Measuring Human-Animal-Interaction with Smartwatches – An Initial Experiment

Abstract The paper describes and evaluates an explorative approach to quantify the relationship between trainable animals and their owners. Data on human-animal-interaction has been collected by using Pebble smartwatches and by observing different kinds of animal training sessions. Tracking movement of horses and dogs with the Pebble Watch, the watch was able to measure data on horses, but not on dogs. Besides the breed and behavior of the animal, weather conditions and the way of attaching the Pebble influenced the measurement quality. In summary, the experiment indicates that there might be a connection between the heart rate (BPM), the average movement (VMC) and the mood data (pleasance and activation) of an animal and its owner during training sessions.

1. Introduction

In the last years, there has been a rise in the popularity of fitness trackers worldwide. Compared to 2016 with a sales revenue of about 2.49 billion U.S. dollars, it increased to around 2.51 billion U.S. dollars in 2017 and is forecasted to 3.33 billion U.S. dollars by 2022 (Statista, 2018). With their growing popularity, a plethora of self-tracking technologies has become available to consumers. The Quantified Self Labs (2011) homepage lists 505 self-tracking tools, including wearable devices, websites, and mobile applications. Those tools enable individuals to track and analyze their athletic performance and health issues (Budzinski & Schneider, 2017). Besides measuring body signals of humans, fitness trackers and smartwatches might also be used to measure those of trainable animals, like dogs and horses (US 6,311,645 B1, 2001). During a training session with an animal, e.g. a horse, the measurement of the heart rate allows the trainer to monitor basic vital values and detect signs of tiredness, sickness, and injury in real-time (Polar Electro, 2017b). Based on insights gained through tracking technologies, training sessions can be designed more efficiently. Further, they enable the trainer to better understand the animal and its reactions, which helps to avoid under- and overtraining and to realize the animal's full potential (Evans, 2000).

Hence, the question arises, whether more information can be derived by connecting the results of the animal's and owner's self-tracking tool, e.g. impacts on the well-being of both parties during and after training sessions. This paper explores the potential of self-tracking devices in measuring human-animal-interaction (HAI) by answering the following questions: First, can the Pebble Watch be used as a tracking tool for biometric signals of animals, second, what are the factors influencing the measurement quality and third, can combined tracking of animal and owner signals be used to gain insights into the connection between animal and owner?

Thereby, the focus lays on horses and dogs as trainable (e.g. US 6,311,645 B1, 2001) and highly social animals (e.g. Deine Tierwelt GmbH & Co. KG, 2015; Evans, 2000).

The paper starts with an overview of the current state of the art in HAI research and types of training with dogs and horses in section 2. In section 3, the paper examines how to measure HAI using affordable, readily available and mobile tracking technologies. Section 4 presents an overview of the methods used in this study and introduces the Pebble Watch as the primary tracking technology used in this study. Section 5 contains the findings and their discussion. The paper closes with limitations and potential avenues for future research.

2. Related work

HAI has gained a considerable amount of scholarly attention during the past years. The literature review by Beetz, Uvnäs-Mobergm K., Julius, and Kotrschal (2012) discusses 69 HAI studies and serves as the foundation for this section. In the following, we summarize some of their central findings, whereinafter basic types of training sessions of dogs and horses influencing the HAI are described:

Beetz et al. (2012) identify eight studies, which report a reduced heart rate while or after the interaction between humans and animals. K. M. Allen, Blascovich, Tomaka, and Kelsey (1991) measured the “autonomic reactivity”, including the pulse rate, skin conductance and blood pressure, of 45 adult women performing a stress task in a laboratory and two weeks later in their home while either being accompanied by a friend, their dog or being alone. The results show that the participants exhibit little or even no physiological reactivity while performing a stressful task when their dog was present and a greater reactivity when their closest friend was present (K. M. Allen et al., 1991). According to Gehrke (2010) negative emotions like “sadness, fear, anger or frustration” lead to more erratic and imbalanced heart rhythms, whereas positive emotions like “joy, appreciation and love” lead to a more ordered and balanced heart rhythm as a result of “autonomic nervous system responses”. Further, Gehrke (2010) observed that the HRV frequency dynamics of humans and horses are similar. The investigation indicates that in six of the seven human-horse-pairs, persons involved synchronized their “HRV frequency cycle” to match the one of the horse; but not vice-versa (Gehrke, 2010). According to these results, previous research indicates a relationship between the animal’s HRV frequency and those of the owner.

