from an HCI perspective. Hence, the thesis attempts to connect both fields more along the chosen example.

**Electromyography**

As mentioned in the previous section, biofeedback represents measurements from body internal senses, in other words from interoception and proprioception. However, the methods and tools to measure biofeedback differ according to targeted sense.

For neuromuscular biofeedback, electromyography (EMG) is an electro-physiological method to measure muscle activity based on, the during contraction generated current (Martin, 2015; ‘Electromyography’, 2018), also called MAP, muscle action potential. It allows the detection of muscle – nerve disorders and is hence, mainly applied in the health and medical sectors. In EMG, there are two forms, intramuscular electromyography and surface electromyography. For the first mentioned, also abbreviated as iEMG, conducting pins are plugged through the skin into the muscle, similar to a needle injection procedure. According to Kim et al. (2014), iEMG is “the preferred method for recording and analyzing deep muscles for trunk stability”. In comparison, the surface electromyography (sEMG) measures muscle activity from superficially located muscles (Chowdhury et al., 2013). As further stated in Chowdhury et al. (2013), sEMG is increasingly used and available in the context of biofeedback technology, as is allows a noninvasive and cheaper approach of measuring the tension of superficial muscles which also non-medical experts may use. Considering the authors non-medical background, the thesis focuses on sEMG sensors in the design process. Another non-invasive alternative is provided by ultrasonography which uses ultrasound images of muscles’ volumes to reveal intensity or damages (Sbriccoli et al., 2001; Ekizos et al., 2013; Yu, Jeong and Lee, 2015). However, as sEMG appears easier in use and availability, ultrasonography will not be considered further in the thesis. According to Bolek (2010) and Cram et al. (1998), sEMG offers good possibilities to train and regain muscle control, but is, however, also quickly influenced by other external or internal factors, so that the output values can vary a lot and are often accompanied by data noise.

Chowdhury et al. (2013) as well as Clancy et al. (2002), discuss several noise causing factors as well as reduction and elimination strategies. Noise causing factors are e.g. differences in the material of the applied electrodes, the signal frequency or skin conditions. Clancy et al. (2002), point out that all electrodes should consist of the same material therefore. Also, the skin area on which the electrodes should be attached to, should be cleaned with alcohol pads to reduce the risk of having any irritating factors on the skin and further prepared with a conductive paste to facilitate the measurements. As
shown also in Chowdhury et al. (2013), noise reduction can be reached by including noise reductors for the radiation caused by power supplies. An internal issue, “crosstalk”, refers to muscle groups in which the signal is influenced by other muscles’ activities. Minimizing the electrode size and considering a bigger inter-electrode distance support the prevention of this issue. Overall, there are many factors influencing the output, mechanical issues such as deformations or hardware motions, biological conditions, electrical instabilities in the current flow etc. It shows the complexity of the topic as well as a high risk of gathering too noisy or invalid data which is taken in the later thesis development. Nonetheless, for conducting the excursion into neuromuscular biofeedback and for understanding its role in the context of body awareness and physical training, the hereby presented insights influenced highly the practical handling and implementation of it. Additionally, the positioning of sensors on the muscle was further considered during the prototype testing. Sensors should be placed in the middle of the target muscle in line with the muscle fibers, including a resonance electrode attached to a non-muscular, but rather bone structure like area.

Lastly, research by Reinvee and Pääsuke (2016), compared low-cost sEMG sensors available for a quick and easy access to neuromuscular biofeedback. They mainly compare four different sensors of which three include raw data filters already, as can be seen in the following table. The table and the paper’s results influence the decision for or against the different sensors during the prototyping process.

Overall, measuring muscle tension via sEMG is already practiced for several decades. However, as seen on the list of noise causing influences and the required expert knowledge about the physiological conditions in the human body, it is still a challenge to gather valid and reproducible data which could be one of the reasons why HCI has not researched it much yet. In the further approach of this thesis, the MyoWare EMG hardware as presented in the table is applied at different stages due to its adjustable gain and in-built filter for rectified data.

### 3.2.2. Vision and Auditory Sense

Re-focusing on the exteroceptive senses that were included in the design process, a short overview about our vision and auditory senses follows as last contribution of the theory chapter.

Our vision is based on the information processed by the Rhodes which are mainly responsible for night vision, and cones receptors in our eyes (Svechtarova et al., 2016). Vision is further connected to two ways of processing (Ware, 2008), bottom-up and top-down. Information processed bottom-up is triggered by a perceived collection of features which a further processed and interpreted to result into an object that corresponds to recognized patterns. Instead, the top-down process depends on directed attention and is hence, always goal oriented. Top-down processing focuses on identifying the object the individual is interested in finding while re-connecting and re-analyzing the perceived information. At the same time, this means that potential important information are missed (Eitam, Yeshurun and Hassan, 2013). Visual cues are often conveyed by pop-out effects. Pop-out effects are mostly effective

<table>
<thead>
<tr>
<th>Shield or sensor</th>
<th>Channels (ch)</th>
<th>Cost</th>
<th>Signal type</th>
<th>Filters</th>
<th>Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>BITalino EMG sensor</td>
<td>1</td>
<td>$80</td>
<td>raw</td>
<td>Band pass 10-400 Hz</td>
<td>1000</td>
</tr>
<tr>
<td>FlexVolt Shield</td>
<td>2 or 4</td>
<td>$60/ $95</td>
<td>raw</td>
<td>None</td>
<td>2336</td>
</tr>
<tr>
<td>Olimex Shield</td>
<td>1</td>
<td>$53</td>
<td>raw</td>
<td>Low pass fe = 40 Hz</td>
<td>adjustable</td>
</tr>
<tr>
<td>EKG/EMG</td>
<td>1</td>
<td>$38</td>
<td>raw/ rectified</td>
<td>none for raw signal</td>
<td>adjustable</td>
</tr>
<tr>
<td>MyoWare</td>
<td>1</td>
<td>$38</td>
<td>raw</td>
<td>none for raw signal</td>
<td>adjustable</td>
</tr>
</tbody>
</table>

Table II Properties of sEMG shields by Reinvee and Pääsuke, 2016
by creating a difference of the eye-catcher to its surroundings. This can be performed by, among other features, a significant color-, shape- or position difference.

The auditory sense is divided into two activities, making sound and listening. Whereas the creation of sound is based on movement and the vibrating stream that a movement transfers, the audition is responsible to receive these vibrations and process them further. Sound incorporates three features, pitch, timbre and spatial location (Shamma and Micheyl, 2010; Carlile, 2015) and is also processed in either a top-down or bottom-up procedure. For the audition to identify the source of a sound, sounds are separated into different streams. According to Shamma and Micheyl (2010), the separation of audio streams requires to activate or trigger them at different times which contributes a temporal characteristics to auditive perception. Further, sound source detection is challenged by the mass of sound waves that are sent through a room at the same time and of which only one sound wave is of interest. This problem is also known as the Cocktail Party Problem (Haykin and Chen, 2005). Attempts to solve this issue show e.g. Pichora-Fuller et al. (2017) by using simple instructions in a conversation or by allocating one’s spatial attention towards the sender. Factors like head movements of the person listening (Kondo et al., 2014) and a busy environment (Sussman-Fort and Sussman, 2014) influence the process in making it more challenging to identify a sound stream. Instead sounds that are triggered from spatial different places are supposed to support an easier clustering process (Shestopalova et al., 2014).

The presented methods and tools that allow an easier perception of either sense, provide a good basis for dealing with potential challenges by the contextual conditions of the physical training of equestrian vaulting. As the interaction space of any introduced prototype or material is influenced and limited by the chosen application area, the knowledge about how to alter the perception of either vision or audition are important to assure a successful experienced prototyping which further is required to allow making assumptions towards the influence of the applied interactive technology on body awareness.
4. Methodology & Methods

This chapter presents briefly the conducted methodology and methods. It serves thereby as an overview and an introduction to each applied method, whereas the approach and the gathered results are separated in following chapters for allowing a better readability and understandability.

Overall, the author decided to apply a research through design approach (RtD) according to Zimmerman, Stolterman and Forlizzi (2010) in combination with embodied interaction methods. The reason to apply methods from embodied interaction design in the thesis is that this research area targets the design of interactive technology towards an embodied experience. Accordingly, methods reflect on the importance of the physical, human body, the space and the artefacts in the space by including a more movement-based interaction approach as well as by conducting methods either in the space where a design should be used in or in a simulated copy of it. Hummels, Overbeeke and Klooster (2007) as well as Svanaes (2013) emphasize the importance for designers of including and experiencing through movement and with the body directly in the design process, so that designers could refer to their own experiences and not only to a theoretical assumption, which has been considered in this context as well.

The following sections embed each applied method as well as the methodology in a research background, so that the reader is introduced to the different qualities of each which further influenced the author’s decisions for its application. Details about the conducted methods and their outcomes can be found in the according chapters, epochés, bodystorming workshops, experienced prototyping, expert interview and pilot study. Motivations and critical considerations of each methods are instead included in the theoretical introduction in the following. Expert interview and pilot study made use of methods applied in the bodystorming workshop and experienced prototyping context, so that these are not further embedded in a theoretic context, but only part of the following chapters.

4.1. Methodology Research through Design

In RtD knowledge is created through a user-centred design approach of testing, evaluating and iterating prototypes towards a preferred “to-be” state in comparison to the current “as-is” situation (Stappers and Giaccardi, no date; Zimmerman, Forlizzi and Evenson, 2007). An advantage of the chosen approach shows in the more cross-disciplinary knowledge base and tool set as well as the supported iterative development of problem statements and research questions which allows a constant shift of focus (Zimmerman, Stolterman and Forlizzi, 2010). The flexibility and agility that this approach offers, allows to be very hands-on and practical which consequently allows an analysis and testing setup much closer to real conditions than other approaches.

At the same time, the volatile character of RtD challenges reproducibility and hence, validity of the final results, as these are also closely embedded into a specific situation and its context. On the other hand, by focusing on a qualitative study approach, the results depend highly on the participating individuals as well as their subjective experience, so that reproducibility represents a challenge either way.

4.2. Introduction Epoché

The first listed method, the epoché, is an exception in regard to the field it was originally invented for, as it derives from phenomenology and not from embodied interaction directly. However, as embodied interaction is, at least partly, based on phenomenology (Svanaes, 2013), the method was introduced to
the younger field as well. As such, it aims towards a purely objective analysis and description of an observed phenomenon to understand the true essence of it (Overgaard, 2015; Butler, 2016; van Manen, 2017). The challenge is hereby for the researcher to naively approach the observation and to liberate oneself from former experiences that are related to the phenomenon. The goal is to describe and interpret the lived experience to its fullest in the moment it occurred, and not an alternate version influenced by former knowledge or experiences (Overgaard, 2015; van Manen, 2017). For a proper interpretation, behaviors, experiences and statements of participants can be used as additional basis in the context of lived experiences. Another suggestion to achieve a true understanding is to gather more data in other, follow-up observations. The sum of objective observations might reveal patterns or other aspects that allow assumptions about the essence of the phenomenon (Butler, 2016).

Critique towards this methods questions the ability to be objective and liberate oneself from former assumptions and experiences. However, Overgaard puts this objectivity into another perspective (Overgaard, 2015) by stating that a phenomenologist needs to differentiate between two perspectives which succeed each other. One perspective should consider the pure experience, wherein the own beliefs, assumptions etc. should be “bracketed” – similar to ignored – and the second, following perspective is supposed to reflect on the former experience by relating it to reality and hence, to previous knowledge, beliefs etc. Hence, the challenge of describing the pure experience stays. However, the interpretation, according to Overgaard, may be influenced by previous knowledge and experiences.

Motivation to conduct epochés in the thesis context are based on the very open characteristic of this method which allows to explore the application area equestrian vaulting without any constraints. Additionally, as equestrian vaulting has not been researched from an HCI perspective yet, the field observations served as an introduction for generating a basic understanding of the sport. As the thesis begun with a very broad scope on physical training without clearly identified problem statement, the naivety of this method supports an open and unbiased approach. Additionally, the motivation to conduct two epochés was based on the possibility to compare between both observations which supported the identification of aspects that are practiced more in general in a training session and which are association specific.

4.3. Introduction Bodystorming

Bodystorming can, e.g., be applied in the ideation phases of research projects by pursuing the goal to “design (interactive) objects in the world rather than a world inside an interactive object” (Márquez Segura et al., 2015 and Márquez Segura, Turmo Vidal and Rostami, 2016). Thereby, it allows to perform with various materials at an early stage of the design process and test a material’s qualities through an embodied interaction approach. That means for designers to, on the one hand, create and test with rapid prototypes and, on the other hand, assure interactive testing within the (simulated) context of use. Thereby, bodystorming represents a set of tools and approaches that can be used during a workshop to generate the best possible outcome. Forms of bodystorming are e.g. the prototype testing in the real, final environment in which the prototype should be used in, prototype testing in a simulated environment of which researchers have more control, but can still simulate a certain setup and lastly, the use case theater (Schleicher, Jones and Kachur, 2010; Loke and Robertson, 2013). In use case theater, participant play predefined scenarios while interacting and testing the developed prototype. The goal of this bodystorming method is to gather insights about the kind of experiences that participants make during the simulation of a real use case scenario.
According to Oulasvirta et al. (Oulasvirta, Kurvinen and Kankainen, 2003), bodystorming considers the social, interactional and psychological aspects of the interaction with the prototype and hence, enables designers to include not only the physical, but also the mental and emotional requirements and limitations in further design suggestions. Another advantage of bodystorming shows in the direct discussion and try out of suggested solutions. Accordingly, designers receive a set of ideas from the participants including potential solutions, but also limitations and concerns. Depending on participants background and relation to the context of use as well as the product-to-be, the procedure and limitations of the bodystorming workshop should adapt. As example, a group that has never come across bodystorming before might not feel comfortable in going ahead in using the provided material for trying out their ideas without any further instructions. On the other hand, participants with an artistic or creative background might be used to such kind of ideation process and would feel rather limited by additional instructions. Hence, under the consideration of the workshop’s goal, available materials and setup as well as participants, the one or the other tool or approach should be applied.

Furthermore, research by Wilde and Schiphorst (2011), as example, show how to inspire participants and to intensify their experience during a bodystorming workshop. Thereby, movements, and hence, the experience of the movement, can be changed by extending the participant’s attention by synchronizing movements with others, by introducing body extensions, by de-familiarization or by creating a vacuum in the movement for an artefact. Due to its flexible characteristics, bodystorming can be conducted in various phases of the design cycle, from ideation up to evaluation phase.

Critique about bodystorming can be made regarding its focusing too much on a certain context or subjective experience which reduces the comparability of the outcome to other areas. Furthermore, during a bodystorming workshop, the researcher provides a selection of materials or prepared use cases, depending on what form of bodystorming is conducted. Accordingly, the outcome of the session is always limited by the subjective choices of the researcher made in advance which influences highly the session’s outcome. Lastly, bodystorming requires from participants to explore and be very active in general. This might cause issues for some participant due to a more shy or reserved personality, especially depending on the overall group composition.

Nonetheless, the motivation of applying the method in the thesis’ context derives from its previously mentioned advantages, such as the integrated discussions and interaction experiences with rapidly applied materials or prototypes as well as its high emphasize on the contextual situation of the targeted application area and its focus on the experience through embodiment. All these characteristics support the decision of bodystorming as follow-up method to the conducted epochés.

### 4.4. Introduction Experienced Prototyping

Experience prototyping comprises a set of approaches and tools to create and interact with prototypes in an embodied context which means that the created prototype is used in context to gather knowledge about the experiences that participants make during the interaction (Buchenau and Fulton Suri, 2000; Milton and Rodgers, 2011; Klann and Geissler, 2012). Prototypes are a pre-version of the product or service that is aimed to be created or altered. Thereby, a prototype can be part in various phases of a project cycle as well as of various skill teams, such as designers, engineers or analysts (Camburn et al., 2017). Accordingly, a prototype has different versions and ways in which it can be created. Classifications include low- and high-fidelity prototypes in which a low-fidelity prototype means a quick and, mostly, cheap version, whereas a high-fidelity prototype aims at a much later state of a project and hence, a much more advanced and developed prototype as discussed in e.g. Sauer, Seibel
and Rüttinger (2010) and Atladottir, Hvannberg and Gunnarsdottir (2012). However, there are more types of classifications depending in which context of use prototypes are discussed. Another classification is, e.g., the separation between physical and virtual prototypes.

The difference in the specification of experienced prototyping to general prototyping is based on the goal. Thereby, the goal is to gather knowledge about experiences that participants make when interacting with the provided prototype in a situation, which considers time, place and other aspects that appear in a real-case scenario. During an experienced prototype session, not all factors of a real-case scenario have to be included at once, instead the influence of the different components can be put more into focus. However, this depends on the overall goal of the session. Experiences, as described in Buchenau and Fulton Suri (2000), are based on embodied situations which carry a certain meaning for the user. This includes a meaning and understanding of the product the user is interacting with. Revealing the entities and characteristics of such an experience enables, e.g., designers to incorporate it in the design. Hence, methods to reveal such experiences are, among others, role plays or use-case theater (Loke and Robertson, 2013).

The prototyping can further be extended by embodied sketching which is a methodology that aims towards sharing and communicating movement and action based experiences, so that the perception and feeling of doing a movement gets aligned with the observer point of view (Tholander et al., 2008; Erkut and Rajala-Erkut, 2015; Márquez Segura, 2015). It utilizes sketches generated through movement as documentation and distribution basis. In the thesis’ context, sketches were used as discussion basis for further, find a common understanding of the sketched issue and suggested solution.

Critique towards experienced prototyping bases on the issues that it can barely be conducted by itself alone, but that it normally requires additional methods to clearly identify advantages and disadvantages. Additionally, by focusing on the experience that participants make and less on the functionality or implementation of the prototype, it supports the identification of sensations and feelings, but rather less clear design instructions and components. While supporting a design-oriented research approach through this, it lacks the connection of design to technical implementation.

Besides its weaknesses, experienced prototyping allows prototype testing from a more qualitative perspective which supports the overall thesis’s approach. Considering the focus on body awareness, which relates to an embodied user experience, and not on the technical implementation, it is rather beneficial for the further process in the presented context. Regarding its additional limitations, interviews or group discussions extend the method to allow the derivation of clearer outcomes including direct user statements.

