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Measuring Equine Locomotion in Personality tests: Validation of the Equisense Motion Sensor

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Hiermit erkläre ich, dass ich die vorliegende Arbeit selbstständig und ohne fremde Hilfe verfasst und keine anderen Hilfsmittel als die angegebenen verwendet habe. Insbesondere versichere ich, dass ich alle wörtlichen und sinngemäßen Übernahmen aus anderen Quellen als solche kenntlich gemacht habe.

Hereby, I declare that I wrote this work independently without outside help and did not use any tools other than those indicated. In particular, I assure that I have identified all the literature and corresponding wording other than such.

15.06.2020 Katrin Portele

Date Katrin Portele

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1. Introduction

According to estimates of the Food and Agricultural Organization of the United Nations FAOSTAT, in 2017 there were approximately 60 million horses and 9 million mules worldwide (FAO 2017). In addition, equestrian sports are among the most popular sports in Switzerland (Lamprecht et al. 2014) as well as in Germany (Zeppenfeld 2019) and in Austria (OEPS, 2019a). According to a marketing research over 8.740.000 people (14 years and above; active and potential riders) are interested in horses in Germany. More than two-third of these enthusiasts ride purely for leisure and do not participate in competitions. They indicate that internal characteristics such as personality and behaviour are more important than external ones such as colour and size (Ipsos 2001). This could be due to these riders' inexperience making the horses' temperament and personality important to ease the handling. Thus, they prefer less challenging animals (Górecka-Bruzda et al. 2011). In general, the relationship between a rider and a horse is complex and relies a lot on human-horse interaction and the way the two are able to cooperate (Visser et al. 2003). The quality of the interactions and the communication depends, to some extent, on how experienced and able the human is to respond to the animal's behaviour. Additionally it depends on the horse's behavioural reactions towards difficult situations (Visser et al. 2008). Therefore, personality of horses is an important factor not only for potential riders, but also for the appropriate use of horses, so that humans are able to adapt their behaviour as well as their handling and training methods during the work with the horse.

1.1.Personality

In general, personality can be described as follows:

"[...] an individual´s unique set of traits, which is relatively stable over time and affects how it interacts with the environment." (p.111, Waiblinger 2009)

To describe personality in humans the five-factor model (FFM, John 1990) in form of a questionnaire is usually applied. The FFM of personality was validated by McCrae and Costa (1987) by using self-reports as well as peer ratings. It describes the multiple variations of human personalities using five dimensions: Extraversion, Agreeableness, Neuroticism, Conscientiousness and Openness (Gosling and John 1999). These dimensions in humans are described with traits by Goldberg (1993) as follows: Extraversion includes traits like talkativeness, activity level and assertiveness; Agreeableness comprises traits like kindness and trust; Neuroticism includes traits like nervousness and temperamentality; Openness comprises traits like curiosity and creativity; lastly Conscientiousness includes traits like thoroughness and reliability.

Reviews of animal research (Gosling and John 1999; Gosling 2001) highlighted personality traits similar to four of the five human factors (Extraversion, Agreeableness, Neuroticism and Openness) across 40 animal taxa. Conscientiousness was the only dimension, which was found only in chimpanzees. An extra factor considered in animals is dominance, which seems to be defined by boldness, physical aggression and low levels of fearfulness (Gosling and John 1999).

In horses, personality is highly influenced by human-animal interactions and has an impact on horses' ability to adapt to different situations (e.g. husbandry) (Momozawa et al. 2003). The daily work with horses becomes easier and the risk of injury (in both human and animal) decreases, when the personality is well known (Graf et al. 2013). Several genetic and environmental factors (including disciplines) could explain different personality traits in horses (Hausberger et al. 2004). For example, dressage horses showed the highest excitation elements and vaulting horses were the quietest (Hausberger et al. 2011). Further, during jumping competition the most fearful horses were the most difficult to ride but performed best (Lansade et al. 2016). However, in leisure, calm and easy to handle horses are preferred (König v. Borstel 2013; Górecka-Bruzda et al. 2011). Additionally, horses expected to work in animal assisted therapy, are selected based on their ability to build a positive relationship with humans (Visser et al. 2003). Another study, which was done by Lloyd et al (2008) supports the theory that there is a relationship between personality and breed differences. With the use of the Horse Personality Questionnaire (HPQ) (Lloyd et al. 2007) they could identify typical breed differences in personality (Lloyd et al. 2008).

This means, that personality also has an influence on individual welfare. Welfare can directly affect physiology and behaviour of an animal and while as in a feedback loop personality can directly affect physiology and behaviour (Finkemeier et al. 2018).

1.1.1. Definitions of sub-aspects of personality

For the concept of personality two sub-aspects exists, namely temperament and coping style. Therefore, they will be described as follows:

1.1.1.1. Temperament

Today the temperament of an animal is described as a steady predisposition, which is mainly influenced by genetic components, and is considered relatively stable across different situations and over time (Goldsmith et al. 1987; Le Scolan et al. 1997; Visser et al. 2001). According to some authors the differences between temperament and personality is that the former is present at birth, thus inherited and has early appearing tendencies which continue throughout life and therefore builds the foundation of personality (Goldsmith et al. 1987; Morris et al. 2002; Kagan et al. 1988; Gosling 2001; McCrae et al. 2000; Finkemeier et al. 2018) .

1.1.1.2. Coping styles

Lazarus (1993) highlighted two distinct approaches of coping in humans. On one hand, he differentiated a coping style, which treats coping as a personality characteristic. On the other hand, he differentiated a coping process, which refers to stress management. The first one describes the personal or individual consistency in their response, while the second one primarily addresses the behavioural and physiological mechanisms (Lazarus 1993). In animals coping style is based on the individual's reaction to its environment with respect of reducing the effect of aversive stimuli (e.g. fight or flight response, approach or avoidance, boldness or shyness) (Korte et al. 2005; Finkemeier et al. 2018). Similarly to humans, it seems that personality and coping styles are closely linked, because animals show individual differences to various environmental changes (Wechsler 1995; Koolhaas et al. 1999; Korte et al. 2005).

The most common distinction is made between two types of (behavioural and physiological) reactions in accordance with the animals' reaction to its environment altering the effect of aversive stimuli: proactive and reactive (Koolhaas et al. 1999; Finkemeier et al. 2018). It is thought, that proactive individuals can perform better in predictable environments, whereas reactive ones do better in an unpredictable surrounding (Koolhaas 2008). This means proactive animals tend to avoid or try to actively take control over a stressful situation ("fight or flight response") while reactive individuals may not show any obvious signs of stress and seem to be unaffected (Wechsler 1995).

1.1.2. Assessment of personality in horses

There are many behavioural tests, which are used by applied ethologists in research on farm animals to measure the different aspects of personality. For example, a behavioural test that measures the response to an aversive or stressful situation/stimulus can be used (e.g. avoidance or approach) to assess the coping style. To assess temperament behavioural tests can be conducted once in a lifetime during the juvenile stage whereas personality should be assessed through various behavioural tests in combination and/or at least twice in a lifetime. (Finkemeier et al. 2018)

A large panel of those behavioural tests (in the following always termed as personality tests) has been developed over the last years in equine science. They allow us to investigate traits such as fearfulness, boldness, confidence, reactivity towards humans, locomotor activity, gregariousness, social motivation, or tactile sensitivity (König v. Borstel 2013). For example, it has been shown that fear tests could be applied for the prediction of horse safety perceived by riders (Górecka-Bruzda et al. 2015) and "calmness-tests" consisting of startling and novel stimuli are used to assess suitability as a leisure horse (Christmann 2005). Most relevant for this thesis are the personality models developed by the team of Lea Lansade in France (Lansade et al. 2008c; Lansade and Bouissou 2008; Lansade et al. 2008a, 2008b). These tests have been used for several years to study the relationship between personality and cognitive abilities. This model regroups five independent dimensions of the personality: fearfulness, gregariousness, reactivity to humans, activity level and tactile sensitivity (Lansade et al. 2017; Lansade and Simon 2010; Valenchon et al. 2013a; Valenchon et al. 2013b; Valenchon et al. 2013c). The personality tests used to measure the fearfulness dimension are the novel object, the unknown surface and the surprise test. To assess the gregariousness the social isolation test is used. To examine the reactivity to humans the passive human test is conducted and with the help of the von Frey filaments, the tactile sensitivity can be tested. These filaments consist of a hard-plastic body connected to a nylon thread and they are used to evaluate the response of the individual to mechanical stimuli by using different strengths of filaments. To measure the activity level the locomotor activity during all the tests is assessed, by dividing the test pen into areas and recording the number of areas crossed by the horse as well as the trotting frequency (Lansade and Simon 2010).