Four studies of the literature review report a positive influence of HAI on the (perceived) human stress level. Barker, Knisely, McCain, and Best (2005) compare the stress levels of individuals who either rest for 20 minutes or pet an animal for 5 to 20 minutes. They conclude that the reduction of stress is higher when petting a dog. According to K. Allen, Blascovich, and Mendes (2002) pets can reduce the reaction to acute stress and also decrease the perceived stress. In addition, pet owners, compared to non-owners, recover faster from elevated stress levels. The initial findings by Gehrke (2010) also suggest that when the horse is relaxed and the human feels stressed, the horse might "transfer" the calmness to the human so that the individual feels more relaxed. Before this background, the experiment conducted in this study explores the effect of HAI on the owner's self-reported stress.

Wells (2009) concludes that although the evidence for a direct causal relationship between animals and the human well-being is not yet conclusive, the literature widely supports that pets are good for human beings. Hence, the owner might experience a higher self-reported *pleasance* at the end of an HAI than before. Therefore, the HAI might impinge on the welfare of the owner. Regarding Góngora and Solano (2015), the pleasant life with α=0.81 (Cronbach's Alpha) is an adequate indicator of measuring the well-being. This present experiment will explore the possible impacts of the HAI on the *pleasance* of the owner as one indicator of well-being.

Summarizing the above, the aim of the study is to measure the animal's and human's heart rate and movement as well as the owner's activation, pleasance and his/her self-reported basic emotions (including stress) by interacting with trainable animals over the course of time. As the study focusses on HAI with dogs and horses as trainable animals that live in packs, the **diverse types of training** (non-professional) with separate aims and consequences will be considered separately.

Firstly, *groundwork* (Pferdeflüsterei, 2017b), which is the basic prerequisite of dealing with horses successfully and comprises training via a direct connection with the horse through a lunge, rope or halter without being on the saddle. Basic skills like hand changing of the horse, standing still during cleaning, giving hoofs and stopping or moving on command, are trained. *Groundwork* even starts with little feedback to the horse in the stable. Threatening gestures, e.g. laid-back ears or bare teeth show that the horse does not accept its owner vs. gestures of friendship (rumbling). Analogous, the *basic commands* are important for the human-dog relation wherefore at least the commands "sit", "down" and "wait" should be trained (Deine Tierwelt GmbH & Co. KG, 2015). Second, the *round pen* (Pferdeweb, 2017), which is a round and fenced place, where the horse is walking around its owner without a physical connection between both (e.g. neither lunge, rope or halter). The owner directs his/her animal only via body language. It is usually used for dominance practice of western horses and is only ending when the horse accepts the owner as its lead animal. By moving the head around, rearing up or rejecting, the horse is trying to test its limits. This can be compared with *dominance training* by dogs, where the dog accepts its owner as the "pack leader" (Deine Tierwelt GmbH & Co. KG, 2015). Third, *riding* (Pferdeflüsterei, 2017a) on a saddle the muscles, the sense of balance, the condition and the dexterity of the horses are trained. The focus lies on optimizing the skills by overcoming obstacles and subtle changes from gait to gait. It is important that the owner is able to parry the horse. If the horse does not accept the rider as the leading animal, the horse won't listen and can buck the rider off or refuse barriers. *Groundwork* or *round pen* sessions are building the foundation for *riding*. A typical *riding* session in this experiment takes about one hour and includes warm up and cool down phases. When the horse is snorting in relaxations phases, it can be seen as a sign of satisfaction, whereas squeaking or a re-deemed tail indicates fear or pain (exercise should be stopped). Taking a dog for a *walk* could be compared to riding, as the basic commands can be seen as a prerequisite of a stress-less walk (Deine Tierwelt GmbH & Co. KG, 2015).