### 4.5. Thematic Analysis

The recordings of each conducted method except the brainstorming were analysed by reviewing camera and sound records several times. With each review, the author noted down the sequence of discussed exercises as well as which equipment was used in each step. Furthermore, mentioned and observed problems were collected and compared additionally to the tried out and discussed solutions. The gathered data was then analysed under consideration of Braun and Clarke (2006)’s thematic analysis process which is a method to identify patterns, thematic groups as well as specialties within a qualitative data set. However, the method had to be adopted to the thesis contextual situation as presented in the following table:
Phase | Procedure
--- | ---
1. | Familiarization
   - Reviewing recordings several times, noting down all argumentations, issues, usability aspects and used materials
2. | Initial Coding
   - Marking all re-occurrences, peculiarities and more general conditions in different colours
3. | Identify potential themes
   - Generate themes to the differently marked topics
4. | Reviewing themes
   - Reviewing themes by comparing them to colour coding classification from step 2
5. | Defining themes
   - Defining and deciding for certain themes and integrating them in the following conducted method

Table III Thematic Analysis

The defined themes supported the decision process in regard to determining the focus of each conducted method, such as the identification of body awareness as overall topic and as “Lacking body control” as one of the themes.

A thematic analysis requires a certain quantity of data to create patterns and groups which often leads to an exclusion of more extreme statements and cases. Accordingly, in the thesis context, this analysis method was only applied at cases in which more than one participant joined. It showed, however, great value in the selection process of prototypes.

4.6. **Overview Methods**

In total, two epochés, two bodystorming workshops and two experience prototyping sessions were conducted including interviews and a pilot study by applying a RtD approach enhanced with embodied interaction methodologies. As follow-up on the second experienced prototyping session, an expert interview was carried out which included enacting with the prototype. Based on the expert interview, a pilot test for a further iteration of the experienced prototyping was conducted. Furthermore, all recorded data was analyzed by conducting a, to the thesis adapted thematic analysis for which the framework presented by Braun and Clarke (2006) was taken as rough guideline. The progress and result of each conducted method is presented in detail after this chapter to provide a better readability.

Each selected and conducted method contributed to the overall research topic as well as enabled the generation of more in-depths insights. The table below provides an overview of all conducted methods and how they depend on each other. Starting with the epochés in two different vaulting associations, the gathered results influenced the further method choice and approach as presented in the middle of the figure. Accordingly, each iteration of this thesis can be followed up by looking at this table. It further includes the name of the conducted method and with which methods it was additionally enhanced.
Epochés aimed at generating an understanding of the targeted application area to further allow decision-making on the follow-up approach and methodology. Bodystorming was conducted twice, as the first workshop aimed at identifying potential application areas for interactive technology in general and the second built up on the findings exploring issue areas and potential solutions focused on body awareness. The experienced prototyping sessions introduced the design phase of this thesis by exploring different possible applications to influence body awareness in the physical training context. An expert interview was conducted to increase the quality of the prototype design and, hence the overall testing results. Lastly, the expert’s feedback influenced the further approach through suggestions for potential test cases to gather more insights about the influence of the prototype on body awareness in the given scope.

In the following, the ethical considerations are presented that influenced the different methods, before presenting in-depth the conduction and results of each applied method.

### 4.7. Ethical Considerations

All participants were asked to give their consent about their voluntary participation as well as the further usage of recorded data. An according consent form can be found in the appendix. Additionally, each received an oral introduction about the thesis topic, the aim of the session they joined as well as the related schedule.

All recorded data was kept confidential at all times and only shared with participants themselves or with the thesis supervisor. Also, the selection of pictures and citations that are included throughout the thesis are hereby confirmed to be based on valid and reliable data or real statements by participants. Nonetheless, due to the translation from German into English, some exact meaning might not have been fully met. Therefore, the German citation is always included in the text.

The author confirms to have conducted each method and each analysis from a most impartial perspective possible to assure a reliable and comprehensible outcome.

While presenting an overview of the applied methods in the previous chapter, the following chapters present each in more detail. Thereby, a chronological order is considered according to how methods were conducted which further allows a better understanding of how the different methods relate to each other. Accordingly, each conducted method type is presented in its own chapter including results and the meaning of the results for the further thesis’ development.
5. Epochés

Epochés were the first conducted method due to the very its open and explorative characteristic. The conducted epochés and its results are presented in this chapter.

5.1. Conducted Epochés

The field observations were conducted as epochés with a fresh and open mind, presuming no pre-knowledge about vaulting. Each epoché was recorded by video recordings with at least one camera and notes taken by the author. Both epochés showed that the length of a training session varies depending on the skill level of vaulters and whether vaulters participate in competitions or not. For the average vaulter, an hour training per week is the regular, according to coaches from both visited associations. Further, all parents, vaulters and coaches gave their consent to record the session on video for research purposes before the beginning of the sessions. After each epoché, a follow-up interview was conducted with the respective coach. The detailed outcome of each epoché can be found in the appendix.

Due to the authors geographical limitations, the further workshops and test sessions were conducted at the Hirschhof only. Instead, insights from the epoché at the Uppsala Vaulting Association are included whenever required in the further design decisions.

5.2. Insights Epochés

By comparing results from both epochés, similarities as well as differences could be identified. Through the conducted interviews, some made observations can be taken as general conditions that re-appear in the majority of vaulting associations. The following pages present the summarized findings.

In general, equestrian vaulting appeared as a complex sport that combines dynamic with static movements in a quick order which are additionally influenced by the horse’s movement or by the interaction with other vaulters. Therefore, many side-activities, as partly described in the appendix, with which the body fitness is trained, aims towards enabling a better body perception and control.

Both epochés showed that equestrian vaulting requires a lot of self-management of participants to continuously train and review one’s own body position or the ones from other participants. This requires at least some fundamental knowledge and understanding about the course of movement as well as about the body. Further, both times, group trainings were observed in which participants cooperated cross-generations (7-28 years old at Uppsala Vaulting Association and 6-63 years old at Hirschhof Vaulting Association), even though the majority of social interactions took place between similar age groups. Additionally, some group dynamics showed in situations in which one participant would start with a new exercise or explore an artefact and other would start following and copying the same activities. Thereby, participants were in general very actively involved in physical activities as well as in social interactions. Consequently, especially the younger participants explored a lot with the artefacts by also creating some smaller games and competitions between each other. Few moments were observed in which participants would concentrate individually on their training. However, in these situations, it were mainly adult vaulters who concentrated on the individual training and conducted their individual training plan.

As coaches of both associations were mostly fully engaged in one area of activity only, participants were further responsible for taking care of the equipment as well as of the horses. Nonetheless, the
relationship to the coaches in either location showed from a vaulter’s point of view a lot of trust and respect as each given instruction was followed, no questions asked. The coaches shared the habit of giving feedback to a performance from a certain distance to the vaulter, on the barrel horse as well as on the horse, also because they gave feedback mainly based on the perceived visual output. In comparison, when explaining an exercise, all coaches used not only verbal feedback, but also performed exercises themselves for giving an example or laid hands on body places of the vaulter where they wanted to trigger a change of position.

Differences between the two associations established already in the nature of the lessons. Whereas at the Uppsala Vaulting Association, the training focused on the vaulter’s performance on different horses of only competing members, at the Hirschhof Vaulting Association the groups were mixed and focusing on the training on the barrel horse. Additionally, similar equipment was found in the use of barrel horses and sleeping mats. Yet, the second location included a lot more equipment with which participants could exercise or play around with. Hence, the assumption is made, also in regard to statements of the coaches that most equestrian vaulting associations use a barrel horse, some form of sleeping mats and the real horse in the training, but any additional artefact would vary a lot. Another major difference was observed in the number of coaches concentrating on the same thing. Whereas in Uppsala, different perspectives were covered by at least two coach on the same participant, there was only one coach reviewing the performances of vaulters at the Hirschhof at a time, so that body parts away from the coach’s sight could not be perceived, neither corrected.

Even though, two vaulting associations are not representable for the average vaulting association, by including the coaches’ statements of the follow-up interviews, some general insights can be drawn from it:

**Physical artefacts**

The availability of a set of training artefacts varies per vaulting association. Nonetheless, a basic setup of sleeping mats, barrel horse and real horse can be assumed to be generally at-present. Each artefact invites the vaulter to explore and to enhance the set of physical activities, whereas the combination of it provides even more possibilities. The selection of physical artefacts supports the training session’s goal by, while enhancing the possible physical activities, also restraining it to a certain known set of exercises. However, especially younger participants explored a lot with artefacts, apparently keen to find out what these could be further used for.

**Space conditions**

The used space is normally framed by size of the indoor riding hall with a rather soft ground on which vaulters can easily run and jump. Nonetheless, the size of the indoor riding hall and the varying availability of a stand determined a lot in which distance the coaches were placed in relation to the vaulters in times where the horse is not involved. Still, in general, it can be stated that coaches position themselves in a few meters distance to the vaulter.

Another important aspects should be considered in form of temperature varying according to season. Accordingly, vaulter wear more or less layers of clothing. However, as skin tight clothing is a requirement in equestrian vaulting, especially for the training on the horse, vaulters have little choice in changing the dress-code.

**Physical activities**
The training always includes a warm-up consisting of running and stretching exercises, for the horses as well as for the vaulters. While coaches control the horse’s warm-up, vaulters mainly warm-up in self-responsibility, introducing the exercises to new members through different group members.

Physical activities vary a lot to enable a balanced training and development of the required motor skills, psychological skills and pedagogical skills by which motor skills are mainly defined as endurance, strength, coordination, speed and flexibility as the basic and essential skills of a vaulter. Hence, also games to increase the team spirit and collaboration among vaulters are included in the training.

Exercises required high coordination skills as well as a good body-control as each landing and transition from one exercise to the following had to be soft and fluent while keeping the elongated and tensioned body posture from the first exercise. Freestyle exercises demand higher attention in regard to safety of all participants than compulsory exercise as in the first, exercises are more dynamic, done together with other vaulters and by using all possible positions, whereas the space and range in which vaulters move in the compulsory is much more limited.

**Social interactions**

Throughout both epoché, there was constantly interaction between the participants. Whereas the coach was clearly seen as respect and authoritarian person whose orders are to be followed, but also highly trusted, the relationship between participants was mainly defined by laughter, exploring artefacts together as well as by the shared training experience. Due to the responsibility of each vaulter to take care of the horse, the training equipment and one’s own training intensity, vaulters also used to review each other’s’ body posture and movement. Hence, equestrian vaulting is a sport highly supporting the development of social skills.

**5.3. Meaning for The Further Development**

Results from the epochés influenced the decision to apply bodystorming as a method in the further process as it enables participants to keep the dynamic and partly explorative character of a training session with which they are already familiar while emphasizing the importance of embodiment. Furthermore, by performing two epochés as introduction to the sport, results revealed already some areas in which interactive technology could be introduced, such as by providing support in reviewing one’s own body movement and positions or supporting the coaches in making the “blind” side of a vaulter’s body transparent. However, the goal was mainly to get a general impression of equestrian vaulting as well as of commonalities and differences in regard to procedures, locations and artefacts.
Bodystorming Workshops

The following presents the conduction of the bodystorming workshops in the thesis context. As in the epoché chapter, results and the meaning of the results on the further development are included.

5.4. Conducted Bodystorming Workshops

Two bodystorming workshops were conducted at the Hirschhof Vaulting Association’s indoor riding hall. The first workshop aimed at identifying and understanding potential problems for vaulters when training on the barrel horse individually. Further, by interacting with the introduced equipment, the goal was to identify what sensory in- or output at what place, exercise and time could support the vaulter’s training. For this workshop, a group of five participants was recruited. In the follow-up workshop, which took place at the same location two weeks later, the same participants but one rejoined. The main goal hereby was based on the analyzed results of the previous workshop, to bodystorm more in depth the vaulter’s body awareness in various exercises on the barrel horse and the real horse. First of all, it was of the researcher’s interest to see if and how the vaulters’ body awareness as well as the coach’s perception of the vaulter’s performance change from the mostly static barrel horse to the living horse. Secondly, various sensory in- and output was discussed and tried out by participants to identify the required intensity and kind of feedback. Thereby, the experience of doing vaulting exercises was altered through emphasizing body parts, extending body parts, by synchronizing movements, by de-familiarization or by creating a vacuum in the movement for an artefact.

As these bodystorming workshops were qualitative studies, it was decided to recruit the same participants for both workshops who were, hence, familiar with the methodology and with each other. Another familiar point to the participants was the venue. The indoor riding hall of the association was selected as it is the same hall, all participants generally practice in or visit occasionally. Further, the venue provided the necessary vaulting equipment. Exercises of equestrian vaulting are trained on a horse or on a barrel horse, so that vaulters’ movements can be adapted to and take into account the (simulated) horse’s body shape. Hence, the usage of a barrel horse or a real horse under natural circumstances is an essential core aspect of the bodystorming method. Both workshops were conducted in about two hours sessions.

5.4.1. Participants

Five participants, each with several years of experience in equestrian vaulting, were recruited for the bodystorming workshops. Each had a different background and a different connection to the sport. Two participant were high school students of which one was active in national pas-de-deux as well as individual vaulting competitions and the other regularly assisting the coach in training sessions. The latter supported the author in recording the workshop and contributed mostly verbally to the discussions. All three remaining participants were adults, of which one was an active vaulter in group competitions with a background in circus pedagogic and licensed as equestrian vaulting coach. The main coach, holder of the highest possible training license, and a resigned vaulter with 5 years experience of participating in group competitions, completed the group. The following table provides an overview of the participants’ background and relation to equestrian vaulting.

<table>
<thead>
<tr>
<th>No.</th>
<th>Background</th>
<th>Relation to equestrian vaulting</th>
<th>Years of experience</th>
<th>Gender</th>
<th>Age</th>
</tr>
</thead>
</table>

27
### Table IV Participants Bodystorming

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>High school student</td>
<td>Active in national pas-de-deux and individual competitions</td>
<td>6</td>
<td>years</td>
<td>female</td>
</tr>
<tr>
<td>2.</td>
<td>High school student</td>
<td>Active without competing, regularly assisting the coach in training sessions</td>
<td>6</td>
<td>years</td>
<td>female</td>
</tr>
<tr>
<td>3.</td>
<td>Circus pedagogic</td>
<td>Active in group competitions, certified trainer license (entrance level)</td>
<td>10</td>
<td>years</td>
<td>female</td>
</tr>
<tr>
<td>4.</td>
<td>Coach</td>
<td>Resigned from active vaulting after 9 years in group and individual competitions, about 30 years of experience in coaching equestrian vaulting</td>
<td>35</td>
<td>years</td>
<td>female</td>
</tr>
<tr>
<td>5.</td>
<td>Student in engineering and economics</td>
<td>Resigned about 6 years ago; was active in group competitions for 5 years.</td>
<td>5</td>
<td>years</td>
<td>male</td>
</tr>
</tbody>
</table>

Due to the various backgrounds and experiences in equestrian vaulting, the author’s assumption was that the bodystorming workshops would reveal several situations and reasons for applying interactive technology. All participants had met before and knew each other at least on a superficial basis.

### 5.4.2. First Conducted Bodystorming Workshop

For the first bodystorming workshop, the focus was on the individual training on the barrel horse. The session started with an introduction to the topic including an explanation of the workshop’s approach and the equipment provided to interact with. Additionally, as all participants were unfamiliar with bodystorming, they were informed about the procedure that they could chose a vaulting exercise with which they would like support or by just taking on of the provided items and try out open-mindedly how it could be integrated in their training. The participants gave their consent to being recorded. From the two high school students, the parents’ consent was collected before-hand.

For the majority of the time, participants concentrated on rather static exercises. For exercise, for which the horse’s movement was mentioned as highly important for learning the correct technique, according to the participating coach, the simulated canter movement of the barrel horse was switched on. The selection of bodystormed exercises was contributed by the participants over the duration of the workshop. Most choices were either motivated due to personal challenges participants had when practicing them or by the knowledge that a certain exercise is generally known to be more complicated than others. For each discussed issue, participants tried to bodystorm various solutions. Arguing about the positive and negative aspects of a suggested solution, some discussions ended with a clear idea, whereas in other suggestions, participants could not agree on a good solution and were kept open. More details about the progress of the workshop can be found in the appendix.
Equipment and Setup

Figure 2 Equipment Bodystorming I

A complete list of all used items can be found in the appendix. Overall, the equipment introduced in the bodystorming workshop was selected in regard to their characteristics of stimulating either visual, auditory or tactile senses as well as due to their identified potential areas of application by recalling mentally scenarios and practices which were observed during the epochés. Additionally to the interactive objects and the normal vaulting equipment, the author provided moderator cards with key words about different sensual stimulations. These cards should serve as inspiration in the case that participants would feel stuck and would need further inspiration of what other sensual triggers could be applied as in- or output. Further, recording devices were used in form of a gopro camera and a sound recording device. The camera was set up stationary at one spot, capturing the activity on the barrel horse, in some distance to the participants. Hence, the sound recording device was used to assure all verbal contributions were captured.

Challenges of The Workshop

Bodystorming as brainstorming method found great acceptance and enjoyment to the participants of whom all were completely new to the field.

However, difficulties occurred in understanding the full potential of the exercise. Partly, the reason is because the method was not presented in-depth to the participants, partly because participants focused strongly on technical aspects of an exercise by ignoring a social or artistic perspective on it, even though, these are fundamental characteristics of equestrian vaulting, too. But considering the limited time and that participants were new to the introduced methodology as well as the introduced artefacts, the results showed great details and insights. The lessons learned in this context is that bodystorming is a very effective method to identify the potential use of interactive technology in the physical training for equestrian vaulting. But as equestrian vaulting is a rather complex sport with many facets, the outcome of one workshop is still very limited in its scope and results in comparison to the full possible potential.

Insights Bodystorming Workshop I

The purpose of this workshop was to conduct bodystorming with a focus on the individual training from a vaulter’s and a coach’s perspective. However, the coach perspective was discussed only during the flag exercise in detail. As the coach’s perspective is very important for a successful physical training, the coach, tried to reflect in between on the effect of a used item from her perspective. But in most cases, she could not find much advantage in the applied solutions as it was to vaulter specific.
As mentioned in the epochés results, especially the first bodystorming workshop aimed towards a very explorative and open approach, so that participants would come up with their own ideas and suggestions, instead of determining a certain topic through a more structured approach provided by the author. Outcomes of the this bodystorming session narrowed down the thesis focus on body awareness. The narrowed scope was initiated due to the multitude of bodystormed issues that were all related to body awareness in its various forms. The table in the following provides a good overview of different discussed exercises, the identified issues and the outcome of the bodystorming.