The focus of this master thesis is the locomotor activity of Lea Lansade's model, since locomotor activity is often used as an indicator for emotional arousal and thus stress across species (Briefer et al. 2015; Forkman et al. 2007). However, no tools seem to exist yet to ease the assessment of locomotor activity.

For a better understanding of the locomotor activity, a closer look into equine locomotion is relevant.

1.2.Equine Locomotion

In his book *Equine Locomotion* van Weeren (2013) explained that during the domestication process, horses, unlike other species, were selected for their locomotor abilities rather than as a provider for food or clothing material. Their locomotive skills gave horses a central role to humans not only in transport or agriculture but also for combat beginning from ancient times until very recently. Furthermore, the locomotion plays an essential role during breeding programs of many horses, as they focus on conformation and gait quality (Wallin et al. 2001;

Ducro et al. 2007; Jönsson et al. 2014). Gait quality traits (the way horses move according to functional and aesthetic principles) are mostly assessed visually by experts of the breeds. This can be carried out using either subjective valuating scores (on a scale from "bad" to "good") or with a linear description (linear profiling scale) (Gmel et al. 2020).

In general, equine locomotion is characterized by different gaits. Although gait patterns are commonly influenced by the age of the horse, and even though little is known about the gait development (Barrey 2013), the following definitions are usually used.

1.2.1. Definition of gaits

A definition of gait is that it is a "cyclic pattern of limb movements" and "each complete cycle is one stride" (Deuel 2013). Quadruped movements allow many combinations of inter-limb coordination. Therefore, a great diversity of gaits and gait variations, including walk, trot, pace, canter and gallop, exist in equines (Barrey 2013). In the next paragraphs, the most common gaits will be explained shortly.

When a horse walks four hoof beats can be heard. Walk is indeed a gait with four leg movements (e.g. front right, back left, front left, back right) and the slowest as well as most commonly used equine gait (Glatthaar 2012) (see Figure 1). In addition, at walk there are always at least two (sometimes three) feet touching the floor at the same time (Hertsch 2012).

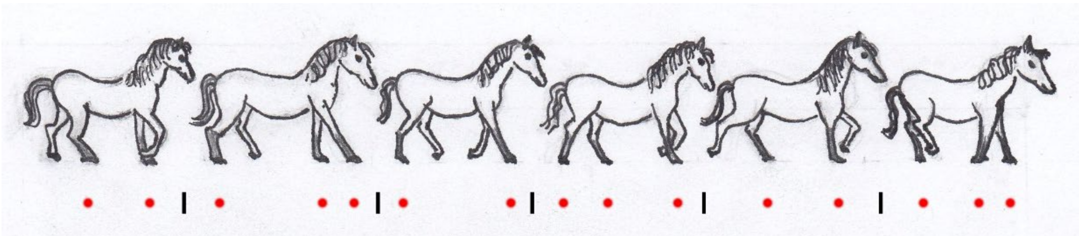

Figure 1: Illustration of walk. The red dots indicate the hoofs, which touch the ground within the moment of movement © G. Rieger

At trot, there is a synchronic movement of the diagonal pair of legs (e.g. front right and back left move at the same time). Trot is intermediate in speed between walk and canter. Horses often trot, when they are running away from a source of danger, while holding head and tail high and looking backwards from now and then. (Glatthaar 2012). Furthermore, when a horse trots faster, a suspension phase occurs (during which none of the limbs touch the ground (Buchner 2013, see Figure 1Figure 2))

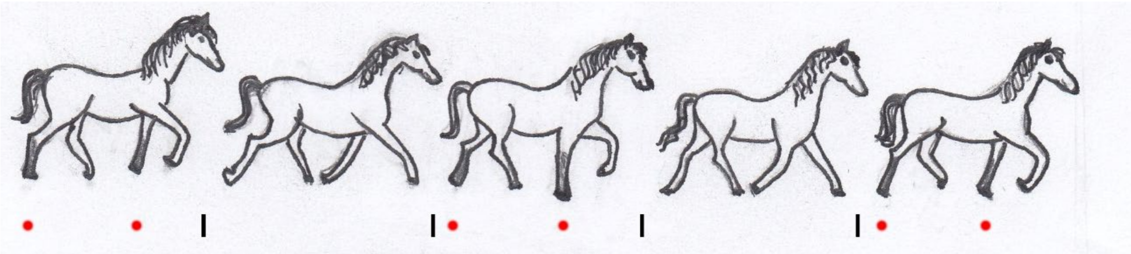

Figure 2: Illustration of trot. The red dots indicate the hoofs, which touch the ground within the moment of movement© G. Rieger

The next faster stride is called canter. Canter is an asymmetric gait with three-beats and a specific footfall sequence (i.e. outside hind leg, inside hind leg/outside foreleg, and inside foreleg) followed by a moment of suspension. The impulse comes from the outside hind leg and pushes the main centre of the body towards the diagonal front leg (Hertsch 2012) (see Figure 3). The gallop is the fastest stride and a four-beat variation of canter. It is the racing gait of Quarter Horses and Thoroughbreds (Barrey 2013).

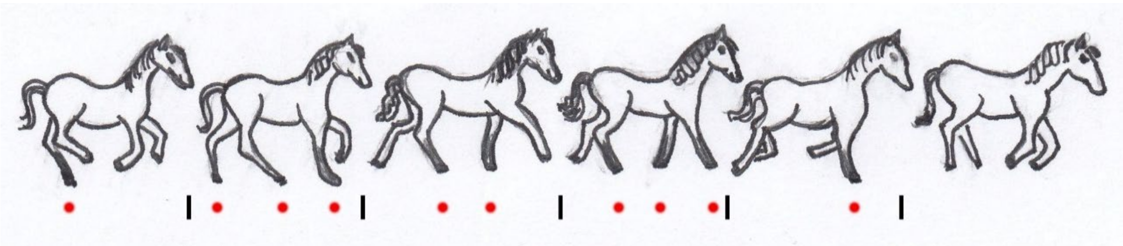

Figure 3: Illustration of canter. The red dots indicate the hoofs, which touch the ground within the moment of movement © G. Rieger

A widespread definition of a jump is, that it is usually a special form of canter, including a flight time (Buchner 2012, Hertsch 2012, see Figure 4) since during this gait performing a jump is easiest (Hertsch 2012).The ethogram we used for the observations in this study was inspired by these definitions but we changed it into smaller jumps during a fear reaction. (see Table 1, p. 26).

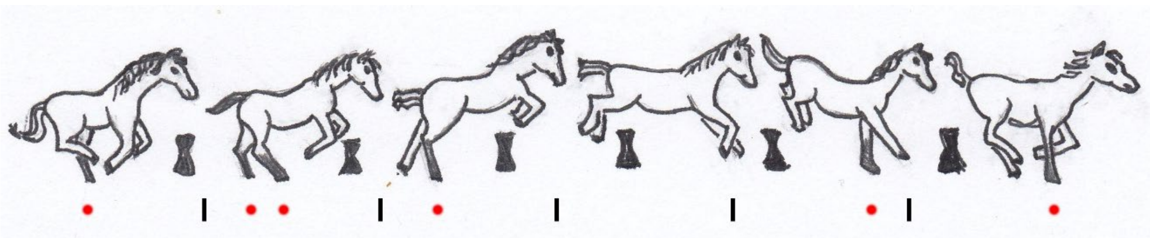

Figure 4: Illustration of Jump. The red dots indicate the hoofs, which touch the ground within the moment of movement © G. Rieger

1.2.2. Gait transitions

Horses can change gaits in order to increase speed. By modifying the spatial and temporal characteristics of the strides each gait can be extended (Barrey 2013). The transitions can be classified based on the limb sequence into two types according to Argue and Clayton. Type 1 transitions do not have mediate steps between walk and trot sequences, while type 2 is characterised by intermediate steps, which include a single support phase (Argue and Clayton 1993).

1.2.3. Measurements of Equine Locomotion

For measurements of equine locomotion the tool of choice was for a long time and mostly still is the human itself, who can evaluate it based on observation and previous experience (Clayton and Schamhardt 2013). One issue with human evaluation is that the observation itself or the human observer can also influence the behaviour of the animal (Martin and Bateson 2013). Especially in appraising gait quality in horses during breeding programs another issue is that subjectivity is an inherent aspect of the human judgement, but scientific analysis should be accurate and requires accurate quantitative data. (Clayton and Schamhardt 2013). Also Gmel et al. (2020) concluded in their research, that in the future quantitative gait measurements might provide new opportunities to define and measure gait quality traits. In the last years some companies already developed automatic tools to record locomotion for horses (Alogo Analysis SA 2019; Trackener 2019; Equisense 2018). One of these tools was the Equisense Motion Sensor, which entered the market in 2016, with the aim to support training sessions of individual riders. The sensor itself is a common Inertia Measurement Unit (IMU) with three accelerometers, three gyroscopes and three magnetometers. This means it is a 9-degrees of freedom (DOF) motion sensor, which Equisense terms it as 9-axis on their homepage. Further, the sensor measures the acceleration and speed of the rotation based on 60 recordings per second (comparable to 60 pictures/second). For the calculation, the system uses the recorded data of the last 2 seconds and determines the indicators (different states of movement) of this period. The Equisense Motion Sensor records different parameters such as the time spent at each lead and gait, the number of transitions and jumps, symmetry at the trot, cadence and cadence regularity, elevation, cadence at the approach and between obstacles and duration of the flying phase during the training session. The algorithms are programmed so that the sensor can measure, calculate the different indicators and transfer the data in real time to an app on a mobile device. However, if the Bluetooth connection failed during a session, it can store the data waiting for a connection (Equisense 2018). It is therefore easy to handle, and one sensor can be used by different people for the same or different horses.