3. Method

For our research, we used the Pebble Watch 2 that was designed to measure e.g. the human heart rate (BPM) and the "vector magnitude counts" (VMC) to improve the owner's performance and to achieve fitness goals (Pebble; Pebble, 2016). To measure the heart rate, the watch uses "optical heart rate monitors" by sending hundreds of flashes each second (Pebble Support, 2016). The heart rate monitor technology measures the beats-per-minute on a periodic basis, whereby the frequency of measurement "varies and depends on the level and activity of the user" (Pebble). VMC is "a measure of the total amount of movement seen by the watch" on the basis of an accelerometer and GPS (Pebble, 2016). As Pebble itself claims, the intention of the data and provided information is "a close estimation" of the activity and the metrics, however, it might be possible that it is not completely accurate (Pebble, 2016). Therefore, the Pebble Watch is no medical device and the data should not be used for medical purposes (Pebble, 2016). To attach the watch to the animal, lashing straps were used as it is possible to adjust the size of the strap according to the thighbone/neck circumference of the animal (close to the main artery) and as it is enough flexible (causes no injuries). Thereby the heart rate (BPM) and movement (VMC) of the animal was measured and proofed due to the observation (e.g. higher BPM and VMS while trotting outside compared to grooming the horses at one place).

In addition, the Happimeter-extension (Budner, Eirich, & Gloor) was used to collect data on pleasance and activation of the owner. These two variables are based on the Circumplex Model of affect (Posner, Russell, & Peterson, 2005) and are built on a nine-outcome grid. Thereby the variables are defined as linear, with a scale from 1-3, representing the dimensions of high *pleasance/activation*, medium *pleasance/activation* and low *pleasance/activation* (Budner et al.). Data is gathered by either entering the *pleasance* and *activation* manually through self-reporting or a learning algorithm that simultaneously records the dimensions of *pleasance* and *activation* based on the prediction model including several variables (e.g. temperature, windiness, air pressure, GPS, VMC, Activity, and Heart Rate) (Budner et al.). As an extension, additional statements were developed to gather data on basic emotions to get a deeper understanding in if and how emotions may affect the HAI. The six basic emotions *happiness, stress, uncertainty, superiority, dejection,* and *excitement* are based on Arnold (1960), Darwin (1872), Dornes (1995), Ekman (1999), Johnson-Laird and Oatley (1987) and Plutchik (1962). Superiority is understood as dominant behavior and respect. The basic emotions were inquired by asking the owner to state how much he/she agrees with the statements “I feel stressed”, “I feel happy”, “I feel uncertain”, “I feel dominant”, “I feel depressed” and “I feel excited” (0 = I do not agree, 1 = neutral, 2 = I do agree). They were entered manually by the owner via the Pebble Watch before and after every HAI training.

The sample of this explorative study included two dogs and two horses (Animal = A) and three owners (O) who are already know each other well (n=4) Data was collected between 28/10/2017 and 30/12/2017 via the Pebble Watch as well as by direct observations and videos in order to evaluate the behavior and success of the different kinds of training sessions described in section 2. Gathered and adjusted data was analyzed by doing a descriptive statistical analysis (e.g. mean values) as well as a qualitative evaluation based on the theoretical settings. Therefore, quantitative data was transferred into MS Excel and SPSS in different diagrams aggregated on basis of the mean values or variances and qualitative results were mainly analyzed by first documenting all training sessions and observations and second by drawing an error-matrix, in which criteria of measurement quality were documented.

4. Results and Discussion

In this section, there will be given an overview of factors that are influencing the measurement quality first. Afterward, explorative results about the owner, the animal and the connection of both parties are shown. Finally, challenges and opportunities of this approach are discussed.

4.1 Criteria influencing measurement quality

The following will give an insight into what worked well or not during the experiment. First, dealing with the **handling of animals** the best attachment area regarding dogs would have been the thighbone, however, the dogs in this study did not accept this way of attachment. As most dogs living together with humans are familiar with collars, this seemed to be the most convenient alternative Nevertheless, the data collection quality was bad as the output only showed punctual VMC and no BPM data. This might be due to the thick fur (both dogs had long hair) and the wrinkles. With horses, the most data were received. According to Pebble Support (2016), even dark tattoos may reduce the accuracy and ability of the optical monitor to read the beat of the heart. The experiment showed that the quality of measurement was even higher when the skin of the horse was wet as is the case on a rainy day. Hence, the following findings of this exploratory study on HAI relate to two horses and their two owners (n=4).

With regards to **technical issues**, one of the biggest problems was to find suitable smartphones that were able to find the Pebble Watch. Further, there were several problems related to the mobile internet access. Due to the setting of the experiment that took place outside most of the time, the WLAN connection was no option in most cases. Surprisingly, a better data collection was achieved during outside *riding* sessions compared to working in the *round pen* or at the same location. In addition, out of 44 times of diverse training on different days, there was no collection of mood data in 38 times and no sensor data in 26 times. Most of the time, it was due to problems with the connection that became visible through frozen data (no data movement at all) or non-existent records in comparison to the observation template.