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Identified Issues</th>
<th>Outcome of bodystorming</th>
</tr>
</thead>
</table>
| Flag     | • Correct weight distribution  
           • Keeping angles  
           • Keeping correct, straight lines  
           • Fluent and harmonic connection of movements  
           • Keeping balance  | Visual output for the coach and haptic feedback for vaulters works best on the spot where an incorrect position occurs  
Many details to review, so that a clear distinction in the feedback becomes necessary  
It is a challenge for the vaulter to keep track of all details at once |
| Handstand | • Lacking conscious of body-space relation  
            • Lacking conscious of own body from upside down  | Audio and tactile feedback is good to indicate where the body is in space  
Support in orientation where “blind parts” of the body are useful |
| Standing forward | • Keeping equal weight distribution  
                     • Lacking awareness of body part position  
                     • Keeping attention to feed  
                     • Keeping feed flexible  | Support of an equal weight distribution (also for flag exercise)  
Interrupting and guiding a vaulter’s attention through e.g. impulses |
| Standing sideward | • Keeping equal weight distribution  
                           • Lacking awareness of body part position  
                           • Keeping attention to feed  
                           • Keeping feed flexible  | See "Standing forward", including:  
Integrating distance or body position to the vaulting artefacts (here, vaulting girth)  
Audio impulses support, but an earlier detection of incorrect position is needed  
Altered skin tension between ribs and belly button prevented too much movement |
| Flank | • Control upper body independently from leg movement  
            • Too slow leg movement  
            • Lacking conscious of focal point  
            • Lacking conscious of sitting position  | Training to achieve high body control is needed for controlling asynchronous behaviour  
Conscious perception of body parts at various positions needed, change of texture supported the process in sitting position  
Interruption of movement through additional |
Table V Results Table V Bodystorming Workshop I

In the following, the main identified issues are presented as well as how participants dealt with them. Thereby, the focus is put on insights that contribute the overall research questions regarding types of body awareness and how to design interactive technology for them.

**Lacking Awareness of Body Position**

In several exercises, the lacking awareness of the actual body position led to incorrectly performed exercises, balance issues and twisted body parts that should not be twisted. Hence, this issue turned out to be a rather dominant one which indicates the need for solutions. While the reason for losing or not achieving a correct body position varied, by participants bodystormed solutions identified along the body attached lights as well as vibrating feedback on certain body parts as most effective and supportive.

In more detail, LED lights proved to support especially the coach’s perspective in emphasizing angles and lines, so that any unevenness was quicker perceived. Also, applying color codes was identified to be helpful to indicate a certain meaning of the attached lights in relation to one’s body positions (such as green = good position, yellow = lacking slightly, etc.).

Applying color codes, however, requires the vaulter to learn its meaning and hence, an interpretation process of the output before being able to react to it. The more immediate solution showed in applying vibration output at concerned body parts. However, the vibrating output is, at least in the form it was bodystormed, only perceivable by the vaulter, so that a combination of both, vibration and light feedback provides a solid solution for coach and vaulter.
**Lacking Body Control**

Lacking body control is also an issue that (re-) appeared in different forms during the bodystorming workshop. One aspect that was a bigger challenge for vaulters, as example, was to move fluently and in harmony with oneself. Many exercise in vaulting include wide, soft and fluent movements. Even static exercises like the flag require movements to get into the position and out of the position. These dynamic changes as well as how the rhythm of the canter is embodied by the vaulter indicates a certain harmony which, however, proved to be a considerable challenge.

Bodystormed solutions showed that external haptic influence on the vaulter’s body were either perceived as really helpful or as rather additionally stressing. The same result was received when introducing a rhythmic audio signal. If the aforementioned external signals accompanied the canter rhythm (of the moving barrel horse) at the same beat as a canter strike, it facilitated the synchronization of body parts as well as the own movements to the external input.

Another solution was bodystormed based on tactile feedback by introducing additional objects that were used to extend or hinder some body parts. Through these additional objects, participants’ body perception changed which allowed them to reflect on – and to become more aware of it. Hence, emphasizing rhythm through haptic as well as audio feedback as well changing a person’s body form through, e.g. extending certain parts, supports the development of an improved body control.

**Lacking Coordination Abilities**

It appeared that participants lacked the ability to transform verbal instructions into physical movements which showed mainly in their lacking ability of coordinating body parts correctly. The latter was related to the lacking awareness of body positions as coordination issues also derive from not knowing how the different body parts are positioned and related to each other.

A potential solution showed in changing the texture of the surroundings that were attached to the concerned body parts. The change of texture which further introduces a change of the surrounding conditions, increased awareness about body positions and hence, improved performances in also more complex, dynamic exercises.

**Lacking Consciousness of Body-Space Relation**

Further challenges were revealed in handstand or standing exercises in which participants lost the conscious perception of the location of their own body in space. Thereby, this identified issue incorporates two types, the first is based on lost perception of the actual position of body parts in space and the second is based on not being able to find the focal point or by keeping balance. The problem increased on the back side of the body due to the lack of visual information.

The blind backside of the body did influence participants’ fear in some exercises, such as handstand or the flank. The danger of swinging beyond the focal point and crash on the back results in holding back. An interactive technology that could support the process here and reduce the fear of swinging to far would not only support the exercise execution, but also the vaulter’s self-confidence.
Potential solutions were found by applying negative feedback in form of slightly painful skin stretch at body parts that were responsible for keeping the body over the focal point. Instead, a combination of haptic and audio feedback supported the perception of body parts’ positions in space and to each other. Applying only either a haptic or an audio feedback proved to be rather insufficient due to the multitude of possible directions and angles that a body part could be moved to and for which one type of feedback would require too much effort to be interpreted correctly.

Altogether, the results show various areas that could potentially be supported by interactive technology, such as giving impulses at the right time and the right position or making invisible space on the vaulter’s back more accessible.

**Meaning for The Further Development**

Results of the first conducted bodystorming workshop showed several areas for a potential use of interactive technology for different purposes, such as reviewing positions, giving impulses at the right time and the right position or making invisible space on the vaulter’s back more “visible” in relation to the body position. Accordingly, it already provides some responses to the first as well as the second research question. The problem of lacking body awareness was discussed and evidently present throughout which led to a narrowed focus on body awareness in the second bodystorming workshop.

5.4.3. **Second Conducted Bodystorming Workshop**

In comparison to the first workshop, the second workshop focused more on body awareness as well as on the coach’s perspective. Additionally, the session’s structure differed as it was split into two parts. In the first hour, participants bodystormed on the cantering or walking horse, while in the second part, the session continued on the static barrel horse. Including the living horse in the bodystorming session allowed to compare the training on the barrel horse as well as to draw conclusions about the third party’s (the horse’s) influence on the training process as well as the vaulter’s body awareness. Also, as the coach’s position to and possibilities to correct the vaulter in the training with the horse are much more limited to the training on the barrel horse, this part of the session offered to bodystorm the sensory in-and output that could potentially support the coach in another, but also realistic physical training scenario.

In the second half of the workshop, the session continued on the barrel horse. Changing the scene had two purposes. First of all, after an hour of cantering and walking, a horse needed a break. Secondly, the discussions turned to more detailed discussions in which participants began to break exercises into sequential steps to evaluate each step thoroughly. The time needed for this process required to concentrate fully on the discussion, without being distracted by the horse, whose well-being and needs would always have priority to an in-depth discussion. By switching the scene to the training on the barrel horse, participants were free of duty and able to fully engage in the second part of the bodystorming. Details to the progress of the second bodystorming can be found in the appendix.

**Equipment and Setup**

The equipment introduced in the first workshop was reused in the second workshop. However, the author decided to add some new items, such as air balloons, water balloons, a plastic box and a neck pillow, so that participants would have some variation and hence, some inspiration. Also, as not all equipment was made use of in the first workshop, the author presented each item again at the beginning of the session, so that participants would be reminded of their availability. A complete list
of all introduced items can be found in the appendix. Additionally to the interactive objects and the normal vaulting equipment, the author provided moderator cards with key words about body awareness, so that participants would have a better understanding of the definition and characteristics of it. These keywords were used to present the workshop’s goal clearly. Further, the same recording devices were used as in the first workshop, a gopro camera and a sound recording device. The camera was set up stationary during the activity on the barrel horse. But to capture closer recordings of the session with the moving, living horse, the author was partly wearing the camera. The sound recording device was again used to assure that all verbal contributions were captured for which it was kept close to the participants at all times.

Figure 5 Equipment Bodystorming Workshop II

Challenges of the Workshop

Including the living horse in the bodystorming led to partly limited concentration on an in-depth discussion and to less taken initiatives by the participants. However, the switch to the barrel horse in the second part of the workshop allowed to continue and deepen the discussions. Instead, the same limitation occurred as in the workshop before that equestrian vaulting is a complex sport with many facets, so that the covered exercises and situations provide still only a small range of the full potential scope. In comparison to the first workshop, the second allowed to reveal more insights about body awareness in detail in the context of equestrian vaulting, also including the mental and emotional level of it. Furthermore, applying the provided equipment in each bodystormed scenario supplied many potential areas of use for interactive technology targeting each level of body awareness, physical, mental and emotional.

Overall, participants were more familiar with the method and had a lot of fun trying out various items and scenarios. They were joking a lot throughout the whole workshop and participated actively.

One significant limitation in the methodology occurred in the guidance and introduction that participants were given. By triggering certain discussion topics and scenarios, participants concentrated a lot on the given sensory in- or output. In a real scenario, their attention would be more distracted and divided by other aspects, so that the conscious perception would be much lower. This questions the level of required intensity of a sensory in- or output and influences the suggested design solutions in the following.
Insights
Bodystorming Workshop II

In comparison to the first bodystorming workshop, the second aimed towards focusing the research on the vaulter’s body awareness in various scenarios and exercises. The influence of the coach as well as of the horse on the vaulter’s body awareness was therefore emphasized in the session. Thereby, the results reveal not only insights about body awareness, but also about the role of each party in the relationship triangle (vaulter-coach-horse) and other, contextual conditions that influence the training, such as space and timing.

Including the horse in the first part of the workshop required to split the concentration between the care taking of the horse and the bodystorming. As the horse is an essential part of equestrian vaulting and as the training on the horse differs to the training on the barrel horse, new insights resulted from this part nonetheless. However, it challenged the participant’s creativity, as most ideas and suggestions were provided by the author in this part of the bodystorming. Instead, during the second part at the barrel horse, participants were more active in trying out the material on their own and provided more ideas by themselves.

An overview of the findings of the second bodystorming workshop can be found in the following table. One of the identified issues focuses on incisive body parts, which are, in the context of the thesis, body parts that participants put into discussion focus.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Identified body awareness issues</th>
<th>Outcome of bodystorming</th>
</tr>
</thead>
</table>
| Visual output on the cantering horse | Lacking awareness of how body parts are positioned to each other  
Lacking awareness of how body parts are positioned in relation to the horse and surroundings  
Lacking awareness of how movements appear in the surrounding space | Quicker and easier perception of body positions through the visual output  
Quicker and easier perception of the overall picture/ overall performance |
| Audio output on the cantering horse | Invisible body parts for coach and vaulter, hence harder to keep awareness in and for that part  
Disability to harmonize movements with | Limited, but distinct audio feedback for single points perceived as supportive  
Additional audio beat to |
<table>
<thead>
<tr>
<th><strong>Haptic resistance on the cantering horse</strong></th>
<th><strong>Performing on other horses</strong></th>
<th><strong>Simultaneous projection of the vaulter’s movements on other parts of the cantering horse for the coach</strong></th>
<th><strong>Haptic resistance on the static barrel horse</strong></th>
<th><strong>Learning course of movement at the static barrel horse</strong></th>
<th><strong>Charismatic execution of free-style on the static barrel horse</strong></th>
</tr>
</thead>
</table>
| the horse’s movements, leading to high expenditures of energy | Complete ignorance of some body parts; disturbing the harmonic flow and clean execution of a movement | Lacking ability to adapt to other range of movements (from other horses)  
Lacking ability to divide attention, so that performance parts get ignored by coach or vaulter | Complete ignorance of some body parts; disturbing the harmonic flow and clean execution of a movement | Lacking ability to mentally and physically understand the course of a movement  
Disability to connect mental understanding of a course of movement to its physical execution | Lacking awareness of how movements appear in the surrounding space  
Lacking identification with the performance/lacking embodiment |
| harmonize with the horse’s rhythm | Disability to keep body awareness at incisive body parts leading to incorrect execution of exercises and movements | Sensitive attentiveness as one of the key aspects to connect and interact with the horse and coach as well as to harmonize movements with the horse | Effect of stretched skin up to the degree of perceiving pain as negative feedback improved performance and body awareness | Effect of vibrating impulses guiding body awareness and hence, influence a proper course of movement or body position | Creating mental images supports another kind of body awareness  
Extending body parts through |

Effect of stretched skin up to the degree of perceiving pain as negative feedback improved performance and body awareness

Disability to keep body awareness at incisive body parts leading to incorrect execution of exercises and movements

Effect of vibrating impulses guiding body awareness and hence, influence a proper course of movement or body position

Learning course of movement at the static barrel horse

Lacking ability to mentally and physically understand the course of a movement  
Disability to connect mental understanding of a course of movement to its physical execution

Increasing body awareness and understanding of one’s own body through breaking the whole range of movement into pieces and train each piece before putting it back together

Simultaneous projection of the vaulter’s movements on other parts of the cantering horse for the coach

Lacking ability to divide attention, so that performance parts get ignored by coach  
Invisible body parts for coach and vaulter, hence no reflection on it possible

Disrupts the coach’s attention which triggers the horse to canter irregularly which influences the vaulter’s performance

Charismatic execution of free-style on the static barrel horse

Lacking awareness of how movements appear in the surrounding space  
Lacking identification with the performance/lacking embodiment

Creating mental images supports another kind of body awareness  
Extending body parts through

Performing on other horses

Lacking ability to adapt to other range of movements (from other horses)  
Lacking ability to divide attention, so that performance parts get ignored by coach or vaulter

Sensitive attentiveness as one of the key aspects to connect and interact with the horse and coach as well as to harmonize movements with the horse

Simultaneous projection of the vaulter’s movements on other parts of the cantering horse for the coach

Lacking ability to divide attention, so that performance parts get ignored by the coach  
Invisible body parts for coach and vaulter, hence no reflection on it possible

Disrupts the coach’s attention which triggers the horse to canter irregularly which influences the vaulter’s performance
Lacking understanding of how body movements are related to artistic expression
Lacking understanding of how the artistic expression derived by body movements influences the perception of others
e.g. cloths, lights etc.
Imagining another person’s perspective; what does another person perceives from my performance

Table VI Results Bodystorming Workshop II

Perception of Various Output Forms on the Horse

Result showed that the emphasize of certain body points supported through different light output the other participants to perceive body postures much quicker and easier. The attached lights, emphasizing angles as well as lines of a body parts’ positions, enabled a quick perception of irregularities or incorrect body movements. As the integration of the horse requires a lot of attention by the coach, enabling the coach to quickly perceive performance errors, allows to give more detailed and immediate feedback under less directed attention on the vaulter.

Furthermore, audio output proved to be, if loud enough, supportive to indicate either or states of body parts that are turned away from the coach’ field of view. Thereby, the output is perceivable by both, vaulter and coach, at the same time, which creates a joint attention towards the same body part. The joint attention intensifies the experience and extends the possibilities, by combining the subjective perception of the athlete with the one by the coach, to train a person’s body awareness.

Refocusing on the audio output, limitations showed in the level of precision. By bodystorming with one kind of audio signal only, it was constraint by the range of information it could convey.

Another, from the first bodystorming transferred idea concerned the skin stretch effect which sustained a supporting tool also as on the real horse. New insights about this type of feedback concerned the exploration of it as positive feedback, besides the previously tested negative application example of causing pain. In the positive feedback, the created feeling of having to push against an obstacle (the stretched skin) would motivate participants to push even harder. Another outcome related to the skin stretch was the appreciation by participants of a constant reminder, hereby, a constantly stretched skin, as then, she would automatically stay aware of properly executing the course of movement (“Ich finde das [konstante Feedback] sehr gut fürs Training. Da werde ich konstant erinnert und kann es nicht vergessen.“, participant 2). In comparison, the vibrating impulse of the dog collar would be better for very specific body parts in short-whiling, but stable situations, whereas the feeling of tension would be better for more dynamic, moving body parts.

Bodystorming the ideas from the first bodystorming workshop in the horse showed that derived suggestion support the training in either situation. Nonetheless, the signal intensity would have to be increased in most output types when training on the horse.
**Horse-Vaulter-Coach Relationship**

The roles and relationships between each player in the general training process revealed that the vaulter has little influence on the horse, but therefore the horse even more on the vaulter’s performance. Instead, the horse’s performance depends mainly on the interaction with the person on the other side of the lunge, hereby the coach. The attempt to divided the coach’s attention between the horse and the vaulter’s performance more resulted in irregular canter strikes that challenged the vaulter to perform exercises properly. Accordingly, participant 3 mentioned that “ich fühle im Hintern, ob eine Übung etwas wird oder nicht” (I feel in my butt, if an exercise will be good or not) before beginning a movement. Further, the participants felt not only the changes in the movement of the horse, but also if the coach was mentally absent or not. This part of the bodystorming showed how much each party, horse, vaulter and coach, are intertwined and that a vaulter’s performance is influenced a lot by the mental and emotional attentiveness of the other two parties, as seems the horse. This gathered insight allows not only a better understanding of the various roles and relationships, but also introduces the area of body awareness which deals on social and emotional aspects, but which has, apparently, a great effect on the physical performance.

**Body Awareness Based on the Perception of Others**

The bodystorming of the freestyle revealed lacking ability of fully embodying performances, including a charismatic and artistic expression that would incorporate the embodiment of music. Thereby, participants lacked in relating their body movements to the effect that the movements had on others. In that case, a lack of sensitivity can be assumed. Further, to perform the freestyle with charisma, or, in other words, a certain artistic expression, requires the vaulter to identify her-/himself with and embody the performance, also on a cognitive level. As the issue further relates to the lacking ability of understanding how others perceive oneself, tools and methods should provide a possibility to close this gap. One potential solution was explored by recording the performance and letting the vaulter watch it afterwards. The video led to an increased understanding of the perception of others as well as a closer relation to oneself and one’s own physical performance.

**Embodying New Movements**

The learning process of new movements was supported by splitting the movement into sequences and physically indicating, through e.g. tape, each sequence at the place where it should done. Further, the timing of each sequence was crucial for which an audio signal as trigger of every new sequence showed to successful. Accordingly, the additional output supported the participant to know when and where to do which movement. In that sense, the bodystormed solutions supported to embody the new movement by emphasizing the role of place and time of the course of the movement.