1.3. Project aims

The present master thesis serves as tool for the post-doc project of Dr. Anne-Laure Maigrot ("Determining personality profiles in horses: Importance for their welfare, for adapted trainings methods and suitable housing forms") conducted at the Swiss National Stud Farm to evaluate a possible measurement of the personality dimension activity level in horses. Among other things Dr. Maigrot tries to find an easy applicable and fast way (especially for potential horse buyers and owners) to differentiate between proactive and reactive individuals. Therefore, validating a possible tool to help with this issue is the aim of this present master thesis. To the best of our knowledge no previous validation of the Equisense Motion Sensor regarding personality tests was done. As a result, the aim of this study was to validate the Equisense Motion Sensor during tests built to investigate different dimensions of the horses´ personality, to find out if this sensor can be used for scientific research to ease the assessment of locomotor activity. Therefore, we hypothesized that the Equisense Motion Sensor records accurate timeframe data (duration) during the different gaits, accurate amount (frequency) of smaller jumps, during a fear reaction and changes between gaits (transitions). Furthermore, we predicted, that Equisense Motion Sensor provides a fast, accurate and non-invasive way to record the locomotor activity data and can link together the measured data to the correct gait pattern, so that the data can be used for personality tests. For this purpose, we compare the accuracy and sensitivity of the Equisense Motion Sensor to human observations.

2. Material & Methods

All methods and animal use in this study were approved by the authority of canton Waadt of Switzerland (VD3351).

2.1. Animals and Housing

In this study, 22 Franches-Montagnes stallions of the Swiss National Stud Farm (SNSF) were tested. All horses were kept and trained in their usual surrounding at the stud. The stallions were housed in single boxes ($9m^2$) and were fed three times a day with hay and concentrate. They spent every day two hours in an individual paddock. Additionally, they were moved in a walker and were ridden or driven. The caretakers were always the same people, who were responsible for the same stable.

2.2. Study design

We investigated the duration of the different gait with two different methods (human observations, “Observer”, and Equisense Motion Sensor, “Equisense”) during two test situations, which took place on two different days. First, we tested a series of personality tests in one of the paddocks and afterwards we tested the animals individually at the longe in a round pen. 17 horses were used for the personality tests and 15 horses for the round pen test (10 horses participated in both test situations). Movements as standing, walking, trotting, canter and jumping as well as transitions have been recorded.

2.3.Data collection

Data collection took place at the SNSF in Avenches, Switzerland in September 2019. The personality as well as the round pen tests were each conducted on one day. In addition to direct observation, those tests were all recorded with a camera (GoPro HERO7) and used for testing the intra-observer reliability. During both tests the motion sensor was attached with a leather gear to a girth using a velcro closure (see Figure 5 and 6). The different movements were directly and continuously observed by a human experimenter in addition to the motion sensor, which transferred the data in real time to an application of a smartphone.

Figure 5: Leather attachment that adapts to all girths as well as fastens the sensor © K. Portele

Figure 6: Motion Sensor attached to the horse with a girth using velcro closure during personality tests © C. Althaus

2.3.1. Test procedure

We needed two experimenters at the round pen and three experimenters during the personality tests. Throughout the tests, the experimenters stayed the same. Experimenter A (author of this master thesis) and B took part in the round pen test. Before the tests (personality or round pen), the horses were in their boxes and were brought to the testing area by experimenter B for the personality and by apprentices of the stud for the round pen test.

2.3.1.1. Personality tests

Six personality tests were conducted in the same order, one after another, on the same day, on 17 horses. The order of the personality tests was always: passive human test, novel object test, unknown surface test, surprise test, ventilator test and noisy approach test (see 2.3.1.1.1. to 2.3.1.1.6.). Four of these had been used previously in research about personality (see 2.3.1.1.1. to 2.3.1.1.4, Lansade and Bouissou 2008; Lansade et al. 2008a, 2008b; Lansade et al. 2008c) and two of them had been developed recently at the SNSF (see 2.3.1.1.5. and 2.3.1.1.6.). In order to have an enclosed space as well as a better surrounding area we positioned a rectangle area (6x10m) made of metal panels attached to one another. In addition, the area was divided into four rectangles of equal size (3x5m) with wood shavings. These wood-shaving marks had to be renewed after every second horse. As these tests were conducted in one of the paddocks of the SNSF, the tested stallions could see, smell and hear the other horses walking freely in the other paddocks around.

There were three experimenters present during the trials and they did not change during the tests. Experimenter C was responsible for the tests' protocol (especially time management with the help of a stopwatch). She was also the unfamiliar person in the Passive Human Test and started and stopped Equisense on her mobile phone (iPhone XS) for each test. Experimenter B was in charge of bringing the stallions from their boxes to the paddock and leading them back again. Furthermore, she recorded the total number of (wood shaving) line crossing during the tests with pen and paper. Whereas, Experimenter A conducted the live observations with Pocket Observer and helped preparing for the next tests. The girth with the motion sensor was attached before the stallion entered the testing area by the help of experimenter A .When the girth was attached, and the experimenters had left the testing area, the habituation period for the horse to get used to the girth with the sensor started and lasted 2 minutes. The horse could move freely in the testing area. After this habituation phase experimenter C went into the centre of the test area and started with the passive human test (see 2.3.1.1.1). For the observations, experimenter A stood always at the right side of the panel except for the noisy approach test (see 2.3.1.1.6). During this test, she observed from the left side, because experimenter C had to come from the right side, as there was the entrance of the paddock. Experimenter B stood always outside the testing area, at the front of the panels with approximately three meters distance, except for the unknown surface test. For this test, she stood outside the panels at the right backside, one to two meters away from the panels, because she needed to go to the horse again. When experimenter C was not needed for the tests, she stood next to experimenter B outside and in the front of the panels. Inside the panels, the horse could always move freely, except for the preparations of the umbrella (see 2.3.1.1.3) and unknown surface test (see 2.3.1.1.4). In total, the duration for one horse to do all six personality tests was about 20 minutes.

2.3.1.1.1. Passive human test

After the habituation phase, experimenter C (unfamiliar to the horse) entered the testing area, went slowly to the centre and remained there motionless with slightly lowered head. Due to security reasons, the experimenter also held a whip (top pointing to the ground) in her hand, in case one of the stallions got rough (see Figure 7). The timer started when the experimenter was in the centre of the area and lasted for 1.5 minutes. When the time was expired, experimenter C went out of the testing area to prepare for the next test.

Figure 7: Unknown person test. Experimenter stands in the centre of the testing area with a whip in her hand for 1.5 minutes. © C. Althaus

2.3.1.1.2. Novel object test

After the passive human test was finished experimenter C went out of the testing area to get the novel object (tube bound together with cloth meshes on it), which was unknown to the horse, to place it in the centre of the area (see Figure 8). The duration of this test was 1.5 minutes and started when Experimenter C had left the testing area. After the test was finished, experimenter C took the unknown object out of the area and prepared the unknown surface for the next test.

Figure 8: Unknown object lies in the middle of the testing area. The white stripes are the marks on the ground to see how much the horse moved. © C. Althaus

2.3.1.1.3. Crossing an unknown surface test

Here the area was divided into three zones: the first zone was the starting zone, the second the "middle" zone and the third zone was the arrival zone. The horse started in the starting zone and had to cross the second one, in which the floor was covered with an unknown surface (black rubber mat with yellow strips) in order to get to the arrival zone, which contained a bucket with food (horse concentrate). Before the test started, the experimenters B and C trained the horse to go from the starting zone to the arrival zone, which contained this bucket. The "middle" zone was not covered with the black rubber mat during training. To do so, experimenter B led the horse to the starting zone and after experimenter C shook the bucket to signalise that there is food in it, the horse was released. After few seconds of eating out of the bucket, the horse was led again backwards to the starting zone by experimenter B. This training session was repeated twice. After this training phase, experimenter B held the horse at the starting zone and experimenter A and C rolled out the rubber mat in the "middle" zone. After the surface was prepared and experimenter A and C had left the area, the horse was released again, so that it was free to go to the arrival zone to eat (see Figure 9). At the same time of releasing the horse experimenter B also left the testing area. The horse needed to walk towards the surface and cross it to access the bucket. The timer of 1.5 minutes started when the horse was released. However, the stopwatch was stopped when the horse reached the bucket. When these 1.5 minutes were expired and the horse remained too scared to cross the surface the experimenter B showed the horse that there was nothing to fear afterwards by leading it on the mat to the bucket.