The influencing factors on the measurement quality related to the parties involved in the HAI can be summarized as follows, suggesting improvements for better data collection quality in the future:

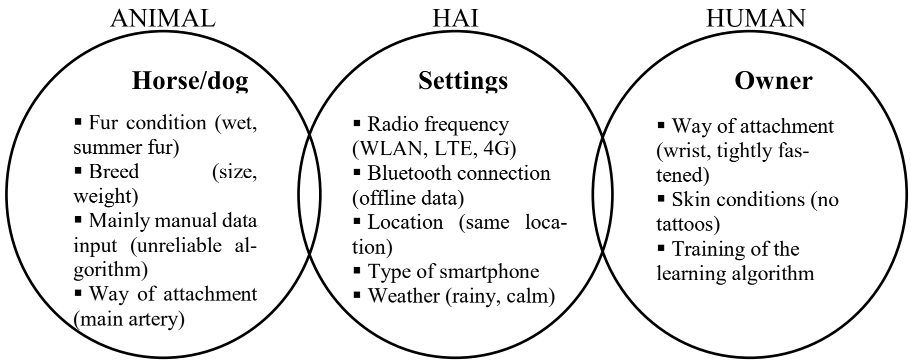


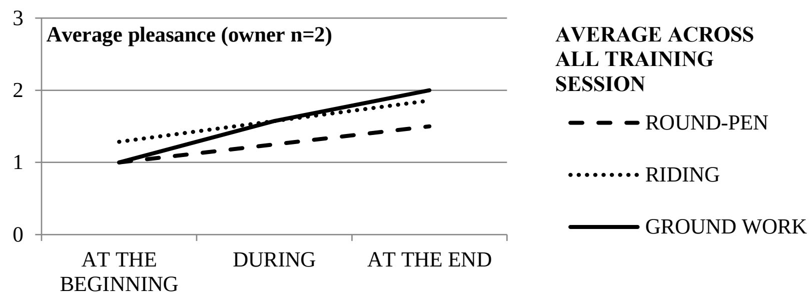
Fig. 1 Influencing factors on the measurement quality

4.2 Implications from the data

In this section, there will be first a focus on the owner's data outputs, before looking at those of the animals (horses) and the interaction of both at the end. Data is based on the exported mood and sensor data from the Pebble Watch in Excel. It is adjusted for incorrect data (due to inappropriate time reporting in comparison to the documented time slots of the trainings), frozen data (as an identical value over a longer time, which did not coincide with the observation by the video documentation) as well as unrealistic data (e.g. heart rate of "190000" which suggests errors in the data collection).

Owner: Analyzing, if the owner reports a lower stress-level at the end of a HAI compared to the beginning, the experiment shows that the stress level of the owner remains steady during the *round pen* session, as the tension whether the animal will accept the owner as the leader continues till the end. Furthermore, as the time of the day for the training sessions, especially for *groundwork*, usually was after work, the stress-level of the owner might have been higher due to work-related stress. The increasing *happiness* and the decreasing *uncertainty* and *dejection* might be other influences on this behavior. As the owner has to enforce his or her will, the dominance level remains stable for all types of training. This is an indicator of a successful HAI and a further reason for the declining stress.

Regarding the self-reported *pleasance* of the owner, especially *groundwork* resulted in the highest self-reported *pleasance* at the end of the HAI (see **Fig. 2**). One possible reason might be the relaxed atmosphere during *groundwork*, which can be seen in the low stress-level. The *pleasance* by *riding* and *round pen* is also growing to the end of a HAI, however, the basic level of *pleasance* is at a higher level from the beginning by *riding*. One cause could be the anticipation of going out with the horse for a longer time. Another reason might be the awareness of the fact that the *round pen* is more challenging for the owner (see *stress* and *activation*). In summary, the statistical analysis determined a highly positive and significant correlation between the variables *time* and *pleasance* of the owner with r=.93 (p=.00), - the longer the exercise went on, the higher the pleasance of the owner - which can be explained by the fact that the variation of time and *pleasance* is identical across all training sessions. Also, this result has to be considered in relation to the small sample (distortion effects). It was also observed that *activation* is experienced in the same way across all training sessions (see **Fig. 2**). The lowest level of *activation* during *riding* is surprising, as the owner's VMC is at the highest level. One reason could be that while *riding*, the hands are moving a lot, whereas the body is not that moving. A statistical check in SPSS supports this assumption of a positive relationship between the time (measured by the length of the HAI in minutes) and the heart rate of the owner (BPM O) with r=.42 (p=.01).