**Meaning for The Further Development**

Overall, the second bodystorming workshop revealed several areas in which a vaulter’s body awareness can be supported by interactive technology. It further emphasized the importance of allowing the adaption of the in-or output provided by the interactive technology to the contextual conditions and a vaulter’s abilities. Additionally, a new insight revealed that the coach is challenged a lot by having to split the attention between horse and vaulter, so that many movement mistakes are not perceived by the coach during the training on the horse. The impact of the coach’s distribution of attention on the vaulter and the horse showed a very sensitive relationship between the three partners that further influenced the vaulter’s body awareness by body extension and external physical forces.
The results of both bodystorming workshop in combination with the previous literature study led to a list of potential prototypes that can be found in the appendix and which could be created and tested. Each prototype relates to an identified issue concerning body awareness and an implementation suggestion. However, due to time and resource limitations, the selection of mainly non-technical, rapid prototypes was reduced to:

- a neck collar for dealing with balance issues,
- altered magnet stripes as haptic limitations for stretch and body position control
- a hair dryer as guiding frame to provide a facilitated focal point
- sketches for a discussion basis of different ideas

The decision for the narrowed down list of potential prototypes was mainly based on the conducted thematic analysis that supported the identification of most dominant, re-occurring issues. For the thematic analysis, the table Results Bodystorming Workshop II was used as basis and reviewed on re-occurrence of each listed item. The analyzed results were then taken to generate prototype ideas by additional inspiration of literature references. Form and implementation of each prototype was further limited by the available material, so that the prototype testing in the following stayed on a very superficial, mostly non-technological level.
6. Experienced Prototyping & Brainstorming

Based on the bodystorming workshop results, possible creations and application areas for prototypes were identified through the analysis of the recorded material with a follow-up brainstorming on the recordings as presented in the following. As the types of body awareness for which interactive technology could be designed for are mainly identified during the bodystorming workshops, the next chapters focus more on the second research question about how to influence it from a mainly design-oriented perspective, but also including materials and technical considerations.

6.1. Conducted Experienced Prototype Iteration I

The prototype testing was conducted with the same participants and at the same location as the bodystorming workshops, at the Hirschhof Vaulting Association. Overall, the session took an hour and aimed at identifying further development potential of the prototypes.

6.1.1. Equipment

For the first iteration with mainly non-technical prototypes, participant no.1 (active vaulter, teenage age) and 4 (certified coach) joined the session. The status of the prototypes differed from using sketches to some low-fi prototypes. As used prototypes sketches, a hair dryer, a neck collar and an altered magnet strip were introduced to the participants. The following table provides a more detailed overview of the tested versions.

The first embodied prototype was based on a leg extension as seen on the figure 8. Two magnet strips were attached to the leg, so that they would allow bending it, but also connect by making a small “click” sound when the leg is stretched. Aiming towards a stabilized line in a stretched leg position and towards an emphasized feedback as soon as the change in the body position was executed, the prototype was supposed to support the vaulter’s body awareness by keeping incisive body parts in the vaulter’s attention span.

The second prototype aimed towards facilitating the attention span by using a hair dryer. The blown air stream was tested by using it as invisible, but tactile guideline that a vaulter should follow with a certain body part.
As last physical prototype, a neck collar was tried out to stabilize head movement and hence, the vestibular system located there. In previous workshops, the challenges in finding or regaining balance occurred mainly in situations, in which the participants were either jumping and rotating or standing sideways. Accordingly, the neck collar was tested in these exercises.

Other ideas were discussed by using embodied sketching. The idea in the hand-stand position was to create a prototype that supports knowing where invisible body parts are positioned in relation to body parts and within the surroundings. Hence, it deals with the issue area of Orientate in disorientation. In the sketch indicated are sensors that would measure if e.g. both knees would be at the same horizontal height. Additionally, the distance between thighs and ground could be measured to assure the same distance.

Table VII Prototypes

6.1.2. Insights Experienced Prototyping Iteration I

The first iteration of testing prototypes revealed that none of the prototypes or discussed ideas was any close to a finished idea. For supporting balance, the upper body needs to be included much more in the design, especially in dynamic situation like a jump exercises. It showed that for exercises without rotation or only 90° rotations the neck collar provides more security and allow an improved, balanced out landing or standing. However, when testing it in a full 360° rotation jump, the participant was moving the full upper body too much to feel an effect of the neck collar.

In comparison, the magnet stripe leg extensions that aimed towards more control in the legs during e.g. a flank exercise, was too soft in the output too be really perceivable. Hence, it had no effect on the participant at all.

About the hair dryer, the participant experienced it easier to support her movement if she moved her leg towards an increasing input and hence, toward the air stream. Feedback from the participants mentioned that a stream from above was experienced as better as then “muss ich dagegen arbeiten und
es wird Stärker, je höher ich komme” (“then I have to work against the stream and the higher I get, the stronger I can feel it”), participant no.1.

The presented hand-stand sketched idea was mentioned to be too confusing “das ist zu verwirrend” by participant no.4 and that the hand-stand position should be rather tried to be stabilized to allow the vaulter to have enough time to adjust the leg positions according to the coach’s feedback. Participants further suggested to measure rather the angle between arm and torso to control which, if fully stretched, would support stability. The suggestion of participants turned the hand-stand exercise example into a topic of the Balancing out area.

In the following, a brainstorming was conducted between the author and a creative technology senior expert from a German service design agency to evaluate the current ideas and the implementation possibilities to narrow it down to one, more concrete prototype suggestion. Due to the limited time scope and amount of resources, the scope needed to be constraint to one prototype only. The senior expert has had a working experience of four years as creative technologist and is constantly prototyping with hard- and software in various projects. For the session, both participants joined in a design studio to collect ideas on a whiteboard while considering a list of the three identified main issues which re-occurred mostly during the bodystorming workshops:

- Keeping incisive body parts at present and making incisive body parts "visible"
- Orient in disorientation
- Balance

The first point targets situations in which participants had forgotten to control certain body parts as well as in which they were not aware of other parts, so that the quality of their performance was reduced. The second repeats the issue of participants lacking the ability to orientate in other positions than the normal forwards up position. Lastly, balance issues re-occurred constantly in various exercises and are hence, included in the list.

For the brainstorming and as the creative technologist was not familiar with the topic beforehand, the author introduced the topic and the identified issues by partly acting out exercise and indicating the issue areas while enacting. In the following, potential solutions were discussed for each issue. Based on the derived suggestions to consider required material as well as complexity of implementation and testing the final decision was made for a prototype outputting neuromuscular biofeedback.

An overview of the four main suggestions as well as a more detailed description of each can be found in the following figure. Each of the suggestions focuses on a different approach on how to change the vaulter’s body awareness.
The four suggested solutions including the summarized argumentation for or against, are:

**Randomly vibrating pads** that could be attached and detached to any part of the body, so that while the vaulter concentrates on the range of movement, the attention is drawn to the stimulated body parts in between. It would have to be tested if this was rather disturbing or had the required effect of including body parts in one’s attention that had not been on the scope before. However, as vibration pads are already commonly in use, this solution risks to be too simple for the thesis’ scope. Through the random vibration along the whole body, the vaulter’s attention would constantly shift by following the vibration impulse through which the body awareness by vibration could lead to a more holistic perception of the body.

A prototype considering **4D positions of body parts** (length, height, width, rotation) that could support the identification of the location in space of single body parts. However, as mentioned by the participants before, to create the feedback to the user in a way to understand which body part is concerned and in which direction it should be altered, risks overloading the user. As, in addition, the complexity of implementation is rather high in comparison to other suggestions, this suggestion is not followed up further. Nonetheless, body awareness is very relevant to orient in space in relate the body to the surroundings. Accordingly, the idea as such provides already a good design opportunity.

The **stretch control prototype** would make use of sensors that measure how stretched an object is. Accordingly, stretch could further be applied to measure angles and positions of two body parts to each other. Vibration could be used as feedback to the vaulter at the local spot which would needed to be changed. However, due to lacking material, also this solution was not followed up further. Thereby, the aim was to identify a solution with which the surrounding space around a body part could be limited to guide a movement by its limitations.
Lastly, sensors conveying **neuromuscular biofeedback** applied by the vaulter could reveal lacking muscle tension as well as too much of it. However, current available muscle sensors cover only one muscle at a time and can only measure the muscle closest to the skin. As many muscles are deeper than directly below the skin surface, the activity of those muscle would not be possible to make transparent that easily and within a low-budget frame.

One way or the other, the first three suggestions were explored on a superficial level during the bodystorming workshops, identifying them as roughly working prototypes. Instead, a possible effect of neuromuscular biofeedback on the vaulter’s body awareness was neither discussed nor known about; only lacking muscle tension issues due to different reasons were discussed and bodystormed, but mainly related back to the bodystormed solutions of attaching vibrating output along the body (similar to the “randomly vibrating pads” prototype idea). Participants did discuss the presented issue of bringing unknown incisive body parts to the vaulter’s attention as well as enabling the vaulter to re-control certain body parts which were replaced in the attention span by other aspects during an exercise execution and which had lost tension. As lacking muscle tension can be revealed by making it more transparent through the neuromuscular biofeedback, the author decided to apply this prototype idea in the further process, based on the, during the bodystorming identified, re-occurring issues.

Furthermore, the idea was not only, in comparison, easy and quickly to prototype, but also interesting to see if the imagined effect of the neuromuscular biofeedback would meet the aforementioned expectations during testing. However, the decision was also made in the knowledge that none of the participants, neither the author, has had experience with the selected sEMG sensors that should be used for the prototype creation.

### 6.1.3. Meaning for The Future Development

The conducted analysis leads to the creation of a prototype based on sEMG sensors that could be attached to single muscles to reveal its performance level, including under-performance and an according lack of required muscle tension. Measurements of the sEMG are displayed through a LED stripe with 60 LEDs. Further, as one of the goals with this prototype was to control body parts that lose muscle tension during a course of movement or exercise, the prototype is extended with a vibration motor that would be additionally attached to the same muscle and which would vibrate in case of too low measured muscle contraction. A too low muscle tension level is thereby only roughly defined by comparing the measurements of the uncontracted muscle to the measurements of the contracted muscle. Further details about the build process and decisions are presented in the next section.

The re-narrowed focus of the thesis concentrates in the following more on the potential influence that neuromuscular biofeedback could have on body awareness and how it could influence the design process of the applied interactive technology. Considering the thesis’ time limitation, the progressively narrowed focus is accompanied by re-defined questions, such as the potential influence of neuromuscular biofeedback on body awareness, which might not be fully explored and responded to at the end. Nonetheless, by following the RtD approach, it is natural development that was also aimed for from the beginning on.

### 6.2. Conducted Experienced Prototype Iteration II

The focus of the next iteration was based on revealing muscle tension by attaching an sEMG sensor along the Gastrocnemius, Flexor carpi radialis, Triceps brachii lateral and Rectus abdominis and by
indicating different intensities via a stripe of 60 LEDs. Aiming to reveal activity levels of each muscle in different exercises, these four muscles were selected in cooperation with both participants who contributed their expert knowledge about equestrian vaulting exercises, but without any further expert knowledge of the human body’s physiology. Additionally, a minimum tension value was pre-defined by the author based on the comparison of measured muscle tension in rest and under contraction which caused a vibration when the participant’s muscle tension was smaller.

Figure 13 Targeted muscles on the human body by anaytomyscience.com, 2018

The setup and testing location stayed the same. However, this time participant no. 3 (circus pedagogic) and no. 4 (coach) joined the session. Attaching the sensor only to participant no. 3 allowed to gather the coach’s statement from a more observing and reflecting perspective. This difference was made also to research further how joint attention would affect the test results. Follow-up interviews with each participant and in the group together were conducted as qualitative feedback about the prototype and the conceptual idea behind it.

The semi-structured interview included questions about participants’ opinion about the prototype’s setup, conceptual idea and effect on their experience. Each prepared question as well as more details about the progress of the experienced prototyping can be found in the appendix.
6.2.1. Equipment

The prototype was created with a MyoWare sEMG sensor with integrated a data noise filter, an Adafruit Huzzah WiFi microcontroller, a vibration motor, an LED stripe, an Arduino Uno, electrodes, cables to connect, a 3.7v battery and a router. Arduino Uno and LED stripe built one unit indicating the intensity of the received muscle tension mapped to the 60 LEDs of the LED stripe. MyoWare, Adafruit Huzzah WiFi and vibration motor built the other unit of the prototype which was connected wirelessly to the Arduino Uno via the router, so that the participant was able to move freely with it. Additionally to the hardware setup, a processing sketch visualized and saved the measured data in a graph in real-time on a laptop screen as control instance.

6.2.1. Insights Experienced Prototyping Iteration II

Participants’ opinion about the prototype was that they thought that the idea could be really good for the own body control. Especially for finding out how to trigger a certain muscle, the LED stripe would help a lot in the reflection and perception. Instead, the vibration motor would not be needed in that case, but in a situation in which the vaulter would need a reminder of the muscle that has lost tension during the execution of an exercise. The LED stripe was also perceived more valuable than the graphs on the screen as it was, according to participants, clearer through the luminance and brightness. However, the position of the stripe was not found ideal, as in many exercises, the vaulter’s field of view would change and hence, lose sight.

The discussion further turned to the joined attention in which both participants agreed in finding the prototype (if providing correct measurements) a useful tool to align the athlete’s self-perception with the external perception of the coach. Participant no.3 mentioned an example scenario which would occur fairly often in a training session that a coach would ask the vaulter to “Exert yourself” whereas the vaulter would think “But I am”. According to participants, the prototype “kann die ganze Diskussion auf eine objektivere Ebene bringen.“ (could bring the discussion to a more objective level) and hence, align self and external perception more. Through the LEDs stripe’s mobility, the coach was also able to direct her attention elsewhere for a short while and by glancing on it on the periphery of her sight only, which would catch the indicated changes, she was able to additionally appeal to the vaulter’s lacking tension. Additionally, due to the quite long length of the stripe, it was easy to
interpret when the tension was too low. Instead, if LEDs were illuminated closer to the half of the full length, it was harder to estimate what that actually meant. Nonetheless, while discussing the potential combination of vibration with the appeal received by the coach, participants could imagine that the double input would push the vaulter even more to exert an intensified muscle tension. However, this was based on a theoretical discussion only due to broken hardware and could also lead to over-tensioning the muscle.

Overall, this testing session revealed further potential areas of use in the context of body awareness based on self-awareness and joined attention as well as revealed some aspects that should be further developed in the prototype, such as a clearer indication of what the represented data actually mean for the physical training context. It also showed the high sensitivity of sEMG sensors toward external influences like dust, movement or sweat on the skin. As it stopped working after re-using it in different positions and muscles, the planned scope of the testing could not fully be conducted. Further aims were to look more in-depth into single muscle performances during vaulting exercises to potentially identify patterns and hence, to gather more insights about the required intensity per exercise or the timing per exercise in which a muscle should be more contracted or less. As a sufficient number of repetitions was not possible to conduct due to the sensor issues, the iteration II had to finish with the insight presented above.

6.2.2. Meaning for The Future Development

This experienced prototyping session revealed that neuromuscular biofeedback has an effect on body awareness which changes how individuals perceive their own body and level of performance. Additionally, the prototype showed potential in solving misalignments caused by different perceptions of muscle contraction capacities and levels between coach and vaulter. The way, the prototype was constructed and explored showed strengths as well as weaknesses. Its main strength showed in the easily and quickly understandable visual output of the LED stripe, whereas a weakness showed in the integration of the prototype into the physical training space which, by having no clear place for it yet, partly prevented participants from fully seeing and hence, perceiving the output.

Another weakness caused the decrease of measured data quality. The concrete reason for the decreased reliability could not be identified as multiple aspects could have contributed to this. As these limitations influence the research regarding its goal of identifying the potential of neuromuscular biofeedback to influence body awareness in also more dynamic physical training situations, the author decided to conduct an expert interview with a practitioner for manual therapy.
7. Expert Interview

This chapter presents the approach of and the gathered insights from the conducted expert interview with a practitioner for manual therapy about sEMG usage, human physiology and the created prototype’s functionalities in an overall context as well as in the physical training of equestrian vaulting. The contacted expert was further a sport scientist with specialization on health-remedial training with over 20 years of working experience. As presented in the previous chapter, the application of the chosen sEMG sensors provided some challenges and limitation, so that the author decided to include an expert’s opinion about the usage of such sEMG in the physical training of equestrian vaulting. Insights enabled further decision-making on the thesis’ progress and are presented in the following. In regard to the further progress, the aims of this interview were to discuss:

1. The general idea of the prototype
2. Potential benefits or required alterations from an expert perspective
3. Potential limitations and workaround for these limitations
4. The application of sEMGs
5. And to identify further muscles and test cases for the final prototype testing

The interview was conducted as open interview and took about an hour, including the setup and testing of the prototype. After a short introduction of the thesis topic and the aim of the interview session, the prototype was setup for the expert to test it on herself. More details about the progress can be found in the appendix. The interaction with the prototype followed a semi-structured interview of which the prepared questions are included in the appendix.

7.1. Insights Expert Interview

Discussing the occurred challenges with the MyoWare sensor, the practitioner suggested test cases as presented in the following table.

<table>
<thead>
<tr>
<th>No.</th>
<th>Case</th>
<th>Aim</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Comparison of muscle tension in the lower back area (Longissimus) in upright sitting position on a chair and on the barrel horse</td>
<td>Aiming towards revealing potential differences in the basic muscle tension when being on the floor or on the barrel horse (⇒ effect of such a sport on muscle tension)</td>
</tr>
<tr>
<td>2.</td>
<td>Comparison of visual output and haptic output while participants do an exercise of e.g. 5x increasing the muscle tension up to a certain range (Longissimus or Gluteus maximus).</td>
<td>Aiming towards revealing the different effect of each output type on the participant’s body awareness</td>
</tr>
<tr>
<td>3.</td>
<td>Measurement of basic muscle tension in upright sitting position on the horse as reference (Longissimus).</td>
<td>Aiming towards revealing how much the tension increases by being on the horse (reference to no.1) and if measurable at all due to increased (bouncing/) dynamic ground</td>
</tr>
</tbody>
</table>

Table VIII Test plan
Further details about the final test plan can be found in the appendix. The selected muscles, Longissimus and Gluteus maximus were suggested by the practitioner as dominant muscles in simple positions such as sitting or standing of which sitting is further the starting position of a vaulter in general. Both muscles are based directly under the skin and hence, easy to access and attach the sensor to. Furthermore, the Gluteus maximus incorporates an important role in exercises like the flag which could be used as testing exercise.

The practitioners opinion about the prototype was at the beginning of the discussion rather critical due to the described issue of receiving a valid data measurement. Nonetheless, while discussing the conceptual idea of conveying the internally perceived muscle tension outside the body to increase body awareness and to enable vaulters to consciously control single muscles, was greatly appreciated. An additional idea changed the current role of the vibration motor as negative feedback to a positive feedback in which, as described in test case 2, the test person would try to keep the muscle tension within a certain range several times in a row and for each correct match the vibration motor would serve as the confirming feedback. Reducing the confirmation to a haptic feedback only would mean a much bigger challenge for the participant’s body awareness in regard to controlling the targeted muscle correctly, according to the expert. She further mentioned, by referring a potential application of the prototype into her work, that her patient would also benefit from such a tool which would allow to concentrate on a specific muscle and which would include different levels of difficulty in the control process for them. Accordingly, such a tool could further be tested and introduced in a physical therapy context and hence, open up the application area for a much broader audience.