Figure 9: Unknown surface test. The picture shows the horse in the starting zone. © C. Althaus

2.3.1.1.4. Surprise test

A bucket with food (horse concentrate) was placed by experimenter B 1.5 meter in front of the panels at one end of the area. Experimenter C kneeled at the same side of the area, near the bucket but outside of the panel, holding an automatic umbrella (navy blue with a diameter of 87 cm) in closed position inside the panel. Experimenter B led the horse towards the bucket and went out of the testing area. Ten seconds after the horse started to eat out of the bucket, experimenter C suddenly opened the umbrella (see Figure 10). The observation and sensor measuring began when the horse started to eat and stopped when the horse got back to the bucket and started eating again, if it had interrupted eating due to the opening of the umbrella.

Figure 10: Umbrella test. © C. Althaus

2.3.1.1.5. Ventilator test

This personality test is one of the two tests recently developed at the SNSF in the course of the postdoc project of Dr. Anne-Laure Maigrot. For this test a remote-controlled ventilator with colourful (red and blue) clothing strips attached was placed in a corner of the area by experimenter C. Experimenter C (outside of the area) controlled the different velocity stages of the fan by remote. The test started, when the horse looked in the direction of the ventilator (see Figure 11). During the first 30 seconds, nothing happened. After that, the ventilator was turned on at the three different velocity stages one after another starting with the lowest and getting to the highest speed. Each velocity mode lasted 30 seconds. In total, this test duration was 2 minutes.

Figure 11: Ventilator test. © C. Althaus

2.3.1.1.6. Noisy approach test

This personality test was also developed by the research group of the SNSF in the course of the postdoc project of Dr. Anne-Laure Maigrot. The horse was confronted by a person approaching the testing area (see Figure 12). This person (Experimenter C) was limping and carrying a big plastic bag filled with five empty cans of spray paint and their loose caps to create noise at every step. The person came from a place out of sight and limped towards the horse for 30 seconds. The experimenter stopped either when the horse showed a flight reaction or when she arrived one meter away from the area and remained still for one minute after stopping. The test area remained closed.

Figure 12: Noisy approach test. Person approaching with a bag filled with (empty) spray cans that was moved at every limping step to create a noise. © C. Althaus

2.3.1.2.Round pen test

Over the course of this test 15 horses were trained individually at the longe in a round pen (17 meter in diameter) wearing a girth with the motion sensor attached (see Figures 5, 6 and 13). Experimenters A and B were present for these tests as well as two apprentices of the stud, who trained the horses regularly. For the round pen test the apprentices did not only longe the horses for the tests but also prepared them beforehand and took them from their boxes to the round pen. When we were finished with one stallion, the apprentice longing him brought him to his box and the other apprentice started longing the next stallion in the round pen. The girth with motion sensor attached was always changed before the horse entered the round pen, with the help of experimenters A and B. All horses were trained on both sides and each side counted as one recording session. Before each test, the apprentices had time to habituate the horses to the girth and warm them up individually in the round pen. The tests started when the apprentice told the experimenters that she and the horse were ready. Experimenter B then started the Equisense on the mobile phone (Samsung Galaxy A8, 2018). Experimenter A directly observed the locomotion. At the end of each test, Experimenter B stopped the Equisense. In order to standardise the different gaits for each individual and to make it easier for the apprentices to longe the horses, the gait changes were determined in advance and Experimenter B was always announcing these changes. The opposite of the entrance was designated as the starting point. At the beginning of the test, the horse had to stand still for 15 seconds at this starting point. Afterwards it walked one round, trotted two rounds and cantered three rounds. Gait changes every half round were tested next. The horses had to change between canter and trot for two rounds (4 changes), between walk and trot for two rounds (4 changes), and between walk, trot and canter for three rounds (6 changes). The whole procedure was then repeated on the other side. When the horse did not change the gait as planned, the test was continued. This means, for example, when the horse should change between trot and canter every half round and it took him one quarter round more to change, we continued with the announcements as planned. When the horse took much longer to respond to the changes, we expanded the rounds until 4 changes were done (but this happened only with 2 horses).

Figure 13: Individually trained horse during the round pen test. The sensor attached to the girth. © K. Portele

2.4.Measurements

In this study, two measurement methods were used: behavioural observations as well as the recordings of the Equisense Motion Sensor.

2.4.1. Behavioural observation

Live observations were always carried out with the help of the Pocket Observer mobile device (Pocket Observer 3.1.68). During both test situations all the observations were done by the same person (experimenter A) and the following movements were observed: standing, walk, trot, canter and jump (Table 1). These behaviours were recorded with continuous focal sampling and comprised the durations of the different gaits as well as the frequencies of small jumps. We changed the original definition of jumps (Hertsch 2012, Glatthaar 2012; Barrey 2013) because we defined it as smaller jumps during a fear reaction, as it was more useful in our case.

Furthermore, we did not differentiate between canter and gallop for our observations, because Equisense also did not differentiate between them.

Table 1: Ethogram, modified from definitions of Barrey (2013), Hertsch (2012) and Glatthaar (2012)

Gait	**Description**
Standing	The horse is not moving forwards or backwards, it stands stationary with all feet placed on the ground. Minor leg movements without a forwards or backwards movement (e.g. stamping because of flies or alternated lifting of left and right leg) or if just one leg was lifted off the ground (no matter if hind or fore limb) were ignored.
Walk	The horse walks its four legs independently in the same order (e.g. left hind, left fore, right hind, right fore). There is no moment of suspension and there are always two or sometimes three limbs at the same time in one support-leg-phase/stance phase. When more than two limbs started to move it was counted as walk.
Trot	The legs move in two diagonal pairs synchronic as a two-beat gait. The right fore and left hind rise and fall together alternately with the diagonal pair left fore and right hind. The swinging side-to-side-movement is reduced to a minimum and if there is a faster speed there could occur a moment of suspension.
Canter	The horse used the following footfall sequence to move forward: outside hind leg, inside hind leg/outside foreleg, and inside foreleg. The three beats are followed by a moment of suspension, when all four legs are off the ground.
Jump	Small jumps during a fear reaction: if less than three limbs of the horse are on the ground and the take-off is very energetic (also in combination of a fast upward movement of the head) but the horse is not moving forward.

2.4.2. Equisense Motion Sensor

The motion sensor was always attached with a leather attachment, which adapts to all girths, to the horse (Figure 5 & 6). It sent its data directly to an application called Equisense on a smartphone. For the personality tests we used an iPhone (XS; iOS version 13.3) and for the round pen tests we used a Samsung (Galaxy A8, 2018; Android version 9.0) device. As stated in the introduction the Equisense can record different parameters. In our study we concentrated on the durations of standing, walk, trot, canter as well as on the frequencies of jumps and transitions. Coincidentally, we noticed that the software of Equisense measured differently on Android and iOS operating systems because it always showed one more transition on the iOS operating system than on the android one. Therefore, we compared the number of transitions between two Android (Sony Xperia Z, Android version 8.0 and Samsung Galaxy A8, 2018, Android version 9.0) and two iOS (iPhone 6, iOS version 12.4.3. and iPhone XS, version 13.3) operating systems. The number of gait changes (transitions) was automatically recorded by the Equisense and was later compared with the calculated data from the Pocket Observer.

2.5.Data handling and statistical analysis

The data from the Pocket Observer device was transmitted via The Observer XT (Version 11.5, Noldus Information Technology) software to Microsoft Excel (version1910). The data from the motion sensor had to be copied by hand into Excel.

On the mobile application of Equisense the total duration of the training session ("Totalger", each personality or round pen test), the time spent in each gait (standing, walk, trot and canter) and the frequency of jumps and transitions was listed (Figure 14). During the copying process to Excel it was noticed that there seemed to be a difference between the total duration given by the Equisense (Totalger) and the sum of the durations spent standing, walking, trotting and cantering. Therefore, we calculated a total duration (named "Totalcalc"; sum of standing, walk, trot and canter, calculated with Excel) and added it to our data in order to have a better comparison with Observer. To have comparable values we also defined the total duration given by the Observer as Totalger and calculated with Excel Totalcalc. Additionally, the sum of all locomotive behaviour (walk, trot, and canter) was calculated and labelled as "TotalLoc".