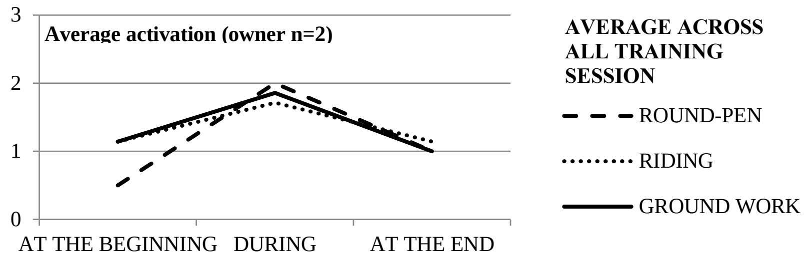


Fig. 2 Average pleasance and activation of the owner

Animal: Due to the problems in the collection of data with horses (see **section 4.1**) there are only a few insights on the horses' behavior based on the observations by the owner, which means that there is a self-reporting bias. However, in specific situations, the following could be observed: First, the rapid increase of the documented heart rate on the Pebble Watch while *riding* and suddenly being close to a hunting season, linked to an unrestful behavior that might indicate a higher stress level. Second, moving heart rate values on the Pebble Watch while feeding treats as a reward, and third, the reduction of dominant behavior during *round pen* and *riding* sessions. Fourth, the growing signs of *pleasance* over time in all training sessions, shown by moving the head down and snorting. Due to the non-significant data basis, the animal part was excluded from statistical tests.

HAI: To analyze the BPM and VMC values, the three types of training with horses had to be distinguished (see **section 4.1**). Hereby, the values of the basic emotions change in the same way, irrespective of the type of training. It is noticeable that there might be a correlation between the increasing average movement of the animal (measured as VMC) and the decrease of more negatively charged basic emotions of the owner (*stress, uncertainty* and *dejection*) as well as the variation of the average movement of the animal (measured as VMC) and the increase of the positively charged feelings (*happiness* and *excitement*) of the owner.

Regarding observed data on animals while *riding* the heart rate and the average movement of the owner and the horses are increasing as this is a typical sequence of a long warm-up, the main high-load, and a short cool-down-phase. Hence, the higher the movement, the higher the heart rate of both parties during *riding*. Consequently, the variation of the heart rate can be explained through the movement and the aim during *riding* (see **Fig. 3 & 4**). While doing *groundwork*, the heart rate of the animal is not moving in a similar direction to the movement, which can be explained due to the fact that the animal is expected to stay calm during grooming at the beginning (low movement), whereas the heart rate increases as the horse might be excited due to the expected treats. During the session, the movement intensity grows as there are little exercises (VMC A is moving up, *see* **Fig. 5 & 6**).

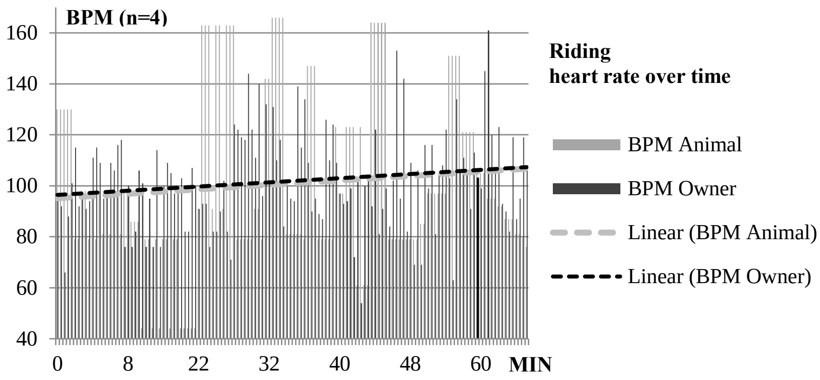


Fig. 3 Heart rate (BPM) over time (riding)