Even though, the prototype idea found the expert’s interest and encouragement, limitations of the study were pointed out in regard to the still very noisy data as well as to external factors such as ground conditions that could influence the measurements and a person’s basic muscle tension a lot.

### 7.2. Meaning for The Future Development

The test plan for the last iteration within the context of the thesis reduces the scope to basic body postures and static exercises while comparing these on different ground conditions and with differently triggered feedback (visual versus haptic). This caused to iterate the prototype as well as to test the changes in a smaller setup before conducting the full scale of the test plan. Accordingly, a pilot study was conducted, aiming to reveal potential issues in the planned approach.
8. Pilot Test of The Iterated Prototype

The pilot test of the iterated prototype was conducted with one test person that has not been involved before and who has had no experience with equestrian vaulting. The testing took place in a design studio aiming to test the new setup and test plan for which experiences in equestrian vaulting was not necessary. As described in the former section, in the expert interview, a test plan was discussed focusing on a very basic level of physical training, which would allow a more focused approach to increase the concentration on the refined sub-topic of changing body awareness based on neuromuscular biofeedback through interactive technology, and less on the case example of equestrian vaulting. Hence, a pilot study was conducted to reveal potential misalignments of the test goals with the defined approach.

The test person was a 27 years old female with no experience in interaction design, but with physical rehabilitation training based on, among others, neuromuscular biofeedback for 1,5 years. Hence, the participant had level of knowledge about placing sEMGs, the sEMG output signal and the rehabilitation training process from a user perspective which allowed her to compare former experiences with the one made during the pilot study.

8.1. Preparation

Advances of the prototype were made in regard to the output feedback regulation, to give it a clearer meaning. As test case 2 aims towards comparing the effect of visual versus haptic output when trying to control the muscle tension, code changes were implemented to only trigger the output after holding the tension in a pre-defined level for a certain amount of time. In this case, every time a test person would hold the attached muscle tension for 3 second on a medium level, the output would be triggered as confirmation. Accordingly, the output devices, LED stripe and vibration motor, were kept separate from each other for this testing round, instead of combining both in one prototype, as in the iteration before. While the vibration motor would give a unified vibrating impulse for every correctly executed exercise, the LED stripe would indicate low, medium and high levels in different colors. For the basic muscle tension comparison, the plan was to identify during the pilot study which output, if any, should be applied.

The participant gave her consent to use any recorded data and observations for research and educational purposes. The pilot study was recorded by pictures and note taking by the author only.

8.2. Insights Pilot Test of The Iterated Prototype

While conducting the pilot study, the test between high sitting position versus both feet on the ground sitting position was the only part which could be tested due to failure of the hardware. Thereby, the sEMG was attached to the Longissimus, as discussed within the expert interview. Further details about the progress of the pilot study can be found in the appendix. Through the limited testing scope, results of the pilot study are based on the participant’s feedback. According to her experience, having a visual representation of the muscle tension intensity supports a lot in increasing the understanding of what muscle is actually triggered at the moment. Further, she preferred the LED stripe visualization, as the level of detail on the digital graph would be too fine-granular and the sections of the LED much clearer to relate to her own performance.

The participant mentioned also “ich [habe] mich ganz genau auf diesen Muskel konzentriert und durch das LED vor Augen geführt bekommen in welcher Intensität ich ihn nutze.“ (‘I fully concentrated on
that one muscle and through the LED, I was able to realize in which intensity I actually contract it”). This indicates that through the representation, it was possible to consciously trigger the targeted muscle. Further she mentioned that through the prototype the body awareness would definitely be trained, “Man schult durch den Versuch [den Prototypen] definitive die Aufmerksamkeit für seinen Körper!” (“The prototype definitely allows to educate the awareness for one’s own body”).

In the context to the comparison between stable versus more unstable seating position, the participant confirmed that on the latter, it was much harder to find the right balance. However, by being already familiar with the LED stripe and its indication, the learning of what the visualized output means and how to react to it was much quicker.

The pilot study, even though it was only a reduced testing of the original test plan possible, still allowed the feedback from an independent participant that the prototype does train a person’s body awareness.

8.3. **Meaning for The Further Development**

Due to repeated hardware issues, the further development and testing of the prototype are not further possible within the time frame of this thesis. Hence, all further analyses and discussion focus mainly on the various identified body awareness issues and potential design solutions, instead of focusing on the effect of the neuromuscular biofeedback prototype in-depth. Nonetheless, the integration of neuromuscular biofeedback in the physical training of equestrian vaulting revealed already in the small scope insights that support the argumentation for a further follow-up on the study.

The following chapter presents the analysis of gathered results by relating them back to the research questions from the introduction chapter.
9. Analysis

The thesis’ results are based on the data gathered and analyzed from the various conducted methods. Thereby, the focus was on qualitative data from recorded observations as well as statements from group discussions or one-on-one interviews.

Results are based on analyzed results from the bodystorming workshops I and II as well as the experienced prototyping I and II and the expert interview. Due to the amount of gathered data, the detailed results and how they are connected to each conducted method are detached from this chapter, but can be found in the aforementioned parts of each single conducted method. The analysis chapter serves rather as a summary, showing how the findings relate to the research questions.

9.1. Types of Body Awareness

One of the first questions that derived through the underdeveloped status in research as well as through the thesis’ progress was questioning the types of body awareness that should be considered in a physical training context and for which interactive technology could play a supportive role:

1. What aspects of body awareness are important in a physical training and can be supported by interactive technology?

This question incorporates the meaning of the type on the physical training, which is hereby focused on the physical training for equestrian vaulting.

Results relating to the first research question derive mainly from the bodystorming workshops. Some additional insights are deduced from the experienced prototyping sessions which, even by narrowing down to one prototype and by focusing on body awareness by neuromuscular biofeedback, included re-occurring as well as newly identified types of body awareness. The following contains an overview of the identified body awareness types that can be supported by interactive technology:

Body awareness by body positions,

One of the most dominant issues as re-occurring in a multitude of exercises is the need of a vaulter of an external review of one’s body position. Body position relates thereby to body parts’ positions to each other as well as body parts to its surroundings. It thereby partly overlaps with an orientation issue as presented below, however, this aspect relates directly to precisely executed and performed angles, lines and forms. Accordingly, it is mainly based on the perception of proprioceptive senses.

Body awareness by the vestibular system

A re-occurring type was the body awareness by the vestibular system which was discussed due to the problem of disorientation in positions like a hand-stand. Body position and orientation is influenced from the vestibular system and the proprioception, whereas proprioception indicates body positioning of different body parts to each other through the feeling of stretch and contraction. As participants of the bodystorming workshops were challenged by coming up with ideas to solve such problems, it provides good areas to apply interactive technology to support the physical training in those cases.

Body awareness by neuromuscular biofeedback
Body awareness by neuromuscular biofeedback was discussed more in-depth in this thesis. Results show that its application which is based already on interactive technology, extend the body awareness by muscle tension a lot regarding its physical, social and cognitive understanding and meaning-making. It allowed a much better relation to oneself and one’s physical performance as seen in the experienced prototyping session II and the pilot study.

**Body awareness by consciously relating to body parts**

The ability to relate to all existing body parts requires are very good perception and understanding of one’s own body which was several times observed and discussed to be an issue for participants of the bodystorming workshops. It requires a very well established body awareness regarding interoception, proprioception and, beyond that, the cognitive functions of body awareness considering the conscious processing.

**Body awareness by consciously controlling body parts**

Relating to the previous type of body awareness, this type also requires very body senses and functions to influence it. However, besides being consciously aware of body parts, controlling them brings body awareness to an even more challenging level, as also discussed in the expert interview, considering the challenge of a user to control one’s muscles based on vibrating feedback only. As the example already shows, interactive technology offers a lot of potential to influence this type of body awareness.

**Body awareness by coordinating a movement**

While this type shows in how a course of movement is understood and executed, it depends also a lot on the cognitive abilities of a person regarding to multitask. Multitasking depends on the ability to divide attention. Accordingly, interactive technology can again influence this type of body awareness in various ways, beginning to facilitate the multitasking process up to triggering certain physical movements or body reactions.

**Body awareness by others**

Embodiment of performances can change self-awareness and -perception, also if indirectly perceived through the eyes of others. Nonetheless, the concerned person requires the opportunity to perceive and interpret the awareness of others of oneself. In this thesis context, it was suggested to record a video from the outer perspective on the performance which is already a type of interactive technology.

**Body awareness by embodying a course of movement**

The learning of new movements requires a proper understanding of the movement that should be performed which includes to know which body parts should be moved how at what moment. It is based on body awareness by the ability of interpreting external simulations which are perceived by exteroceptive sensations. The interpretation is further related to previous experiences, the social surroundings, education etc. which cannot be further explained in the thesis’ context. Nonetheless, by splitting the new movement into sequences and focusing on learning each first before putting it back together, shows an opportunity for interactive technology to support the process of cognitively understanding a course of movement first. Secondly, the cognitive understanding would have to be conveyed to actual physical movements for which no results are offered in the thesis course, but leave room for further research.
Body awareness by horse-vaulter-coach relationship

The first mentioned belongs to body awareness by a combination of social relationship, vestibular system and proprioception as the perception through the participant’s butt was interpreted under the influence of the social relationship between horse, vaulter and coach as well as under the unconscious consideration of physical forces provided through the horse’s movement. Without having more in-depth insights about this type of body awareness, a take away of its identification is that body awareness is based in many situations on a combination of types as well as that body awareness enables you to make prognoses about courses of movements and performances and hence, can determine a person’s gut feeling.

Altogether, the assumption can be made that interactive technology could support any of the identified body awareness types which offers a vast variety of design opportunities. However, the introduction of interactive technology as supportive tool has to be put in relation to costs and usefulness. While the identified needs indicate a potential usefulness, the required effort to achieve such a tool remain an outstanding question.

9.2. Influencing Body Awareness Through Interactive Technology

The second research question focused more on the physical training area of equestrian vaulting and questioned how the identified types of body awareness resulting from the first research question could be influenced within the training. Thereby, analyzed results show already design potential for interactive technology for a more general audience than only equestrian vaulting. The second research question was about:

2. How can interactive technology influence body awareness in the physical training for equestrian vaulting?

In this thesis, body awareness through motor skills was the main researched, also due to the targeted physical training context and the excursion into neuromuscular biofeedback. Hence, as presented in the results of each method chapter, several suggestions and design ideas were tested which are hereby discussed in the following. A rough overview is further provided through a list of derived design implications which are based on the various bodystormed and tested ideas for potential solutions:

1. Emphasize body parts and positions

Emphasising angles and incisive body parts enabled the coach to perceive out of the peripheral more details of the vaulter’s body position while focusing on the horse. Further, the attached lights influenced the perception by others of the participant’s artistic expression. Hence, it supports further a development of a charismatic appearance.

2. Guide movements through the restriction of surrounding space

Hereby tested by the hair dryer or the duct tape, by reducing the possible movement space or by emphasizing movement direction in space, the vaulter senses the changed conditions which accordingly influence the body awareness in relation to the surrounding physical space.

3. Facilitate the synchronization and harmonization with other external influences
Interactive technology could further support the embodiment of external influences like the horse’s movement in form of providing additional haptic and audio impulses. Facilitating the embodiment of external influences would also extend a person’s coordination skills in regard to connecting a person’s body or only certain body parts with external aspects. As one of these aspects can be other vaulters as well, the supported training could further improve the cooperation and social interaction experience with other vaulters.

4. **Re-direct the conscious perception**

As presented, the issue of losing control or forgetting to control body parts due to divided attention appeared frequently throughout the training process. The identified problem is based on a reduced self-consciousness which can be changed through interactive technology. Either in form of emphasizing the feedback from a second person through, e.g., locally applied haptic feedback, or by outsourcing to control of the body position to a system.

5. **Serve as communication tool of biofeedback**

Increasing the awareness about interoceptive sensation and, additionally, enabling to share this sensation up to certain degree supports learning and understanding processes about either the personal or another person’s body. Cognitive understanding of process and movements influences body awareness in regard to enabling interpretation and meaning making. Consequently, connections can be easier understood and hence, it is easier to embody the perceived as meaning-making and interpretation of the world in relation to the own body are essential aspects of embodiment (Dourish, 2004).

6. **Enable joined attention of coach and vaulter**

Similar to the previous point, interactive technology can facilitate the communication between coach and vaulter, or between vaulters in regard to emphasizing certain messages or parts of message. Additionally, interactive technology can support in bringing ignored body parts or parts that participants were not able to perceive into focus. Thereby, the application if interactive technology would alter the individual body awareness, but also the body awareness derived from joined attention.

7. **Neuromuscular biofeedback**

The availability of the neuromuscular biofeedback through interactive technology to participants caused a different perception of the own performance, as the sensed proprioception was emphasized through additional exteroceptive output. The same aspect, the muscle tension intensity, is understood and perceived differently depending on which sensation it is processed.

8. **Focus on tactile and haptic sensation**

Not only mentioned by participants that haptic output would be the preferred form of feedback, it also showed during the various bodystormed explorations. A change of texture (tactile) or the introduction of an additional haptic feedback for rhythm finding, as examples, were outputs that participants could pay attention to while still perceiving it immediately. Restriction was thereby mentioned in placing the output directly to the concerned body part as any other position would require learning for which a course a movement leaves no time to do. Nonetheless, interactive technology looking into such kind of output could definitely provide a supportive tool in a physical training context.
9. Cognitive load

As mentioned before, during a course of movement, provided feedback is required to be easy understandable and interpretable which means it further needs to allow a direct relation to the concerned body part and issue. Furthermore, introduced external devices that are detached from the body require a very thorough consideration of positioning to allow a quick and direct perception of its output.

10. Positive versus negative feedback

Both forms of feedback were appreciated by participants. In fact, the negative feedback of limiting a person’s liberty of movements through obstacles or by inducing pain resulted in much better performances, also over a longer time. E.g. the duct tape attached to the belly skin of one participant prevented her of losing balance by causing slight pain when bending to far backwards during the first bodystorming workshop. In the second, the same participants mentioned that, even without the tape, she would keep the form. Nonetheless, both types of feedback triggered participant’s motivation, either by making an exercise more challenging or by receiving the positive confirmation. Thereby, interactive technology can easily applied as a form of feedback, negative or positive and hence, change the vaulter’s perception of an exercise.

Overall, there are several design possibilities and implications deriving from the gathered data that allow to respond confidently to the presented research question. As the applied RtD approach lead to a more in-depth research focusing on the role of neuromuscular biofeedback on body awareness, the author decided to present a short summary of the findings from this excursion in the following section.

9.3. The Meaning of Neuromuscular Biofeedback in The Design Process for Interactive Technology

The hereby presented insights are based on the experienced prototyping session II, the pilot study as well as the expert interview. Some insights derive from user interviews directly and some derive from the applied thematic analysis. Nonetheless, the available data base for the following insights is still very limited, so that these insight can mainly be understood as hypotheses that require follow-up studies to assure less subjective results. The subjective results in this thesis are caused by the limited number of participants with which the prototype was tested. Nonetheless, the following assumptions can be drawn from the gathered results:

- Making neuromuscular biofeedback perceivable through exteroception allows a new perspective to reflect on the individual body awareness as well as to share the perception with others and receive, hence, a more objective reflection of the perceived (serving as discussion basis)

- Introducing neuromuscular biofeedback enhances the design area by including interoception in the instructed physical training which enables the possibility to target problems areas and weak spots based on lacking muscle tension more precisely

- The inclusion of exteroceptive senses allows a better reflection and perception of interoceptive senses.
• Interactive neuromuscular biofeedback increases in time a person’s body control through giving meaning to a certain muscle contraction in the overall course of movement as well as the possibility of training the focused activation and deactivation of it

• Interactive technology provides the medium to interact and influence with one’s neuromuscular biofeedback and is hence, indispensable for accessibility and meaning making of it

• Choices for interaction types in the design process should consider the effect of the required muscle force per interaction as it could cause muscle strain and hence, back pain, head aches etc.

While the research results stay on a superficial level, the aforementioned insights allow a better understanding of neuromuscular biofeedback and its role towards body awareness as well as for the design process of interactive technology. Further, by aiming towards finding a solution for the issue of lacking body awareness in regard to being unable to trigger or control certain body parts, the few test rounds and interviews already show a potential solution in neuromuscular biofeedback which also interested people who are not anyhow involved in equestrian vaulting.
10. Discussion

This chapter serves as discussion basis about how far the applied methodology and methods supported responding to the thesis’ research questions. Recalling the questions, the first aimed at identifying the types of body awareness that should be trained in the physical training context of equestrian vaulting, and the second focused more on the application of interactive technology in this context in regard to how it could influence body awareness. Furthermore, as the targeted physical training area of the thesis aims at a rather small target group, a discussion is presented about how the outcomes as presented in the analysis could be relevant for a broader audience. Limitation are presented in form of shortcoming or constraining conditions as well as the relevance of the thesis’ findings. Thereby, the chapter finishes with recommendation for potential future work as continuation of the thesis’ work.

10.1. Strengths

At the beginning of the thesis, the problem statement focused on a rather broad scope as well as the question about how interactive technology can be integrated into the training process of equestrian vaulting. Throughout the iterative development, the topic narrowed down to body awareness and how it could be influenced through interactive technology in a physical training context. Therefore, RtD was applied in combination with embodied interaction design methods. Considering the various applied methods and user studies, the thesis manifests through its qualitative and explorative user-centered approach.

The combination of involved users and experts further affirms the quality of presented results. Also, the various iterations, introduced by the RtD approach, show a logic coherence which allow to easily understand the thesis development and motivations for or against the various design decision. The applied methods from embodied interaction design enabled to explore a currently still under researched area of design and to reveal several application opportunities for interactive technology in it while keeping in mind the role of the physical body and experiences of a physical training. The thesis’ strength further shows in the broad results that include several types of body awareness for which there is an identified need for training tools that can be based on interactive technology as well as design implications for potential design solutions. While the focus was on body awareness in a physical training context, by conducting the expert interview and the pilot study in a non-physical training environment and according participants, the thesis allowed to draw a few comparisons with further lead to assumptions of a more general interest of the gathered results than in equestrian vaulting only.

10.2. Weaknesses and Limitations

Considering the very broad topic of body awareness, it is clear that the gathered results are only a further contribution to it, but not a complete answer. This reflects further as the thesis topic narrowed down to one type of body awareness only, the one by neuromuscular biofeedback. Even with the specified focus, due to time and expertise limitations, the full potential of neuromuscular biofeedback on interactive technology or body awareness could not be fully explored. Considering the additional hardware issues which are a common challenge according to e.g. Bolek (2010) and Cram, Kasman, and Holtz (1998), it questions if, besides its proven beneficial effect on body awareness, is sustainable enough for the target physical training context.