In summary, for further analyses the following variables from both methods were used: durations of standing, walk, trot, canter, Totalcalc, Totalger, TotalLoc as well as frequencies of jump and transitions. All the durations found by the method Equisense and Observer were converted into seconds. In the following Equisense and Observer data points refer to the durations of the different gaits and frequencies of jump and transitions, i.e. nine data points per method per session were available for comparing the two methods.

In addition, the number of lines crossed by individual horses during each sub personality tests (Lines), were calculated for comparison with the sensor data.

Figure 14: Screenshot of a part of the app of Equisense showing measurements of Horse 5 at the right hand in the round pen test. In this case Totalger = 242 seconds and Totalcalc = 240 seconds.

The statistical analysis for comparing the two methods were conducted in R (version 3.6.1., R Development Core Team, 2019). Durations from the observation as well as from Equisense were tested using linear mixed effect models (LMMS) fit with the Gaussian family distribution and identity link function (lmer function, lme4 library in R). P-values (PBmodcomp function, package pbkrtest) were calculated using parametric bootstrap methods (1,000 bootstrap samples). P-values calculated with parametric bootstrap tests give the fraction of simulated likelihood ratio test statistic values (LRT) that are larger or equal to the observed LRT value. It was considered as a significant difference between the two methods when the p-Value was lower than 0.05. LMMS function was used to test the gait durations (standing, walk, trot, and canter) and the different totals (Totalcalc, Totalger and TotalLoc). As fixed factor the method (Equisense/Observer), as random factors the individuals (horses), the tests (personality or round pen tests) and subtests (2.3.1.1.1. to 2.3.1.1.6.) were used. The models were checked graphically with a residual analysis to verify the model assumptions. The model assumptions were not fulfilled for transitions and for jump, therefore for these two a Wilcoxon test (wilcox.test function in R) was applied. Additionally, Pearson's correlation coefficients were calculated for each variable over all tests as well as separately for the sub tests. Apart from that we correlated the Lines with the TotalLoc of Equisense as well as Observer. A correlation was considered strong, when its correlation coefficient was at least 0.8 (on the basis of Martin and Bateson 2013) .

Scatterplots for illustration of correlations and boxplots based on absolute values were made with R. All means and standard deviations (SDs) shown in the results section were calculated with the raw data in Excel. To better illustrate the differences between the methods we calculated the differences by calculating values of Observer minus the respective values of Equisense and presented these differences in boxplots as well. These calculations and their plotting were performed in Excel.

The Intra-observer reliability (IOR) was tested using BORIS (version 7.013; Cohen´s kappa, interval time: 2 s). For this purpose, 20 randomly chosen videos (10 personality and 10 round pen videos) were watched twice from the observer with two weeks apart. The overall IOR was $\kappa = 0.858$. For the personality tests the IOR was $\kappa = 0.805$ and for the round pen tests the IOR was $\kappa = 0.911$. For the single gaits during the personality tests the IOR was as follows: standing $\kappa = 0.796$, walk $\kappa = 0.934$. For the round pen tests the single IOR had following results: standing $\kappa = 0.934$, walk $\kappa = 0.925$, trot $\kappa = 0.925$, canter $\kappa = 0.884$. The jumps occurred during the video analysis three times and the IOR was $\kappa = 1$. The IOR for transitions in general was $\kappa = 0.903$, for the personality test $\kappa = 0.912$ and for the round pen test $\kappa = 0.893$.

3. Results

In total 22 different stallions carried the motion sensor and were observed during one of the two or during both tests. From 132 sessions (30 for round pen and 102 for personality tests) with Equisense data of only 124 sessions could be collected, due to Bluetooth connection issues. These 124 sessions resulted in 1124 Equisense data points and 1188 Observer data points of which also only 1124 could be used for the comparison analysis, because the equivalent Equisense data of the others was missing.

3.1. Differences between methods over all tests

Our comparative analysis of the two methods to record gaits in horses revealed that there were significant differences in duration of standing and walk, in the total duration of locomotion, in the frequencies of jump and in the calculated (Totalcalc) and recorded (Totalger) duration of the session (Table 2). For both methods neither trot and canter nor transitions showed significant differences, but correlation coefficients of transitions were below 0.8. Correlations were above 0.8 for all other variables, mostly above 0.9 (Table 2).

3.1.1. Duration of gaits and total observation times

The average duration of walk was longer for Equisense than for Observer. In line with that, the average duration of standing was shorter (Table 2, Figure 15, Annex 1 Figure A1 & A2) . Accordingly, the duration of TotalLoc was also longer for Equisense than for Observer (Table 2, Figure 16, Annex 1 Figure A3). Regarding trot and canter there was almost no difference in the average duration (Table 2 and Figure 15).

Significant differences between the methods were also found in Totalger and Totalcalc. On average Observer recorded longer duration in Totalger and Totalcalc than Equisense did (Table 2, Figure 15). Within Equisense the duration of Totalger was, on average, 2 seconds longer than the duration of Totalcalc, with the extremes of no difference in one horse during the ventilator test and 71 seconds difference during the round pen test in another horse.

Table 2: Results of linear mixed models (LMMS, p-Value), Wilcoxon tests(p-Value), Pearson correlation coefficients (Pearson's r) and descriptive statistics of the durations of different gaits and totals and frequencies of jumps and transitions. Mean and standard deviation (SD) are based on raw data, not model estimates, and show seconds for durations or number of events for frequencies. Difference was calculated by subtracting the Equisense mean (E) from the Observer mean (O). The p-values, which show a significant difference were highlighted in bold. N=124 for all variables.

Parameter Gait	p-Value	Pearson's r	Type	Mean	Difference (O minus E)	SD
Standing	**0.001**[1]	0.954	Observer	54.02	14.08	34.68
			Equisense	39.94		32.40
Walk	**0.001**[1]	0.894	Observer	21.03	-5.27	17.40
			Equisense	26.3		18.92
Trot	0.396[1]	0.990	Observer	15.22	0.66	27.37
			Equisense	14.56		26.36
Canter	0.551[1]	0.986	Observer	12.34	0.20	22.65
			Equisense	12.14		22.02
Transition	0.612[2]	0.752	Observer	1215	23	-
			Equisense	1192		
Jumps	**0.01**[2]	-	Observer	12	9	-
			Equisense	3		
TotalLoc	**0.001**[1]	0.991	Observer	48.6	-4.3	63.13
			Equisense	52.9		61.83
Totalger	**0.001**[1]	0.991	Observer	102.63	7.08	54.54
			Equisense	95.54		55.13
Totalcalc	**0.001**[1]	0.986	Observer	102.63	9.59	54.54
			Equisense	93.03		55.34

[1] p-Value of LMMS

[2] p-Value of Wilcoxon test

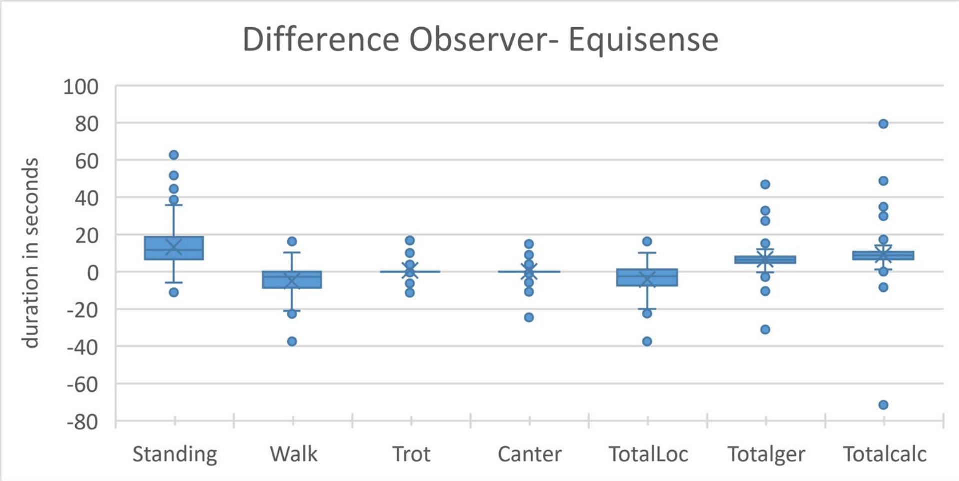

Figure 15: Boxplot show the differences of Equisense Motion Sensor (Equisense) and live observation (Observer) for the durations of the gaits and the different total durations in seconds over all personality and round pen tests (n=124).