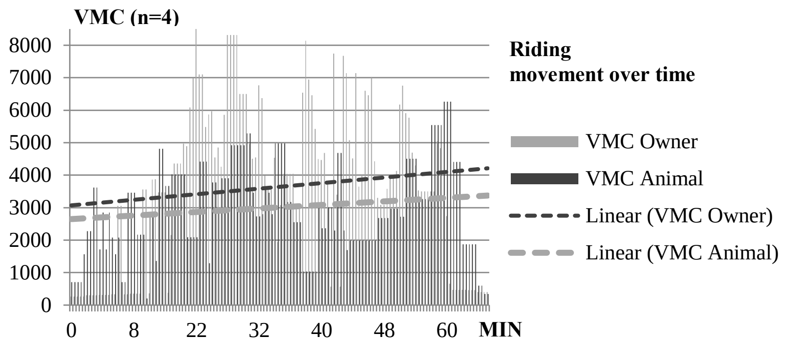


Fig. 4 Movement (VMC) over time (riding)

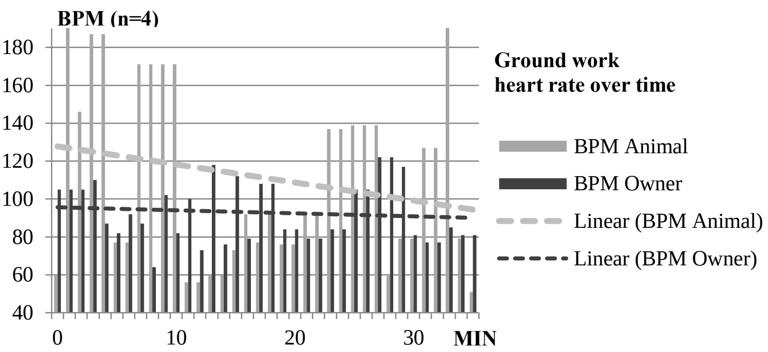


Fig. 5 Heart rate (BPM) over time (ground work)

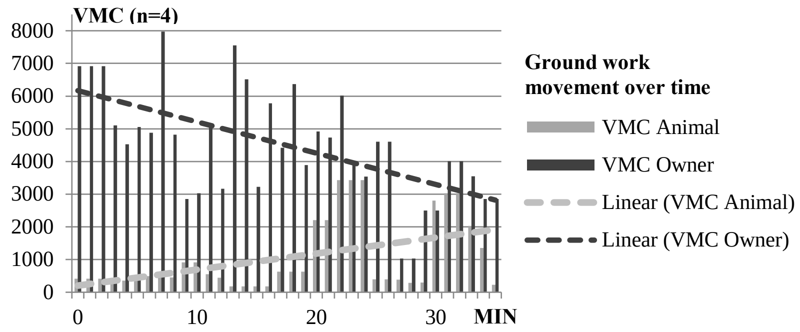


Fig. 6 Movement (VMC) over time (ground work)

The heart rate (linear BPM values) of the animal is varying similarly to the owner's one during *riding* (lines are moving up) and *groundwork* sessions (lines are moving down), whereas the results are varying inversely during *round pen* (see **Fig. 7 & 8**). Successful *round pen* training may be indicated by decreasing need for direct commands through explicit body language of the owner. Hence, the heart rate and the movement of the owner (BPM & VMC O) decline while those of the animal increase. During a *round pen* training, the BPM of the horse is almost constant, whereas the average *pleasance* and *activation* of the owner are growing (see **Fig. 6**). The BPM and VMC values of the owner are also slightly decreasing. As the decreasing movement of the owner is not the reason for the increasing *activation*, the growing VMC of the horse might cause the high BPM O and VMC O values.

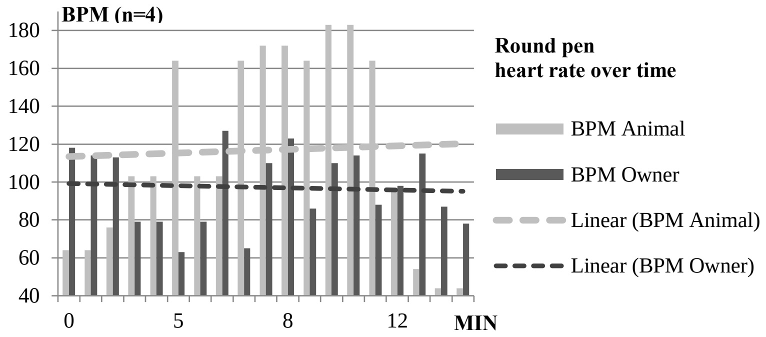


Fig. 7 Heart rate (BPM) over time (round pen)