While the applied methodology and methods led to clear results, they also restrained the thesis regarding the in-depth level of results. The gathered outcome qualifies rather through its broadness
than its focused in-depth results. However, considering the thesis’ explorative characteristics, that was a risk known since the beginning.

Other weaknesses show in the considered characteristics of the chosen physical training area. Equestrian vaulting is mainly a group sport in which the horse is an essential partner of the training. However, the thesis mainly reduced the scope to the training on the barrel horse and to individual training exercises. By aiming for more insight about body awareness in particular, scoping the thesis was necessary. On the other hand, instead of continuing with experienced prototyping, there would have been the possibility to continue the broad focus and rather iterate on another bodystorming workshop, as example. However, as equestrian vaulting is rather a niche area, the thesis benefited from focusing less on the sport itself and rather on body awareness in a more general context.

Another limitation is found in the applied material to influence body awareness as the majority of it consisted of interactive non-technology. Consequently, a direct application of interactive technology was explored in a limited scope. Interactive technology like 3D capturing of movements as shown by Ribeiro, dos Anjos and Fernandes (2017), VR environments as applied by Chen et al. (2012) and Grewal et al. (2015) or the combination of video projection and sonification with the human heartbeat as implemented by (Neumark and Khut, 2007), as example, are completely lacking in the thesis. Limitations like available resources and time did not allow, however, to implement a more complex setup, neither would such a setup have supported the explorative characteristic of the thesis, in which a potential area of application for interactive technology still needed to be identified.

The aforementioned limitations summarize the main issues and drawbacks that the thesis faced. Even though, some, such as the limited amount of applied interactive technology, have a fairly big impact on the thesis’ outcome, its contributions show great variety and validity.

10.3. Relevance of Outcomes

Discussing the meaning of the presented outcome, the thesis succeeds in identifying clearly the need in the physical area of equestrian vaulting for tools and methods to train vaulters’ body awareness. Furthermore, the real contribution is based on the guidelines and design suggestions on how to the various types can be trained and what tools, also non-technological can be used for it. However, as equestrian vaulting is a rather small target group for which to design, this section discusses briefly the meaning of the outcome in a broader scope.

Overall, there is a lack of training tools and methods supporting the development of body awareness (Nunez-Pacheco and Loke, 2014), even though the consideration of body awareness in the design as well as in the implementation process of interactive technology would increase a user’s interaction experience (Christou et al., 2011; Levisohn and Schiphorst, 2011). Considering the thesis’ results, many insights can also be considered in a more general context. E.g. the lacking body awareness by body position can very well be transferred to other physical training areas or rehabilitation. Also, the communication issue between an athlete and coach which was in the thesis context aligned through the prototype, was an issue also discussed in other research context (Nash, Sproule and Horton, 2016; Stein, Bloom and Sabiston, 2012; Carpentier and Mageau, 2013; Warren, Matkin and Antle, 2016; Moeini-Jazani et al., 2017). Thereby, the prototype added the possibility to align the perception of the athlete’s proprioceptive sensation of muscle tension with the coach’s perception. Having the muscle intensity provided as discussion basis develops the common understanding of a performance and hence, increases the athlete’s body awareness by being able to relate to the concerned body part as well as by being able to estimate better how much a muscle need to be exerted.
Further, in the area of rehabilitation is the influence of neuromuscular biofeedback on body awareness widely discussed (e.g. Wang et al., 2017), however solutions lack the consideration of user experience design in the design and implementation process (Peerdeman et al., 2011). Hence, the introduced design implications for training body awareness could further be of interest for the rehabilitation sector, especially where similar lacking body awareness types occur, such as the ones by the vestibular system or the ones dealing with a complete lack of awareness for certain body parts. Thereby, for defining the right intensity of the applied output signal for a user, the user’s attention capacities, level of body awareness and perception should be considered. Especially during a concentration phase, other informational input could be easily ignored, due to the fact that humans can, in general, only consciously deal with 4 things at the same time (Miller and Buschman, 2015). Hence, depending on which aspect the interactive technology is supposed to support, the designer needs to find the right balance for the timing and strength of the signal.

Derived design implications partly overlap with the guidelines presented by Isbister and Mueller (2015) for the design of movement based games. For example show both studies that haptic feedback should be also used to find a certain movement rhythm or that feedback to a movement is important. Additionally, this thesis explains, e.g., the advantages and inconveniences of positive and negative feedback as well as emphasize the overall role of body awareness in a physical training which is missing in the guidelines by Isbister and Mueller (2015). Nonetheless, while physical games differ from physical training regarding their design focus, each research contributes through the different perspectives and findings to the other.

Furthermore, considering the type and form of the influence by interactive technology on body awareness, results relate to research about multimodality (Wechsung, 2013; Afzal et al., 2016), which show that a multimodal feedback is the most natural and effective. Applying multimodal feedback in various forms throughout the thesis, it showed that during the physical training that the effectiveness of multimodality is limited by the human’s limited perception abilities. Therefore, haptic and tactile feedback should be prioritized for an immediate perception and effect, in general. Depending on the physical exercise, visual cues are not perceivable due to a too quick change of position or dynamic movement, for which, instead, audio output could support the training process. Instead, audio signals are easily drowned by surrounding sounds, so that the setup and the distance between sound source and athlete need to be carefully considered. Accordingly, even though, multimodality is proven to be the most natural and easy to use, depending on the training situation, it might not have the required affect, but rather risk to overload or distract the athlete.

Lastly, the insights deriving from the application of the neuromuscular biofeedback allow assumptions that are especially relevant for interaction design. As these are based mainly on the authors opinion than on proving data, the following explanation is presented in more details.

Neuromuscular biofeedback represents muscle tension intensity which belongs to the kinesthetic sensations and accordingly, to the proprioception. As embodied interaction according to (Dourish, 2004) claims that any interaction we do is experienced through our body, it is also processed through our proprioception. Hence, a certain influence of neuromuscular biofeedback on an experienced interaction on a very granular level cannot be denied. Accordingly, the question arises how this influence looks like and how much it should be considered in the further design process. Research like Fjellman-Wiklund et al. (2004), Kropp and Niederberger (2010), Barbero, Merletti and Rainoldi (2012), Harvey, McPhetridge and Thorne (2012) and Giggins, Persson and Caulfield (2013) state that the increased awareness about the own muscle intensity provided by interactive technology supports
the reduction of medical conditions and issues deriving from overstressed muscles. This further means that the level of required as well as actually applied muscle tension in an interaction influences essentially the user experience. As example, if conducting a hard finger press interaction, you feel the sensation up to shoulder. Without specifying the exact muscles that are involved, that an executed force requires a counter part is already proven by basic physics, in this case Newton’s 3 Law (Tamir and Tamir, 2008). The same applies for the force applied during any kind of interaction. Accordingly, for one interaction it is not only the one “finger” included, but also other body parts. Continuing with the chosen example, the hard press is repeated several times per day because it is the required interaction to switch on and off my induction stove, as example. The related contraction of the whole connected muscle apparatus could lead to an unbalanced muscle strain which consecutively could result in back pain, shoulder pain, head aches etc. Accordingly, the user experience could be influenced negatively a lot over a longer-term, consciously or unconsciously. So, while presenting this discussion without supporting data, the logic coherence of the argumentation still provides valid reasons to consider muscle tension and physiology more into the design process of interactive technology, especially in the choice of the interaction type.

10.4. Ethical and Social Consequences

The thesis dealt very little with ethical or social consequences of the findings as the context in which it is embedded does not allow much insights in this regard, neither was it the focus of this thesis. Nonetheless, some smaller claims in the context of equestrian vaulting can be made towards these consequences.

Social consequences of the introduced methods and materials show mainly in the successful implementation of the thesis that one, very particular, nonetheless fairly often re-appearing communication issue could be softened by the integration of e.g. a further developed version of the prototype.

Ethical consequences can be considered under two perspectives. First, in equestrian vaulting, the horse is very essential, so including the animal in the research and testing is unavoidable. On the other hand, a horse cannot be included in the established methods as a human for which alterations or the invention of new methods has to be conducted. Secondly, referring back to the previous section about the effect of neuromuscular biofeedback on interaction design, the thesis revealed through its connection to human physiology, how important the long-term effect of haptic and physical interactions are to be considered in the design process. Hence, an ethical appeal is made to interaction designers to accommodate human physiology and the effect of the various interaction types more in the design process.

While discussing a lot the advantages and disadvantages of this thesis, not much has been discussed about its potential to be continued. Accordingly, the last discussion section present a short outlook of potential future work.

10.5. Future Work

An important contribution of such a thesis is its meaning for potential future work. The questions arise about what could be further done with the presented results and why should the work be continued? This final chapter provides perspectives on how to use this thesis and the impact it contributes beyond the represented scope of this research.
As mentioned at the beginning of the thesis, research about the potential use of interactive technology in instructed physical training is currently still underexplored and under-researched. Accordingly, the presented results can be considered to enhance the understanding about how various movements as well as situations in a physical training are related to body awareness. Further, it contributes with insights about how to trigger changes in a movement to influence body awareness or the other way around.

Additionally, an important aspect of all body-stated solutions was their supportive characteristic that would influence the training process and results, but which would enable users to keep the core characteristics of equestrian vaulting. As such, the presented insights and approach should further serve as inspiration for those interested in integrating supportive technology in a physical sport or training context. Thereby, several new design opportunities were presented that could not be further developed within the thesis scope, such as the outstanding exploration of skin stretch through interactive technology and its effect on body awareness or of the limitation of the space for movement.

Further, the role of neuromuscular biofeedback on embodied interaction design has not been discussed in research, only the more general context of biofeedback. Hence, the discussion in this thesis introduces neuromuscular biofeedback in such a context which triggers the need for further research about the explicit role of it in the design process of interactive technology. Through the direct influence of muscle tension on body awareness, it further influences the user experience during an interaction process. Hence, it is very important to conduct more research in the area of interoception and proprioception in relation to user experience design.

Therefore, researchers should make use of collaboration across different areas of expertise, such as engineering (software and hardware) as well as physiology. Especially in regard to designing a reliable and robust device to discover further insights, expert knowledge from various areas is highly recommended.
11. Conclusions

Overall, the thesis contributes by identifying various aspects of body awareness that can be supported through interactive technology in a physical training. Further, the thesis explored multiple potential design solutions through a user-centred approach. One derived design idea, about influencing body awareness through the interaction with neuromuscular biofeedback, was developed further to a physical prototype level. Thereby, the thesis concludes with design implications that should be considered in the design process of tools for the training of the related and presented body awareness types. By referring the results of the prototype testing to a more abstract level, the thesis points out why the consideration of muscle tension in a haptic interaction is important and should further be considered in the design process of haptic interactions more in general.

The applied RtD approach combined with embodied interaction methods, provided a very stringent argumentation structure for or against the various research and design decisions made in this thesis as well as its results. Due to the thesis explorative approach while narrowing the focus to influencing body awareness through interactive technology in a physical training context, a huge variety of insights and observation was made which are, however, only partly represented in the thesis. For example, conducted the author a bodystorming workshop which included the horse as essential partner in equestrian vaulting. However, derived insights and experiences towards that context are only mentioned briefly. Instead, various types of body awareness were identified including their meaning for the potential application of interactive technology and the design process. Additionally, the following design implications for interactive technology in a physical training context could be derived from the conducted research: emphasize body parts and positions, guide movements through the restriction of surrounding space, facilitate the synchronization and harmonization with other external influences, re-direct the conscious perception, serve as communication tool of biofeedback, enable joined attention of coach and vaulter.

Lastly, by looking more in-depth into the effect of neuromuscular biofeedback provided through interactive technology on a person’s body awareness, the thesis concludes with the effect of the repetitively applied muscle tension of an haptic interaction on the user’s physiology and health that could affect essentially the user experience, also over a long-term. Furthermore, neuromuscular biofeedback provides an interaction possibility to extend a user’s body awareness by revealing and connecting muscles in body parts that a user is not able to consciously trigger or control. In the context of the physical training of equestrian vaulting, the conscious relation of controlled muscle contraction and triggered output provided through the supporting interactive technology might be difficult to be included in the normal course of movement of a vaulting exercise, as it requires a lot of directed attention. However, it could be applied as addition to the current physical training of equestrian vaulting.

In sum, the thesis provides various insights and potential interaction design areas for influencing body awareness in the physical training context through interactive technology.
12. References


Reiterliche, F. (Deutsche (2013) *Aufgabenheft Voltigieren (Nationale Aufgaben)*. Germany.


13. Appendices

13.1. Epochés

13.1.1. At the Uppsala Vaulting Association

The Uppsala Vaulting Association is one of the most successful in Sweden participating in international competitions like CHIO at Aachen, Germany etc. (Kull Sui and De Bruin Ned, 2014), competing against the world class of vaulting. The club has in total five groups of which two are competing in the highest competition level. Each of the two groups in the highest competition level trains in parallel twice a week on and with horses. One group represents the club in senior competition level, the other on junior level.

The groups training during the observation were the two groups competing on the highest level. Each participant gave her consent to be recorded. As the former sentence indicates, both, coaches and participants, were female only. Participants age ranged from 7 to 28 years old and were in total 11 persons, 5 in the junior group (one person missing on that day) and 6 in the senior group. The three coaches had at least 5 years experiences in teaching vaulting. At all times, at least two coaches were actively involved in the training session.

As with that number of people moving around in a 20m x 40m indoor riding area it was impossible to focus on everyone and everywhere at the same time, the observations are neither complete, nor timely coherent. In the following the observations are described in four categories, external conditions, social interaction between participants as well as between participants and coaches, physical activities and the role of the horse.

Space conditions and training artefacts

By the time of the field study, it was winter season in Sweden and even though the training took place in an indoor riding area, the temperatures were about -4°C (according to phone indication). The riding area had a high ceiling, sandy ground, and was framed from wooden ties. Two loudspeakers were placed at about 3m height of the entrance side. Music was played during the whole time of the training. One of the participants regulated the song selection by phone using spotify. The participant changed the music about 8 times during the training. Bags, jackets and other belongings of the participants were put along the wall at the entrance side. Several times during the training, participant would go to their belongings and take either a layer of cloth of or on. Further in the hall were two training horses made of wood, in the following referred to as the barrel horse, standing in the left and right corner of the entrance side as well as three mats of which two were thicker air mattresses and one was a yoga mat. During the training, one participant introduced another object in from of a stepstool as part of exercise unit.

Social interaction

It showed that there were four different types of social interaction from a participant perspective. First, the interaction within the group during which there was a lot of giggling and dancing to the music involved. However, there was a clear difference between senior and junior group. While doing the warm-up together, during the main training, each group stayed mostly within their own group. Secondly, participants spent often time together with one other person only when doing exercise without the horse on the mats or the barrel horse. One person was executing the movement or exercise,
whereas the other would watch and correct noticeable mistakes. It included turn-taking in most cases, so that each participant would be in the role of a coach to a certain extent, and in the role of a student doing the movement. Also hereby, there was laughter, joking and hugging involved, especially at times, where a participant tried out a new movement that ended up looking rather inelegant and bizarre. Thirdly, the interaction with the coaches was mostly reduced to receiving and executing instructions. Nonetheless, an observation before the start of the training session showed that there is a great trust relationship between the coaches and the participants as three of the participants were put in charge as coaches in the session before, acting completely autonomously with children and animals.

Lastly, each participant had moments of individual training times in which the focus was strongly on the exercise execution. Other participants did not interrupt the concentration, but would rather join silently next to the person doing their own exercises. Sometimes, instead of joining the individual exercises, a participant would start a conversation, leading to the other participant stopping or altering her exercise.

**Physical activities**

Part of each training session with the horses is to clean the horses as well as the boxes they are standing in. In that sense, the physical activity begins already before the actual session. In discussion with one of the coaches, a training session is split into two activity levels, beginning with the warm-up followed by the training on the horse. For the warm-up, both groups put on warning vests and run outside along a street for about 1km. Back in the riding area, the participants started to stretch as well as doing push-ups with moving legs. During this time, participants placed themselves on one of the mattresses, so that they formed an unsorted line. Thereby, activities were conducted mostly independently from others.

The total time of the warm-up was about 15 minutes including breaks for changing cloths. Participants changed from their warm-up routine to the main training in self-determination. The process was fluent, but obvious as participants stepped down from the mattresses to use the barrel horses, talk to each other or did exercises like handstands or wheels which require a warm-up beforehand. One group began training on the first horse, soon after. Participants jumped on the horse in gallop by themselves and started with single exercise like kneeling forward and backwards, standing forwards and backwards, flags or mills. Each exercises required a lot of body control and body tension, but also a certain flexibility to adapt to the gallop rhythm of the horse.

When standing on the horse, participants struggled with their balance, trying to regain it by waving with their arms or shifting their weight back and forth on their feet. Another exercise requiring in comparison more concentration was the mill. In that exercise, participants have to rotate 360° around their own axes in a sitting position by lifting up one leg at a time, moving it in a semicircle to an estimated 90° position from their former place to the new side. The challenge is hereby to move the leg as straight, slowly and high as possible from one side to the other while sitting straight and keeping the other leg completely calm. The coordination of the different body parts combined with physical challenge to reach the optimal form lead to highly concentrated participants.

Other exercises required similar concentration when participants did partner exercises together with one or two others. One observation was about the youngest participant of the junior group trying to get up the horse by being pulled from another participant kneeling backwards on it. A third participant attended the exercises from the ground, running next to the youngest. However, it required several
attempts before a successful execution. The problem was based on the speed and the centrifugal force the youngest had to cope with while coordinating the communication with the one on top of the horse.

While participants trained individually or in smaller groups with the horse, others were standing at the entrance area, using the mattresses, the barrel horses and the stepstool for other exercises. Also thereby, participants decided self-autonomously what exercise they wanted to do for how long. Sometimes, a participant went to a board on which 4 papers with exercise instructions were pinned, to get further ideas for the next exercise. A group exercise was done by the junior team who practiced the greeting process at a competition in which the group runs synchronously in a line, standing behind each other to the middle of the circle, facing the table of judges, greets them and runs out to position themselves around the circle. Music played a big part in this exercise as it gave the rhythm to set the feet. Nonetheless, participants struggled with synchronizing their steps.

Another noteworthy detail was that one participant put on a belt at the end of the training session. It was used to provide a better grip for another participant who was supposed to back her up while she practiced with the youngest a more dangerous figure on the galloping horse.

Overall, participants trained on three horses and had constantly the opportunity to exercise in various ways. However, many times, participants were also only watching the training on the horse or chatting rather than exercising.