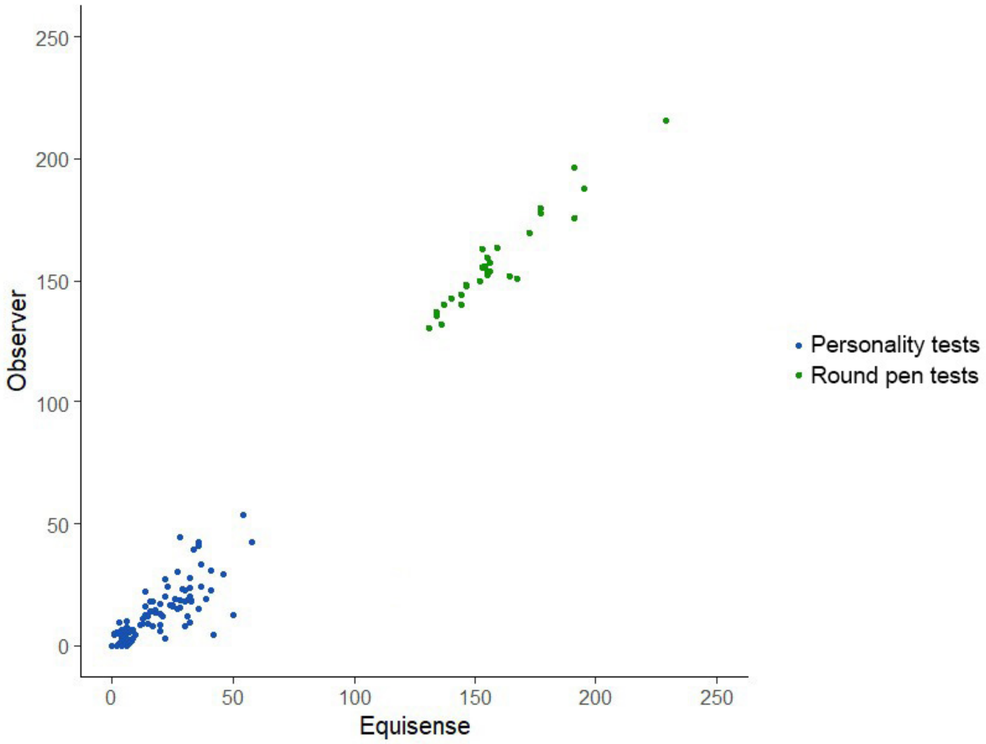

Figure 16: Scatterplot of total of locomotion during the personality (in blue) and during the round pen test (in green) measured by Equisense Motion Sensor (Equisense) and live observation (Observer) over all tests (n=124).

3.1.2. Differences in frequencies of jumps and transitions

The horses rarely jumped and Observer recorded more jumps than Equisense did (Table 2). Observer recorded 12 jumps, whereas Equisense only recorded 3 jumps, only one of these agreeing with a jump recorded by the Observer. All the recorded jumps from Observer occurred during the personality tests (3 jumps during the noisy approach and the other 9 jumps during the surprise test). Equisense recorded 2 jumps in two different horses during the round pen test and 1 jump during the noisy approach test.

A total of 1215 transitions were recorded from Observer and 1192 were recorded from Equisense (Figure 17 & 18). No significant difference, i.e. no directed bias, between methods was found in the number of transitions (Table 2). The biggest outlier was found during the round pen test in one horse. In this case the Observer recorded 50 while Equisense only recorded 23 transitions (Annex 4 Figure 21). However, the correlation coefficient of transitions was 0.752, which is close to the threshold of 0.8 (Table 2). Precise comparison within the transitions (for example the amount of transitions between standing and walk) could not be done, because Equisense only recorded the general number of transitions for one session.

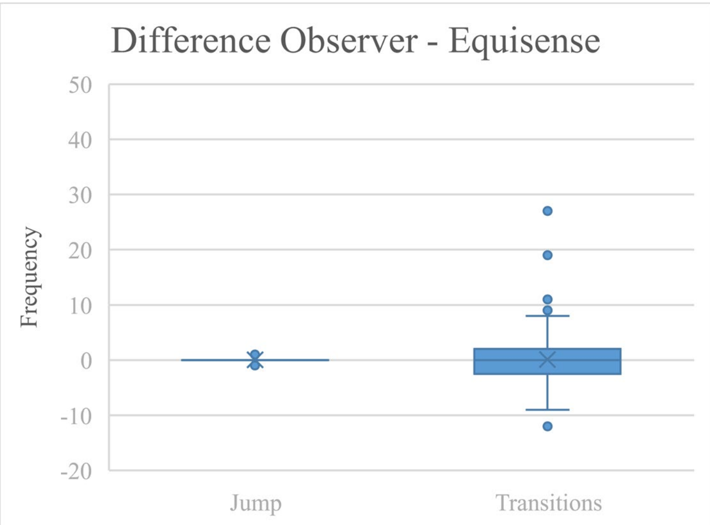

Figure 17: Differences between Equisense Motion Sensor (Equisense) and live observation (Observer) in the frequencies of jumps and transition during personality and round pen test

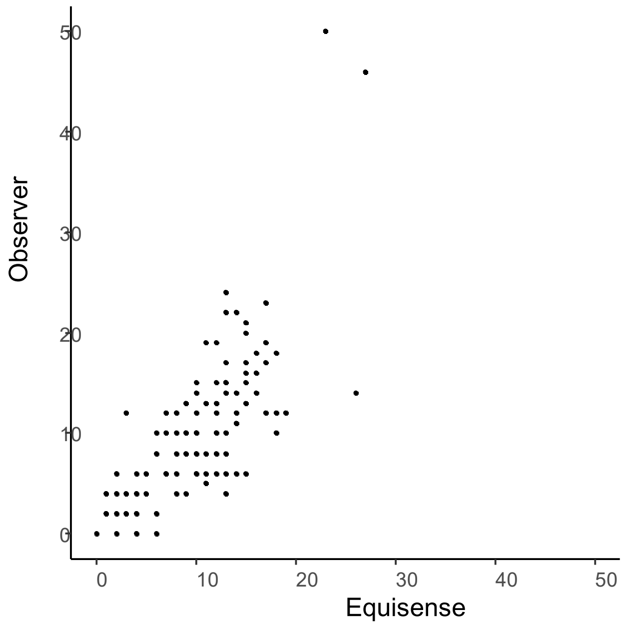

Figure 18: Scatterplot of transitions measured by the Equisense Motion Sensor (Equisense) and live observation (Observer) over all tests. Pearson correlation coefficient was close to 0.8 (r=0.752, n=124).

3.2. Differences between methods within tests

The correlation coefficient of standing was above 0.8 for the personality tests in total as well as for the unknown surface, the surprise and noisy approach test, whereas it was below this threshold for the other single personality tests and the round pen test. For the latter and the novel object test the correlation coefficient was below 0.3 (Table 3, Annex 2 Figure A4 to A11) While walk showed correlation coefficients above 0.8 for the round pen test and the passive human test, it was below this threshold for the personality tests in total and the other single personality tests (Table 3, Annex 3 Figure A12 to A19). For the round pen test trot as well as canter showed correlation coefficients close to 0.8. For the personality tests canter was not recorded either by Observer nor by Equisense, while trot was only recorded by Observer in 5 different horses in each case during the noisy approach test. The duration of trot ranged between one and seven seconds. Trot occurred in two horses twice during the noisy approach test.

The transitions showed a correlation coefficient above 0.8 for the round pen test, whereas it was below the threshold for the personality tests. Within the single personality tests the correlation coefficient was only above 0.8 for the unknown surface test. The surprise and noisy approach test showed a coefficient in the minus range (Table 3, Annex 4 Figure 21 to 28).

Regarding TotalLoc the correlation coefficient was above 0.8 for the roundpen as well as the passive human and noisy approach test, while it was below 0.8 for the personality tests in general and the other single personality tests. Totalger and Totalcalc showed a correlation coefficient above the threshold for the personality and round pen tests in general as well as for the unknown surface and surprise test, whereas the other single personality tests revealed a coefficient below 0.8.

Table 3: Pearson's correlation coefficients of the durations of gaits, the totals and the frequency of transitions within the Personality and Round pen test (Personality and Round pen) as well as within the sub personality tests. The correlation coefficient above 0.8 are highlighted in bold.

Gait	**Personality** N=94	**Round pen** N=30	**Passive Human** N=15	**Novel Object** N=16	**Unknown Surface** N=15	**Surprise** N=16	**Ventilator** N=17	**Noisy Approach** N=15
Standing	**0.939**	0.289	0.782	0.107	**0.886**	**0.936**	0.639	**0.827**
Walk	0.780	**0.879**	**0.838**	0.645	0.491	0.405	0.657	0.789
Trot[1]	-	0.784	-	-	-	-	-	-
Canter[1]	-	0.762	-	-	-	-	-	-
Transition	0.724	**0.838**	0.718	0.786	**0.901**	-0.279	0.593	-0.06
TotalLoc	0.785	**0.959**	**0.838**	0.645	0.491	0.405	0.657	**0.813**
Totalger	**0.978**	**0.995**	0.314	0.351	**0.998**	**0.939**	-0.348	0.03
Totalcalc	**0.983**	**0.874**	0.323	0.329	**0.998**	**0.939**	-0.381	0.606

[1]Trot did only occur rarely and canter did not occur at all during personality tests and thus no correlation coefficient were calculated.