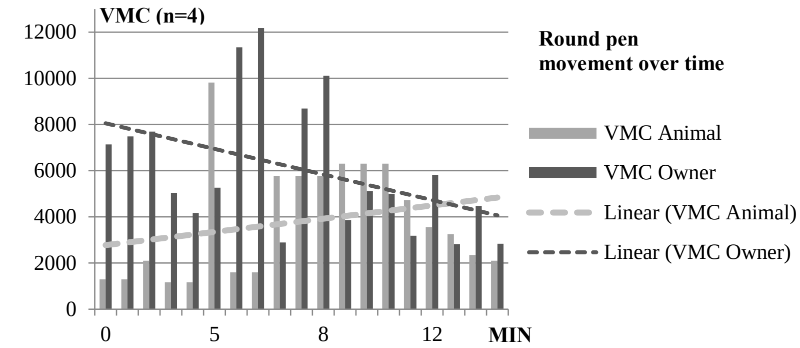
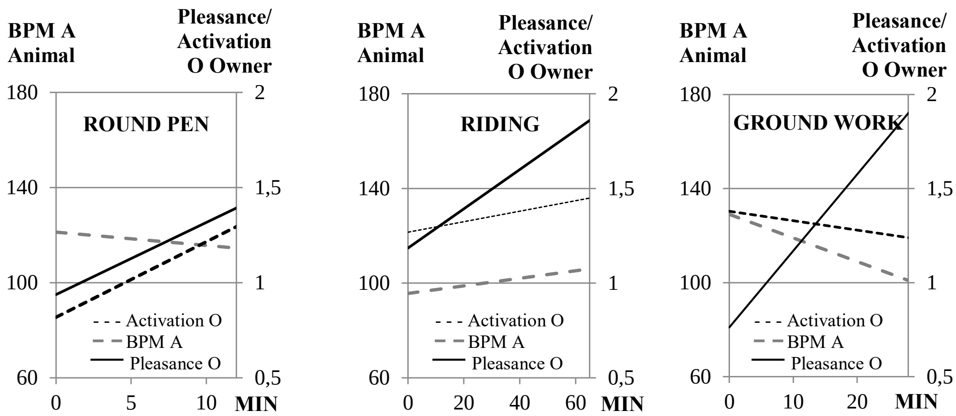


Fig. 8 Movement (VMC) over time (round pen)

While doing *groundwork*, the *pleasance* and *activation* curves of the owner move in different directions, whereby the *pleasance* rises enormously (see **Fig. 9**). As the *activation* curves move equally to the *pleasance* curves while *riding* and doing *round pen*, there could be a connection between *activation* and *pleasance* (see **Fig. 9**). Regarding *groundwork*, the *pleasance* and *activation* curves move in different directions, which might be a consequence of the calm situation at the end of the session (e.g. stretching, massages).



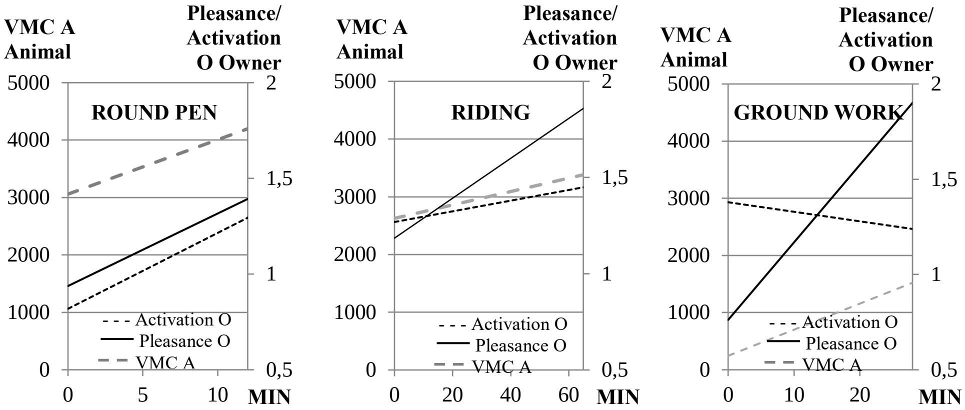


Fig. 9 Heart rate (BPM) and movement (VMC) of the animal (A) in context with activation and pleasance of the owner (O), (n=4)