The role of the horse

The horse is essential for the vaulters and the coaches. So, it showed during the training session as well as before and after. Throughout the whole time, the horses were taking care of by either participants or coaches, warmed-up and stretched. Hence, it has an obvious and characterizing role in the social interaction. However, it was not as equally important to the majority of participants as other participants with whom they laughed, danced and trained. Instead, especially the younger participants saw it more as part of a routine and assisting tool. The impression changed with the older participants and coaches who treated it rather as a partner whom one has to take care of, but who also contributes essentially to the overall experience.

Besides the horse’s role in the social interaction, it highly influences the training as well as exercise executions. As mentioned in the physical activity section, exercises were significantly more complicated and challenging when conducted on the horse back. The additional challenges are based on the centrifugal force which cannot be replicated without a horse at the current status, the speed in the forward direction as well as the up, down as well as sideward movements. One aspect should not be forgot in the whole research, even though vaulting horses are in most cases more relaxed and more stress resistant to horses deployed in other areas, they are still natural flight animals (Neumann-Cosel, 2017). Hence, it can happen that a horse gets scared of something, we humans do not even perceive and for which it changes its movement behaviour radically. Further, also without a triggered flight reflex, it is always possible that irregularities or similar aspects get the horse out of step, influencing immensely the experience and control of the participant on the back. However, this could not be observed during the observation, but was only mentioned by the coaches.

13.1.2. At the Hirschhof Vaulting Association

The second epoché was conducted at the Hirschhof Vaulting Association in Germany. Germany is together with Switzerland and US the leading nation in regard to performances at international
vaulting competitions for several decades (FEI, no date). The Hirschhof Vaulting Association was contacted for this epoché as vaulters from various age groups, genders and skill levels train under the instruction of a main coach who is certified with the highest instructor level possible and who is additionally known for her workshops about body posture correction with so called equi-eggs. Offering a broad spectrum in regard to active vaulters as well as used physical artefacts and training methods in comparison, this association provided good conditions to conduct further the bodystorming workshops.

At the Hirschhof vaulting association, the visited training session lasted 2.5 hours in which different groups and skill levels were represented. The mix of participants and skill levels was due to conducting the epoché during a holiday season, in which training sessions are sometimes merged together. Each group had a separate session with the coach at the barrel horse while others interacted and exercised with further training artefacts which are introduced at the physical artefact section below. Overall, the training session took place without horse to mainly concentrate on vaulters performances and fitness levels. Additionally, one of the groups needed to create a new freestyle for upcoming competitions which is done on the barrel horse first, before trying the new composition out on the real horse. Besides this one group competing in walk/canter competitions, one group participated competing in walk/walk competitions as well as two adult vaulters from a non-competing group and two adult vaulters from a group participating in competitive sports. Accordingly, the age of participants ranged from 6 years to 63 years old. However, the majority of participants was between 6 years to 13 years old as both adult vaulting groups were only represented by two actives each. The coach and one assistant run the session together (here further summarized to two coaches). While one coach corrected the exercises with the youngest group on the barrel horse, the other discussed with the walk/canter group the session’s goal which was creating the new freestyle. Adult vaulters joined the session later in the process, warming-up in individual responsibility per group.

**Space conditions**

The training session took place in the indoor riding hall at the association’s riding stable. The hall was about 20x40m² large and included at one short side a stand, separated from the training space by a side fence. On the stand was space reserved to watch the training sessions, were mostly parents were sitting and chatting during the epoché. A, from the stand separated space at the continuing from that short side served as storing area for training artefacts. In the training area of the riding hall, artefacts were mostly placed close to the stand, so that the coach could also give instructions from there as seen in the picture below.
While the stand was made out of wood and equipped with blankets for the audience, the ground in the hall was made of shredded carpets which gave a slight bounce effect when walking, or in general moving, on it. Further, even though the training took place in an indoor riding hall, the temperature was similar to outdoor temperatures, varying according to season. According to coaches, it can get very cold in winter in general, which would influence the vaulters’ and horses’ performances negatively, while in summer, the higher temperatures could cause the raising of dust with every move on the shredded carpet. So, the space properties like temperature and ground conditions show potential in influencing performances in equestrian vaulting. Colder temperatures cause a higher risk for injuries, whereas the dust in summer leads to a lack of fresh air provision, especially for exercises done in lying positions.

**Training artefacts**

During the training, several artefacts were used for different training purposes at different point of times. In a chronological order, vaulters used either camping mats or airtrack mats for the stretching after the warm-up as well as later again during the instructed strength exercises. For the main part of the training, two barrel horses were used. The bigger barrel horse includes a motor to simulate the canter movement of a real horse. Depending on the exercise and the vaulter, the canter simulation was switched on or off. Additionally to one of the airtrack mats being placed between both barrel horses, another gym mat was placed at the other side of the bigger barrel horse.

In the course of the training session, the free part of the indoor riding hall was equipped with three airhorses, another airtrack mat as well as a sub-construction for one of the airhorses. Especially vaulters from the walk/walk group interacted very actively and for a longer period of time with the three airhorses, sitting or lying vertically on them while either pushing each other playfully or while trying to synchronize movements.

At a later time, when the groups were supposed to do strength exercises together in a circle, camping mats were used as pads as shown in the picture below.
Social interactions

There was a constant social interaction between participants during the whole session. Vaulters interacted more within their group than in between, but there was barely a situation in which a vaulter was training by her-/himself. Furthermore, interactions developed between groups in situation between all age groups where exercises were instructed to be done together (see picture above). In most of these situations, the adult vaulters participating in competitions supported the younger and the older ones in exercise executions and gave ideas for further training possibilities. Thereby, it showed evidently the difference in the level of experience and fitness, as all other groups but those two adults from the canter competing group were instructed several times to exercise together, while these two trained on the barrel horse under the supervision of the coach. This reveals also that for (instructed) physical activity, age is less important than fitness and performance level of a vaulter in regard to the level of difficulty of an exercise. The group dynamics in interacting with the artefacts differed a lot, as well. While the members of the walk/walk group used the training artefacts and the hall rather in an explorative, playful manner in the time the coaches were focusing on the other groups, the walk/canter group partly discussed within the group the next steps and reviewed each other in the execution and were hence, more strategic and controlled in their approach. Both adult group members kept to repeating known exercises, either in individual training or in cooperation, also correcting each other.

The variety of groups led to the observation that, at least during group training, the majority of the session is up to the vaulter to exercise in individual responsibility, by her-/himself or together with others. Coaches gave instructions as well as correction now and then to some of the groups or individuals, however, their main focus was on the persons who practiced on the barrel horses. Accordingly, the dynamic and the training effect of a session depends highly on each vaulter’s individual’s attempt to challenge her-/himself. This individual responsibility lead to artefacts not being used until the coaches gave instructions respectively. However, instructions were always followed without questioning which showed the coaches authority, but also the trust relationship between vaulters and the coaches. Questions were only raised about how to execute a certain instruction, but never the reason for it. However, according to the coaches, this differs especially in regard to age groups. Adult vaulters are more likely to ask for the reasoning of a certain activity while younger ones barely seem to think about it.

Some of the parents sitting at the stand, joined the session at the training area. One actively supported the session by recording the newly created freestyle of the walk/canter group on the mobile phone for review and learning purposes. The recordings were shared via the group’s whatsapp messenger group.
to make it available for everyone. Homework, or home training in individual responsibility, is the more important, the higher competing level vaulters participate. Therefore, video recordings are partly used or training schedules passed out by the coach. The parents’ presence did not disturb the training process or vaulters’ concentration. Instead, the exercise flow was sometimes interrupted by two of the three dogs that were running around freely in the riding hall. Standing in the way or begging to be petted, vaulters had to watch the dogs’ position or got distracted by their insisting attempts to receive stroke units. Yet, the interruption was welcome and laughed about. As the dogs belong to the riding stable, vaulters were used to have them around and showed rather a caring behaviour towards them.

**Physical activities**

The variety of groups caused a great variety of physical activities and of interactions with provided artefacts. Some physical activities were instructed by the coach, some were implemented based on former experience and some on exploring new movements. Intentions for doing physical activities, or vaulting in general, varied with age and group belongingness (if a group participates in competitions or not). In the individual training moments in which vaulters trained without the interaction with any other person, exercises were done with great concentration and it could be observed that the experienced vaulters reviewed their own body positions by pausing the movements in between and adapting certain positions or body postures after a short moment of reflection.

The training session included activities to practice balance, coordination, springiness, technique and strength. Peiler and Peiler (Peiler and Peiler, 2014) present in their work an overview of motor skills with essential meaning for the “optimal […] training”. Accordingly, endurance, strength, coordination, speed and flexibility build the basic and essential skill set of a trained vaulter. During the epoché, not all motor skills were trained, as, according to the coaches, each session had a different focus in which certain motor skills or a combination of them were trained. Other motor skills were supposed to be trained in individual responsibility in parallel or would be part of following training sessions. Vaulters participating in competitions would be further required to exercise at home on the remaining weekdays.

As this thesis focuses on equestrian vaulting, the part of the epoché about the physical activities further focuses on the training of the barrel horses in detail, as thereby vaulters practiced equestrian vaulting techniques under the coaches’ instructions.

On the barrel horses, static and dynamic movements as well as single and partner exercises were combined in the training. As example, vaulters had to swing from a sitting position into a “flag” position which means in a position where one leg kneels in 90° to the upper body and the other leg is extended in full length in parallel while holding on with one or both hands on to the handles of the vaulting girth.

The challenge thereby was to change quickly and fluently from one position to the other by controlling a soft landing in the kneeling position. In the next step, vaulters were supposed to swing with the extended leg in a speed and strength that the body would follow the swing movement up to a one-leg standing position, into a so called “standing scale” (“Standwaage”). It required high coordination skills as well as a good control over the vaulter’s body, to land softly on the barrel horse and to keep the elongated and tensioned body posture. Another exercise focused more on balance and exact upper
body and arm positioning. Therefore, vaulters had to stand up from a kneeling position to a standing position on the slightly soft and bouncing surface of the barrel horse.

Besides the individual exercises, freestyle choreographies were trained. Coaches explained in detail the various compositions and acted some of the movements out to give an example about the course of movement.

According to the coaches, freestyle requires a lot more attention in regard to safety. Vaulters had to communicate with each other and move from one exercises to the other dynamically. Other aspects that increased the risk to fall or to be hurt were in form of exercises in which vaulters would stand or kneel on top of each other as well as in which vaulters had to execute movements in different angles to the horseback (sideways, backwards or from the horse’s neck). Vaulting girths are generally equipped with two handles as well as two footstraps of which the later was used to stabilize the vaulter securing the second one.

Yet, during the epoché, it showed that vaulters who were responsible for the safety of the second person had to highly concentrate in giving the right impulses at the right time as well as to move the second person so that this person would not get caught on the girth, the barrel horse or anywhere else as well as enable them to land in the right position.

More advanced exercises with higher difficulty were requested by the coaches from the two adults who participate in competitions. It was apparent that coaches’ corrections were more in detail and that exercises required a greater deal of body control and strength.

### 13.2. Progress Bodystorming Workshop I

The group decided to start with a technically complex exercise, the flag, which requires a very precise body position. According to the coach (participant No.4), the flag is an exercise simple to understand as it is a static exercise where the position, once taken, has to be kept for 4 canter strikes. Nonetheless, the exercise description requires the inner arm and the outer leg to be stretched into the air, so that the sole of the foot, the ears and the back of the hand create one horizontal line. Additionally, the remaining arm and leg are supposed to be in exactly 90° to the upper body as well as shoulders and hips have to stay in a horizontal, parallel line to the horse. The challenge thereby is to know how to balance one’s weight while keeping all lines and angles in the right position. For this exercise, participants tried out the dog collar as vibrating input over the external knee as well as on the butt cheek of the same leg as well as light sensors placed on the wrist, directly behind the ear and the ankle as output for the coach.

After this discussion, three participants got a second, smaller barrel horse to brainstorm in parallel. They focused on a handstand exercises in which the participant struggled knowing in which angle the legs were to the ground and to each other. She tried to use a flexible tube filled with marbles as indicator. Therefore, the marbles were supposed to move only when she had reached the correct position, but not before.
In the meantime, the other participant discussed the challenge of finding the right rhythm as well the correct position for the upper body in a standing exercise. According to all participants, a further issue of many is to keep one’s own body weight equally distributed on both feet. A suggestion was made in gluing duct tape on the skin from lower rib cage down to the belly button. Another suggestion was to have an early audio output that would indicate the vaulter’s wrong body position. Overall, they agreed in having some kind of solution which would increase the vaulter’s attention towards the feed. However, participants could not decide on a good solution.

The first part of a flank (Reiterliche, 2013), an exercise in which the vaulter swings from a sitting- into a handstand position caused various difficulties. Participant number 1, had problems of lacking strength in the arms to push herself up to the handstand position as well as lacking perception of her focal point in the sitting position. She finally used a sand cushion to sit on, to change the perception towards her sitting position. The third participant faced the issue of keeping the whole body in the right and continuous tension. Every time her legs swung back, her upper body would move to quickly downwards, so that there the body would not stay in one continuous line. In an attempt to prevent this, a softball was put between her upper body and the vaulting girth. Lastly, participant number 5 struggled with using the momentum provided by the barrel horse’s movements (which was switched on at that time) to his advantage. However, no effective solution was found during the workshop for this issue.

Towards the end, participant 1 did her complete freestyle choreography with attached light sensors on hands, hip, and ankles. Thereby, the goal was to observe if the light sensors would have an effect on the artistic expression of the vaulter which it had only on the audience, but not on the vaulter herself.

Participants also tried to find out if vibration was useful to keep the back straight during a jump. So, every time a jump was conducted and the back was moving into the wrong position, a vibration was triggered.

At the end of the workshop, there was a short round of last contributions in which one participant mentioned that he thinks thin sensors integrated in a gluing stripe could work best considering that in vaulting everything needs to fit skin-tight around the body. Another participant referred back to the freestyle choreography saying that it looked nice, but she would doubt that participant 1 received the same beautiful image the same as she did.

13.3. Equipment Bodystorming Workshop I

<table>
<thead>
<tr>
<th>Goal</th>
<th>Identifying potential problems by mainly focusing on a vaulter’s perspective and individual training on the barrel horse</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration</td>
<td>2h, 2p.m.-4p.m.</td>
</tr>
<tr>
<td>Location</td>
<td>Indoor riding hall</td>
</tr>
<tr>
<td>Equipment</td>
<td>Barrel horse with motor,</td>
</tr>
<tr>
<td></td>
<td>Barrel horse without motor,</td>
</tr>
<tr>
<td></td>
<td>Vaulting girth,</td>
</tr>
<tr>
<td></td>
<td>Sand cushion,</td>
</tr>
<tr>
<td></td>
<td>LED lamps in different colors,</td>
</tr>
<tr>
<td></td>
<td>Push buttons, with yes/no sound</td>
</tr>
<tr>
<td></td>
<td>Vibrating dog collar,</td>
</tr>
</tbody>
</table>
13.4. Progress Bodystorming Workshop II

Including the living horse in the bodystorming session required some additional preparation in regard to cleaning the horse and warming it up. Hence, the workshop began with a warm-up for the horse as well as for the participants to prevent any injuries. The warm-up was done by the participants by conducting their normal training routine.

In equestrian vaulting, the horse is kept over a lunge (a long rope) on a circle. In the training, exercises on both movement directions, clockwise and counter-clockwise, are practiced. However, as in competitions, the formalities define the movement directions of the horse to be counter clockwise, during the bodystorming workshop participants concentrated on that one direction.

Additionally, the author decided to follow-up on last workshop’s exercises and used equipment at the beginning, so that the re-entry to such a bodystorming workshop would be facilitated for participants. Therefore, lights were attached to one of the participants on six points of the body, ankles, wrists and above the ears as in the first workshop, while the coach controlled the horse on the lunge. First the participant performed a flag in walk, then in canter. Afterwards, the horse was stopped to discuss the experience of the performance for all participants, from the one participant on the horse, from the ones observing from the middle of the circle and from the participant who positioned herself outside the circle. The light display was adapted on the participant by adding the glowing sticks along the length of the left leg as well as red-coloured tape at the inner side of each leg and reflectors around the ankles. Each attached item had the purpose to create a pop-out effect by either emphasizing angle positions or straight lines in the body posture. Instead of repeating the flag exercise only, the participants decided to do the whole compulsory, so that they could get a more general impression of effect that the attached lights and reflectors would have. The circus pedagogic positioned herself at the outside the circle again, to observe how much she would see from that perspective and what information would be conveyed through it. However, as the glowing sticks were attached on only one side of the body, the effect had little effect from the outside perspective.

The coloured tape hang slightly loose on the participant body in a normal standing position, so that it created a slight resistance as soon as the leg was fully stretched. After the performance, a discussion about the different types of applying such a resisting feedback began, followed by the coach’s perception of the performance. “Ich sehe nichts.” (I don’t see anything), said the coach when...
describing her general perception of the vaulter’s performance while she was interacting with the
horse. Still, she was able to see the tape as well as the lights from the corner of her eye and follow at
least a part of the performance. The participants wearing the lights, reflectors and tape agreed in
perceiving some items from a similar perspective as the coach, from the corner of her eye.

Focusing on the coach perspective, the participants were questioned about how the coach’s perspective
could be changed or enhanced, so that one could perceive more of the vaulter’s performance. A
discussion arose in which the possibility of bringing the vaulter’s movement into the coach’s angle of
vision by e.g. attaching something on the horses neck that would simulate the vaulter’s movement
synchronously. However, the coach suspected this to be rather distracting then supportive. Hence, the
group returned to bodystorm this idea further directly with the cantering horse. Therefore, the coach
who was still standing on the lunge, tried out different areas on the horse where she lied eyes on while
another participant performed the compulsory exercises. The goal was to find out the place, something
could be introduced at to facilitate the coach’s perception of the performance, before discussing
further about how the solution could look like. Approaching the topic from this perspective was also
due to the assumption by the coach, that she could not consciously perceive anything else than the
horse due to not being able to divide her attention. After the try out, a use case was introduced by the
author to trigger the discussion in a broader direction. The introduced use case dealt with the same
situation, but on different horses. Participants were asked to imagine to have another horse as training
partner instead and to share their opinion about what would change accordingly.

In the following, the bodystorming turned to the potential use of audio in-our output for the coach. Use
cases were discussed in which exercises include body movements and positions at the outside, in other
words the, for the coach, blind side. One use case, as example, focused on the jump on the horse and
to receive an audio signal for the vaulter’s right foot as feedback if it is stretched or not. Another
possibility for making the outer side of the vaulter more transparent to the coach was discussed by
transferring a correctly performed body posture or the lack of it via vibrations on the coach’s body. As
example, if the vaulter stretches her outer foot, the coach would receive a vibration input on her right
foot as well, or the other way around.