3.3.Associations of duration of locomotion and lines crossed

The highest number of lines crossed by one horse was 9 during the ventilator test, the second highest number was 7, once during the noisy approach test and once by another horse during each the ventilator and unknown person test. TotalLoc from Equisense as well as TotalLoc from Observer were correlated with the numbers of Lines. The correlation coefficient was below 0.8 for Equisense (r = 0.731) but just reached the threshold for Observer (r = 0.795).

3.4.Differences between operating systems

During the transmission process, we noticed differences between operating systems running the Equisense application. The iOS operating device recorded always one more transition than the Android operating device. Therefore, we compared the data with another iOS device (iPhone 6) and another Android device (Sony Xperia Z), with the same result, iOS devices recorded one more transition.

4. Discussion

4.1.Gait differences

During this study all gaits (standing, walk, trot, canter) were recorded and observed as well as the amount of gait changes (transitions), jumps and the duration of total locomotion.

4.1.1. Walk and Standing

The results revealed that the Equisense Motion Sensor recorded more walk and less standing behaviour than Observer did. One explanation could be that different definitions of walk and standing were used. As the observer was following her definitions, which implied that walk was counted when more than two limbs started to move, she did not record scratching as walking behaviour. It might be that the motion sensor started recording walk, when the horse just did minor leg movements (for example stamping because of flies or scratching with the hoof on the ground). However, this cannot be checked without the raw data of Equisense, as the application only shows the duration of the gaits but not the exact time codes of the individual gaits. Furthermore, Equisense does not share their exact definitions of the gaits on their homepage. We tried to get in contact with Equisense to acquire the raw data to verify our theories, but we did not receive an answer at the time of writing this thesis.

4.1.2. Jumps

The Jumps recorded by Equisense and Observer only overlapped once. Observer only recorded jumps during the umbrella and the ventilator test, whereas Equisense recorded two jumps during the round pen test and one during the ventilator test. The latter one was corresponding to Observer. The recorded jumps during the round pen test could be explained by bigger canter jumps of one horse and a kick by another horse when changing from canter to trot. The lack of agreement might indicate that there are also differences in the definitions of the behaviour, as the jumps during riding including a flight time (for definition see 1.2.1.) and the small jumps during personality tests as defined in our ethogram (see 2.4.1.) are completely different. Furthermore, the jumps during the personality tests also do not correspond to the requirements of Equisense (jumps has to be at least 70 cm or higher; Equisense 2018) and also differ from the definitions of Hertsch (2012) and Buchner (2012) shown in the introduction (1.2.1). The reason why Equisense determined the threshold of 70 cm, could be because the sensitivity of the sensor is not high enough to record smaller jumps accurately.

4.1.3. Transitions

Since there are differences between the observation and the measurements of the sensor for standing and walking behaviour as well as some technical issues, it is not surprising that transitions correlated below the threshold of 0.8, although there was no significant difference between methods. The transitions are only calculated overall for each test by Equisense. This means that it cannot be interpreted between which gaits the transitions took place. On the one hand, even a perfect correlation would not mean too much, because, for example, if the observer recorded a transition between standing and walk, but Equisense between walk and trot, there would be no possibility to differentiate those two recorded transitions. On the other hand, if we take the other results into account, we can give that value more meaning, because if the correlations within the different gaits are very high, it can be assumed that also the gait transitions were similar. However, this cannot be verified conclusively with the data provided by Equisense (Equisense 2018).

During this master thesis the observer recorded 23 transitions more than Equisense. This could also be the result of differences in the perception of the velocity or rather at the hoof beat between the sensor and the more sensitive observer.

4.2.Tests

In total seven tests were conducted during this master thesis (six different personality and one round pen test). The round pen test was intentionally implemented to test faster gait changes. Certainly, the round pen test is more in accordance with the intended usage of the sensor, which could explain the good correlation in this test.

4.2.1. Personality tests

Overall personality tests for standing showed good correlation between methods, however, within the personality tests, standing correlated sufficiently high only for the unknown surface, the surprise and the noisy approach test. In the novel object test this might be because some horses scratched the novel object some time but then ignored it. As described above, we assume that the Equisense Motion Sensor recorded scratching already as walking behaviour. If we look at the scatterplots of the sub tests in detail, we can see that the outliers, i.e. where the difference between methods was especially large, were recorded mostly during the ventilator and unknown surface test. This could be similarly due to these divergent definitions of Equisense Motion Sensor and the observer, as the horses scratched during these tests more on the ground than during other tests. Further, it is notable, that the Observer recorded in two horses during the unknown surface test less standing than Equisense did. The difference was 30 seconds for one and 44 seconds for the other horse. These two horses were particularly cautious when crossing the surface, so that they may have walked too slowly for the sensor. Standing has a strong correlation during the surprise test, which could be because some horses only moved their head upwards and did not move their whole body away from the surprising opening of the umbrella.

Not only the unknown surface test but also the surprise test scored poorly for the correlation of different methods measuring walking time. Sudden movements like the ones in the surprise test, which lasted only a short time, seemed to be difficult to record for the sensor. To find another explanation for the bad results, we looked at the western disciplines, in which the horses also have the basic gaits (walk, trot, canter) but also have additional movements (also called manoeuvres) which slightly differ from other disciplines (Holtappel 2008). In some western disciplines (e.g. reining) the so called roll back (180 degree turns on the hind legs; OEPS 2019b) occurs, which reminds of the reactions of some horses during the surprise test. This might explain why walk scored so poorly during this test, as the developers of Equisense state that their algorithm does not consider specific western gaits (Equisense 2018). The reason why specific western gaits are not considered by it is not further explained by them but similar measuring problems could occur for movements such as sliding stops (fast stopping of the horse), back up (to direct the horse to go backwards) or spins (quick turning) as well (Holtappel 2008). Most likely back up or roll backs could be compared to some reactions during the surprise test, in which some horses tend to turn away from the umbrella or just walk few steps backwards.

4.2.2. Round pen test

Standing did not correlate between methods in the round pen test. This could be because standing was such a small part of this test compared to the other gaits: only 15 seconds at the beginning. Few horses stopped during the change between walk and trot or between walk-trot-canter for few seconds. This stopping was abrupt and short. Therefore, the bad correlation of standing could be either because the sensor is not sensitive enough to measure sudden movements, or because there is a problem in the resolution of the sensor. It could also be a mixture of both problems. Walk and transitions correlated strongly while trot and canter correlated below the threshold of 0.8. Another reason, why walk was strongly correlated could be that the sensor could better measure the walking behaviour during the round pen test, as it was of longer duration than during the personality tests.

4.3. Association of duration of locomotion and lines crossed

In our study we also recorded the areas the horse had crossed during the different personality tests (Lines), which is normally done to assess the activity level during these tests. However, we did that mainly for another study. The correlation coefficient of Lines with TotalLoc for

Equisense was below 0.8, whereas for Observer it just reached the threshold. This could be because the divided areas had a size of 5x3 m, which is big enough that the horses could move within the squares without crossing a line. Lansade et al. used for their studies smaller sizes of the squares. The size of one square ranged from 2x1.5m to 2x2m (Lansade et al. 2007; Lansade et al. 2008a; Lansade et al. 2008c; Lansade et al. 2013). Even though our squares were bigger we still had a correlation of 0.8 with the observer. If we would focus on an automated comparison of line crossed with the data of a motion sensor there are two possible solutions: One would be to pinpoint the exact location of the horse in the test area during the whole test procedure with a very accurate geo-tagging feature. The other would be to use laser sensors or light barriers in the testing area, which track the crossing of the lines.

4.4.Technical Issues

We could not get Equisense data of 5 sessions because of connection problems to the phone during the personality tests, despite their earlier information, that the sensor has a recording capability and should transfer the data once the Bluetooth connection is established again. (Equisense, 2018). Those 5 sessions which are corresponding with 63 data points were lost. During the round pen tests, the connection to the phone got lost just once, and it happened during the habituation phase and therefore no data was missed. This might have been because two different phones (Personality tests: iPhone XS, Round pen test: Samsung Galaxy A8) and therefore two different operating systems (IOS and Android) were used.