4.3. Challenges and Opportunities

Due to the pre-experimental design of this paper, there are some limitations and inspirations for future research. As Pebble (2016) admits, the described experiment shows that the measured data was not always accurate. In several cases, the data was "frozen" (see **section 4.2**). Second, due to the technical issues mentioned in **section 2**, the focus was on two horses and their two owners. As the basic emotions are only collected twice, at the beginning and the end of a training session, the findings might only indicate trends. Even if the limited (quantitative) data allows no generalization and is not representative, the results show tendencies that might be the basis for further research. Besides looking for a more objective way of recording the main feelings, future studies might document the basic emotions more frequently and include other factors (moderating variables), like the character of the participants, time of day or other activities, done before and after the session. Another extension of this study could be to use machine learning for higher prediction accuracy. **Fig. 10** lists challenges and opportunities.

Opportunities	Challenges	Further research
▪ Attachment and usage of a Pebble Watch on horses ▪ Supporting positive effects of HAI regarding related work ▪ Separation of the training types of horses (related to aims)	▪ Way of attachment and tracking on animals ▪ Reliable data reporting and transmission via the Pebble Watch and other technique ▪ Reliability of the learning algorithm (esp. on horses)	▪ Deeper insights in body signals while/after the HAI regarding animals and owners ▪ Larger and more diverse sample (esp. A&O pairs, other breeds) ▪ Longer period of time to investigate the HAI

Fig. 10 Challenges and opportunities – experimental overview

5. Outlook

It can be concluded that the first question of the project “Can the Pebble Watch be used as a tracking tool for biometric signals of animals?” was partially met. The Pebble Watch could not be used for dogs, however, it worked well on horses. The data indicates that there might be connections between the measured Pebble Watch values of the heart rate (BPM), average movement (VMC) and the mood data (basic emotions, *pleasance* & *activation*) of an animal and its owner during training sessions. However, only the owner’s values could be tested statistically with the result, that there is a correlation between the progressive time of the HAI and the growing pleasance of the owner as well as the decreasing heart rate of the owner. Further, the variation of the animal’s heart rate changes in synch with those of the owner in *groundwork* and *riding* sessions, whereby it is inversely related during a *round pen* session, which can be explained through the different aims of those types of training.

According to Gehrke (2010) and Beetz, Uvnäs-Mobergm K., Julius, and Kotrschal (2012), the experiment also supports the relationship between the animals and owners’ HRV frequency, though the type of training session has to be considered. Further, the self-reported stress by the owner is lower at the end of the HAI; except after a *round pen* session (consistent stress-level). One reason for this might be that tension remains high to the end whether the horse accepts the owner as the leader. Hence, this paper confirms the findings of Allen, K. et al. (2002). Furthermore, the relationship between the variable time and *pleasance* of the owner could be confirmed, especially during *groundwork* (see Góngora & Solano, 2015; Wells, 2009). A cause might be that *groundwork* takes place in a calm environment, in which the animals and owners heart rate (BPM) and movement (VMC) values go down. In summary, the research question “Can combined tracking of animal and owner signals be used to gain insights into the connection between animal and owner?” can be approved with some reservations regarding the limited data quality. Especially the setting conditions can have a huge influence on the measurement quality (e.g. radio frequency, bluethooth connection, location, type of smartphone, weather). Also, the way of attachment and the skin or fur conditions are relevant factors referring to the question “What are factors influencing the measurement quality?”.

To overcome especially the issue of getting a huge volume of data (larger sample and a longer period of time), further studies should use a watch that is designed to measure the body signals of an animal. Therefore, the POLAR Equine might be an option for the measurement on horses, because it is equipped with synthetic electrodes, which adapt to the movements of a horse and achieve high measurement accuracy due to the permanent contact to the skin of the horse by attaching the sensor under the saddle pad (Polar Electro, 2017a).

Furthermore, in this case, the horses and their owners were familiar with each other for more than five years (first pair) and more than ten years (second pair), whereas the measurements on the dog were carried out on a one-year-old dog. As the animals might be more relaxed when knowing the owner well and when they trust each other, it would be interesting to measure data with animal-owner-pairs that are not used to each other (e.g. during the break-in of a horse or a new owner for an old dog). In addition, other circumstances (e.g. summer fur, shorthair dogs) might lead to a data collection on dogs.

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