A participant mentioned that she would like to discuss another exercise with which she would have a
problem understanding the correct movement to arrive at the goal position. The exercise was a base
jump induced by a wheel movement around the grip of the vaulting girth. To understand the course of
the movement, the group changed from the living horse to the barrel horse. Hence, a short break was
taken to look after the horse and to setup everything for the second part of the workshop split into the
single movements it consists of. As neither of the participant had a full understanding of the exercise,
three points were mainly discussed, the vaulter’s body position in relation to the horse and the space,
the correct arm movement and the timing of the hip movement. The additional challenge was to
consider the influence deriving from the horse’s movement correctly. Accordingly, the participant’s
landing position on the ground was placed in parallel to the horse’s head, while the jump position to
get back up was placed in line with the vaulting girth which is attached directly behind the horse’s
shoulders. As support, lines were glued on the ground to indicated the different positions in relation to
the barrel horse. For the arm movements, two participants emphasized that the form would depend on
the vaulter’s body height in relation to the horse’s height at the withers. Instead, they introduced a
role-like movement which should be executed after the jump to get the hip up towards the horse back.
In other words, the vaulter was supposed to make a role movement vertical in the air around the grip
of the vaulting girth. During the base jump exercise discussion, the bodystorming was highly
dominated by mentally imagining the course of the movement and analysing it step by step. As the
exercise had only been seen from watching other professional vaulters in their free-style performance, the two younger participants had a harder time understanding and analysing the course of the movement. Both, the coach and the circus pedagogic, took the lead in this part of the discussion. As soon as they agreed on the course, they moved from the barrel horse to parallel bars, to make the concerned participant do a swing up forwards. The goal was to simulate the upwards body movement of the base jump by the movement of the swing up forwards, so that the participant would experience the movement and transfer it to the other exercise.

In the following, participants discussed other areas for applying the resistor feedback. As one participant mentioned to struggle with lacking awareness in her feet, she tested the tape as resistor which would indicate if her right foot was fully stretched. The tape was applied on two sides of the foot, first on the arch and then to the sole of the foot.

The effect was tested in several exercises, such as the jump on the horseback all exercises of the compulsory. Another participant copied the idea, but instead of using it on her feet, she taped one leg and used the dog collar as vibrating input on the other leg. The effect of the vibration versus the felt resistance in a stretched position was compared by the participant.

Lastly, the group focused on body awareness in the context of free-style performances. During free-style, a vaulter is judged also for the level of charismatic execution which means the level of whole embodied body expression throughout the performance, music interpretation as well as level of harmony with the horse’s movement and the own movements (Reiterliche, 2013). In other words, it is about the vaulter’s ability of artistic expression and embodiment of the freestyle’s performance. In the first bodystorming workshop, this topic was briefly addressed by trying out the effect of the LED lights which had been attached on one of the participants bodies for performing the free-style. However, besides making it look nicer, there was no obvious effect. Nonetheless, one participant pointed out that it would be necessary to let the person wearing the LEDs see herself at least in a mirror or on video once, to be aware of the changed look and to be able to embody it. Hence, the same participant performed her free-style again with the LEDs and additional glowing sticks. Another participant recorded the performance on video, so that the performance could be watched afterwards. However, as light condition were too bright for the camera, the light effect could not be properly seen on the recording. Instead, the circus pedagogic asked if she may do an experiment and tell the performing participant something in secret. The remaining participants were to observe the performance after their secret conversation and tell if they saw any difference. Afterwards, the secret was revealed that the performing participant was supposed to imagine as if the lights were in total darkness and supposed to do big, fluent and round movements. Hence, a mental image was created in the participant’s mind which she kept vivid during the performance.

**13.5. Equipment Bodystorming Workshop II**

<table>
<thead>
<tr>
<th>Goal</th>
<th>Identifying further body awareness issues in the training of equestrian vaulting by concentrating on the coach’s perspective and by including a real horse</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration</td>
<td>2h, 2p.m.-4p.m.</td>
</tr>
<tr>
<td>Location</td>
<td>Indoor riding hall</td>
</tr>
<tr>
<td>Equipment</td>
<td>Horse and vaulting equipment for the horse, Barrel horse with motor,</td>
</tr>
<tr>
<td>Barrel horse without motor,</td>
<td></td>
</tr>
<tr>
<td>Vaulting girth,</td>
<td></td>
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<tr>
<td>Air ballons</td>
<td></td>
</tr>
<tr>
<td>Water ballons</td>
<td></td>
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<tr>
<td>Neck pillow,</td>
<td></td>
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<tr>
<td>Plastic box,</td>
<td></td>
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<tr>
<td>Sand cushion,</td>
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<tr>
<td>LED lamps in different colors,</td>
<td></td>
</tr>
<tr>
<td>Push buttons, with yes/no sound</td>
<td></td>
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<tr>
<td>Vibrating dog collar,</td>
<td></td>
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<tr>
<td>Colorful tape,</td>
<td></td>
</tr>
<tr>
<td>Isolation material,</td>
<td></td>
</tr>
<tr>
<td>Glow sticks,</td>
<td></td>
</tr>
<tr>
<td>Tube black,</td>
<td></td>
</tr>
<tr>
<td>Tube transparent partly filled with coffee,</td>
<td></td>
</tr>
<tr>
<td>Marbles,</td>
<td></td>
</tr>
<tr>
<td>Bells,</td>
<td></td>
</tr>
<tr>
<td>Gums,</td>
<td></td>
</tr>
<tr>
<td>Paper,</td>
<td></td>
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<tr>
<td>Pen,</td>
<td></td>
</tr>
<tr>
<td>String,</td>
<td></td>
</tr>
<tr>
<td>Magnetic tape,</td>
<td></td>
</tr>
<tr>
<td>Reflectors,</td>
<td></td>
</tr>
<tr>
<td>Small skateboard,</td>
<td></td>
</tr>
<tr>
<td>Softballs in various sizes</td>
<td></td>
</tr>
</tbody>
</table>

### 13.6. Progress Prototype testing II

As none of the participants had any experience with the sensor, the first muscle it was attached to was the Flexor carpi radialis which allows a quick appendix for introduction and presentation purposes. Attaching the sensor on the cleaned skin according to (Bianchini and Dimanico, 2010), the participants received time to familiarize with the technology and the data output visualized on the screen and on the LED stripe. It was, on the one hand, necessary to give the participant time to explore and experience, but also, on the other hand it provided the required time to adapt the sensor gain to participant’s conditions. As mentioned in the chapter Electromyography, sEMGs are easily influenced by various causes. Among other aspect, each user has an individual basic muscle tension and physiological condition to which the hardware needs to be adapted to.

After the familiarization, the prototype was attached to the Rectus abdominis and measurements were compared between inactively lying on the back and holding a plank position on the ground. Especially in the plank position, clear impulses were measured and visible. Participants were discussing their experience partly during the testing. Participant no.3 mentioned e.g. that “es ist interessant die eigene Anspannung, dich ich zwar gut fülle, aber sonst nicht ausserhalb sehen kann, mal so vor sich an den Lichtern zu sehen“ (it is interesting to actually see the tension that I feel inside my body, outside my body by observing the lights”).
In the next step, participants moved to the barrel horse and tried different exercises while the LED strip was positioned on the barrel horse’s neck. The position was selected as it was still in the participant’s sight and would allow her to trace movements in relation to her muscle tension.

However, after the barrel horse simulated the canter movement once, the LED stripe connection did not stay stable enough for real-time indications, but was always a second delayed. Causing rather irritation than support for both participants, the researcher decided to take the LED stripe out of the testing and replace it with the graphical representation on the laptop screen. Additionally to the LED stripe, the MyoWare sensor began to measure invalid data which was controlled by the participant’s statement of when she was contracting her muscle and when she was not, as well as the coach’s confirmation which based on her expertise on looking at the participant’s concerned muscle area and seeing the difference in body posture if a muscle was contracted or not. As the debugging attempt of re-cleaning the skin, using other electrodes than the ones used or by re-attaching the sensor slightly differently did not show better results, the testing was interrupted at that point and moved forward to the final discussion. Therefore, participants were first asked in a semi-structured interview format for their individual opinion while standing in distance to not influence the other’s opinion. Afterwards a discussion between both participants was moderated by guiding through the same questions together again.

13.7. **Progress Expert Interview**

At the beginning, the expert attached the sensor first at the Flexor carpi radialis as it being, in comparison, a muscle directly under the skin and surrounded by less other interfering muscles. Through the measured clear output, the expert was able to interact with it and to manipulate her own level of muscle tension. Further, the interaction with the prototype supported the creation of a common understanding of the targeted prototype functionality and its aimed for effect on body awareness in the training of equestrian vaulting.

While interviewing the expert, different vaulting exercises were discussed and movements simulated with the own body to identify the most significant muscles that are located most directly under the skin. Dynamic vaulting exercises, such as the flank, were mentioned as rather difficult in this context, for which the flag and the basic seating position were put into focus of the discussion. For finding the right muscle for the seating position, the sEMG was attached to the expert’s back, at the Longissimus. It was observed if different seating positions and hip positions would influence the Longissimus’ muscle intensity. For the flag exercise, the expert suggested the Gluteus maximus which is the biggest muscle in the body and essential for the exercise.
After the testing, the interview closed with final questions about the kind of feedback the expert would suggest, especially in regard to comparing visual versus haptic feedback. The results of the interview were analyzed with a qualitative analysis by reviewing notes and recorded statements as well as cluster them according to importance and relevance for the further progress according to the expert’s opinion. However, as there was only one expert interview conducted and hence, limited amount of data, no patterns or grouping could be implemented, as in the thematic analysis. Nonetheless, through the combination of semi-structured interview, enacting exercises and prototype try out, many insights as well as a, with the expert confirmed test plan could be created.

### 13.8. Prototype testing 3: muscle tension transparency

Goal: Making muscle tension transparent outside the body and observing how this potentially changes body awareness (on a small scope)

Guiding questions:
- How does the sitting position on barrel/ horse influence the muscle tension in comparison to a basic sitting position (example on 1 muscle)
- How does the visibility of the differences of the point above influence the athlete’s self-perception and body awareness
- How does the form of the output changes the body awareness
- How does it change the joint attention between vaulter and coach

Location: VRV Hirschhof riding hall (maybe on 1. Sitting position on the ground outside as floor there is consisting of massive ground)
Participants: 1 participant for measurements + 2 participants for discussion

<table>
<thead>
<tr>
<th>No.</th>
<th>Case</th>
<th>Aim</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Comparison of muscle tension in the lower back area <em>(muscle name)</em> in upright sitting position on a chair and on the barrel horse</td>
<td>Aiming towards revealing potential differences in the basic muscle tension when being on the floor or on the barrel horse (--&gt; effect of such a sport on muscle tension)</td>
</tr>
<tr>
<td>2.</td>
<td>Comparison of visual output and haptic output while participants do an exercise of e.g. 5x increasing the muscle tension up to a certain range; mix into other cases (always: basic tension, active triggering)</td>
<td>Aiming towards revealing the different effect of each output type on the participant’s body awareness</td>
</tr>
<tr>
<td>3.</td>
<td>Measurement of basic muscle tension in upright sitting position on the horse as reference</td>
<td>Aiming towards revealing how much the tension increases by being on the horse (reference to no.1) and if measurable at all due to increased (bouncing/) dynamic ground</td>
</tr>
</tbody>
</table>

Remark: to test lower back and on gluteus maximus in flag exercise; maybe additional test could be to actively relax a muscle during an exercise to test how that affects the body awareness; think aloud method during the testing
Schedule: sequence of test cases as in table above with 1 participant, maybe 2

Follow-up group discussion including these questions:
For participants trying out the sensor:
- How did it feel to concentrate that actively on 1 muscle in particular?
- How was it to see the differences in the muscle tension on the various grounds?
- How did the different forms of feedback affect your perception and your understanding of your own muscle tension?

For participant watching (coach):
- As the coach, what was the effect on you when you saw the muscle tension on the LED?
- Especially in the context of the exercise of actively triggering the muscle, what did you perceive? And how did it change your perception by having the LED as visible output?

For both:
- How did the shared understanding of the performance change? With "shared understanding" I mean a common understanding of how the participants performed between participant and coach.
- How did it change the relationship between observer and participant?
- How could you imagine that it could even influence the relationship with the horse?
- How do you think could the exercise benefit you in future?
- How would you alter it to benefit you even more?

Limitations: no absolute values, only ranges to compare and make a statement as potential noise arising as seen in the prototype testing 1; maybe only possible to run test case 1 and 2, depending on availability of horse, testing on max. 2 muscles only due to the limited amount of capacities and time
13.9. Progress Pilot Study

While conducting the pilot study, the test between high sitting position versus both feet on the ground sitting position was the only part which could be tested due to failure of the hardware. Thereby, the sEMG was attached to the Longissimus, as discussed within the expert interview. The participant was first asked to sit straight on a bench with both feet on the ground, legs in about 90° angles to the upper body. Constant data noise which could e.g. derive from breathing, was indicated via the screen, however not on the LED. The different sensibility for fluctuation is based on the mapping of measured data to the available 60 LEDs on the stripe. In comparison, the digital graph shows an absolute value between 0-1023 to which the sensor maps the raw measured muscle tension values, whereas the conversion from the sensor to the LED maps about 17 value points from the sensor to 1 LED. Asking the participant to tilt her hips a little back and forth, value changes were followed up on the screen and via LED strip in parallel.

After five times observing the differences, the participant moved to the higher chair on which the feet float a few centimetres above the ground. Due to the movement and slightly sweat on the participant’s skin, the sEMG needed to be re-attached. To assure proper values, the participant’s skin was locally cleaned with alcohol pads before each new appendix. On the new, higher position the values increased slightly, but stayed too noisy to allow the calculation of the average increase. The increased data noise was also caused by the increased instability of the participant who moved her pelvic in small movements to balance her position quite a lot until having found a comfortable position, also because the provided chair required balancing out one’s weight on one leg only.

Even though, the participant had found her position after a short while, the data noise did not decrease anymore. Actions against the sensor’s instability like re-booting the microcontroller, like exchanging the EMG electrodes, re-cleaning the skin as well as attaching the sensor to another muscle again, did not lead to a recovery. Hence, the pilot study had to be interrupted at that point. The participant was asked, however, to stay and walk through the prepared interview questions together, as presented in the appendix, so that formulations and questions could be tested. Furthermore, the follow-up interview was conducted to gather more insights about the participant’s opinion and experience about the prototype and the testing. Thereby, the questions for the coach were also asked while requesting the participant to imagine to be in an observing position. The questions for discussion between coach and vaulter were discussed between researcher and participant instead, which, of course, means a limitation in validity. But as the participant’s statements are further only considered in the context of the individual questions, this should not influence the further outcome.

13.10. Consent Form

Consent Form

This is a consent form for your participation in the study of my master thesis about potential enhancement or improvement of physical training tools or methods in equestrian vaulting through interactive technology, conducted at Uppsala University.

With this consent form, I am asking for your permission to share potential visual or audio recordings with people who are not part of today’s study, in the ways described below. In any use of these records, your name will not be included.
The video recordings will only be used for internal reviewing. Some of the photographs or citations of
the audio records might be included in the final master thesis. The master thesis will be viewed by
other people than myself, such as my supervisor or examiner.

I have read this form and give my consent for use of the records as indicated above.

Name ________________________

Signature ___________________________  Date __________________

13.11. Prototype ideas based on literature studies and bodystorming workshops

1. Acc. to Warren et al., 2016

Review of “physical self and the objective reality of the physical self” as potentially
misaligned. → increase self awareness by revealing misalignments between personal
perception and reality; usage of pressure and vibration sensors

2. Acc. to Nunez-Pacheco & Loke, 2014

Synchronization of body movements to a sensory input to achieve a positive sensory feedback.
→ align rhythm of horse or music with vaulter’s movement/ facilitate vaulter to embody the
other input; usage of e.g. light sensors

3. Acc. to Schiphorst, 2009

Shared embodiment through “Whisper”, wearables worn by each participant which transfer
physiological output from person A to the others etc. → create shared embodiment between
vaulter and coach to receive further input and corrections + make “blind” side visible to coach


Understanding music through movement → exercise free-style performances/ artistic
expressions by learning to embody music

5. Acc. to e.g. Grewal et al., 2015

Creating VR environment to practice the vestibular system, namely balance → related to train
orientation in space, balance and weight distribution

6. Acc. to Dancey et al., 2016

Motor learning through acutely applied pain → trigger pain at body spots which move
incorrectly in the learning process; e.g. power surges triggered by another person.

7. Bodystorming Workshop

Changing light display provided to peripheral attention of coach and vaulter; color coding for
certain messages or extended to multisensory input for the vaulter, such as visuo-tactile
8. Bodystorming Workshop

Flexible neck collar that hardens and softens according to situation; aiming towards stabilizing vestibular system to keep balance and orientation easier after e.g. a jump or a role → similar use for applying it at other body parts, such as legs, knees/ joints in general

9. Bodystorming Workshop

Alignment/ body posture control incl. Audio feedback

10. Bodystorming Workshop

Make pressure distribution transparent by e.g. inducing pressure on opposite end of body part that is supposed to conduct an equal weight distribution. How should that work on a foot? → maybe split between exercise; if for standing work with head position; if for kneeling or flag exercises than exert pressure

11. Bodystorming Workshop

Shared touch: pressure sensors on e.g. the coach’s body sending signal to sensors on vaulter’s body in form of vibrations or similar. If coach touches one of the sensors on her body as form of correction feedback to the vaulter, the vaulter gets additionally to audio/verbal input the tactile feedback.

12. Bodystorming Workshop

Blind spots for vaulters in e.g. handstand positions; echo or distance sensors for measuring distance/ body parts’ positions and give sound feedback. Other way: to use tactile lines attached to e.g. leg which constrain movement range/ provide a guideline

13. Bodystorming Workshop

Attention: inability to concentrate on all incisive body parts; apply pressure sensors at these parts which are automatically triggered every 2 or 3 seconds (as an exercise is only ~4 sec long) should be flexible in attaching (could also work without computer)

14. Bodystorming Workshop

Embody canter rhythm; give additional tactile and sound rhythm which is synchronized to the horse’s canter rhythm. Position of tactile input has to be tried out
13.12. *Semi-structured Interview Prototype Iteration II*

The following questions were included:

- What is your opinion about the prototype?
- What is your opinion about the conceptual idea of the prototype?
- What is your opinion about the LED stripe in comparison to the graph on the screen?
- Where would you place the LED stripe ideally?
- What are your thoughts about the vibration feedback?
- How did the prototype support you in regard to how you understand your body?
- How could you imagine the prototype to support further in other training situations?

13.13. *Semi-structured Expert Interview Question*

The following questions were included:

- How was your experience with the prototype?
- What is your opinion about the current setup?
- By considering equestrian vaulting, which muscles would you recommend looking further into?
- How would you attach the sensor at the recommended muscles and what needs to be considered in general in the appendix process?
- How could you imagine your patients using the prototype?