Another co-worker of the Swiss National Stud Farm using Equisense Motion Sensor on the field reported more regular connection failures with her mobile device (Sony Xperia Z) compared to the ones which happened during our study. Therefore, it can be assumed that depending on the mobile phone the connection quality varies. It might be because recent phones have a better Bluetooth Version. As stated on the Webpage of Equisense Motion Sensor it has a Low Energy Connection Version 4.0+ (Equisense, 2018). It is specified in the FAQs, that Equisense is compatible with iOS 10 and newer, as well as Android 4.3 and newer. Further they blacklist some phones and state, that one is responsible for any errors that occur, when using one of these blacklisted phones (Equisense 2018). Another reason for this problem could be that interference can occur between Wi-Fi and Bluetooth, when they operate at the same time in close proximity (as it is the case for a mobile device; Challoo et al. 2012) As we were not aware of this problem beforehand we did not turn off the Wi-Fi during the testing. However, problems with the Wi-Fi and Bluetooth should be avoidable as Equisense (2018) indicates that you do not need an internet connection to use the app and the sensor. Once logged in (for this step you need internet connection), one can use the sensor without an internet connection.

Another issue found during analysing the Equisense data on the phones is that the total duration of all gaits (Totalcalc) is always lower than the total duration of the session given by the Equisense (Totalger). This means, if standing, walk, trot and canter recorded by Equisense is summed up to 150 seconds, then Equisense itself will output a total of, about, 152 to 155 seconds of session length. In one case (during round pen test) the difference was as large as 71 seconds and in another case (during ventilator test) it was equal. An explanation could be that it is a rounding issue, which might be verified by checking the raw data of Equisense.

As in this study, the focus was on the gaits and not on the individuals, it would be interesting to know if the sensor would score better or worse with other horse breeds. Especially, since the Franches-Montagnes stallions are known for their calm mind and their broad field of application (Schweizerischer Freibergerverband 2020; Röger-Lakenbrink 1997), it could be that their calmness affects their locomotion. A breed with more or less stride frequencies could bear new problems for the sensor similar the one described before with the surprise test (see 4.2.1.). For example, in the study of Burla et al. (2014) Icelandic horses showed relatively high stride frequencies, i.e. a higher number of steps/min at least for walk. However, to our knowledge, there are no further studies on influence of breed classes on walk parameters to compare with.

4.5.Future applications and lookout

If the issues of Equisense can be solved there are some possibilities to objectify analysis and information available in today's equine science, as for example in activity measurements or detecting lameness (Lopes et al. 2018; Burla et al. 2014). Equisense (2018) already indicated that the motion sensor could also be used for lameness detection, but to our knowledge this was not yet validated. In other species, e.g. cows, sensor techniques to monitor locomotion or other health parameters are already used additionally for herd management (Fasching et al. 2018; Rombach et al. 2018; D'Andrea et al. 2017)

The main issue of any technical device is to make sure that the delivered data is accurate. The Equisense Motion Sensor seemed to be relatively accurate in some instances, especially measuring locomotion during the round pen tests. It also showed good results during the passive human personality and noisy approach test, but it had some clear problems differentiating standing and walking as well as fast changing movements like smaller jumps during a fear reaction or short trotting sequences resulting from flight-responses, which were only recorded by Observer.

Our hypothesis that smaller jumps during a fear reaction can be recorded accurately was refuted. Also, the issue that different versions and devices partially deliver different results cannot be underestimated. The latter issue could be circumvented by defining a standardised version and device for everybody in a study to work with. However, the problem with jump detection needs to be resolved by Equisense or improved in joint work of science and Equisense. Since this work linked a lot of issues to different behaviour descriptions between Observer and Equisense, it would be a necessary starting point to standardize definitions. Furthermore, the availability of the raw data of Equisense would help to compare it with observer data and facilitate the Equisense exclusive analysis in the long run. When those issues are solved, Equisense could build a foundation for further work and a baseline for objective analysis in horses would be created.

This would be especially important if researchers wanted to efficiently investigate behaviour or maybe personality in individuals in free living herds. For instance, in young horses and stallions the movement activity of trot and canter is higher than in mares (Zeitler-Feicht 2015). If using such a sensor these or similar investigations could be extended, by recording the movements of more animals for longer time more easily. This could only be reflected in the recorded data if the technical innovations were highly improved because today the Equisense Motion Sensor does not reach the standard of human observation. In a study of Dahl et al. (2018), they used a new tool (bio-logging with inertial sensor techniques), which they subjected to a machine learning algorithm to investigate behavioural patterns in a free-ranging horses range but did not cover any problems with the technical device. Bio-logger is a device, attached to the animal (directly or mounted on collar or even implanted), which provides data about the animals movement, behaviour or physiology (Fehlmann and King 2016). Dahl (2018) concluded that bio-logging via inertial sensor techniques can replace video camera recordings and their extensive analysis. Furthermore, this should help automatic ethological investigations to categorise movement patterns of freely moving animals into reasonable classes. (Dahl et al. 2018)

Generally, a technological support bears possible problems, be it for accuracy, ethogram definitions or reliability, or also interpretation of the finished data. The final analysis can result in different interpretations of the recorded data, especially in the field of personality tests. Therefore, more studies like this one, in which human observations are compared to the technical data, should be done before any technical aid could and should reach a status to replace professional / scientific human analysis or observation.

5. Conclusion

The results revealed that the Equisense Motion Sensor is not valid to record locomotor activity in personality tests. They showed significant differences between human observations and Equisense measurements regarding the gaits standing and walk, which indicates that the sensor has systematic errors regarding the different definitions of the locomotor activity. In accordance with that, the Equisense Motion Sensor did not measure the total of locomotion accurately either. Furthermore, it did not measure smaller jumps as a fear reaction accurately. In addition, there were also some technical inconsistencies between different devices and software, which minimise the overall precision of the sensor. The imprecise gait measurements and the considerations regarding sudden movements and jumps suggested that Equisense also had problems with sensitivity and resolution. This indicated that there are also reliability problems beside the validity problems.

6. Abstract

Assessing and understanding personality in animals is a rising scientific field. This is the case especially in the horse field, where many approaches about measuring personality through different indicators exist. One of these indicators is locomotion. Since observations of animal locomotion are generally time consuming and require proper training of the observer, the interest in automatic assessment tools increased. The Equisense Motion Sensor is a commercially available sensor recently developed with the aim to support training sessions of individual riders and to measure the different gaits. The aim of this master thesis was to validate the use of the Equisense Motion Sensor during personality tests, in order to find out if this sensor records gaits, transitions as well as small jumps during a fear reaction accurately for scientific data acquisition. In the Swiss National Stud Farm in Avenches horses of the Franches Montagnes breed were tested with this sensor. 17 horses were tested during six different personality tests and 15 horses during one round pen test. The accuracy of the Equisense Motion Sensor was compared to human observations. Equisense recorded significantly more walk (LMMS $p = 0.001$) than the human observer, whereas the human observer recorded significantly more standing (LMMS $p = 0.001$) than Equisense did, which means that the sensor does not measure these gaits accurately. Furthermore, the sensor did not record smaller jumps during a fear reaction. In addition, there were some technical inconsistencies between different devices and software. In conclusion, the Equisense is not yet valid for use in personality tests.

7. Zusammenfassung

Das wissenschaftliche Interesse an der Persönlichkeit von Tieren ist ein stetig wachsendes Feld. Besonders auch bei Pferden, für welche es eine Vielzahl von Konzepten zur Messung der Persönlichkeit, mithilfe verschiedener Indikatoren, gibt. Einer dieser Indikatoren ist die Bewegungsaktivität. Da Verhaltensbeobachtungen sehr zeit-intensiv sind und eine angemessen geschulte und erfahrene Person benötigen, ist in den letzten Jahren das Interesse an technischen Hilfsmitteln gestiegen. Eines dieser potentiellen Hilfsmittel ist der sogenannte Equisense Motion Sensor, welcher mit dem Ziel entwickelt wurde, Trainingssitzungen von individuellen ReiterInnen zu unterstützen und die Dauer der verschiedenen Gangarten aufzuzeichnen. Das Ziel der vorliegenden Masterarbeit bestand darin, diesen Bewegungssensor auf seinen Einsatz im wissenschaftlichen Bereich bei Persönlichkeitstests zu validieren. Der Fokus lag hierbei auf der akkuraten Aufzeichnung der Gangarten, der Übergänge und Sprünge aufgrund einer Schrecksituation. Parallel dazu wurde auch bei allen Tests eine klassische Beobachtung durchgeführt. Für die Tests wurden Freiberger Hengste am Schweizer National Gestüt in Avenches verwendet. 17 Pferde wurden während sechs unterschiedlichen Persönlichkeitstests und 15 Pferde mittels eines Round-Pen-Tests getestet. Die Aufzeichnungen des Sensors wurden dann mit denen der Beobachterin verglichen. Im Hinblick auf Schritt (LMMS $p = 0.001$) zeichnete Equisense signifikant mehr auf als die Beobachterin. Damit übereinstimmend zeichnete die Beobachterin signifikant mehr Stehen (LMMS $p = 0.001$) auf. Dies zeigte, dass der Sensor nicht akkurat misst. Weiters zeichnete der Sensor kleinere Sprünge aufgrund einer Schrecksituation nicht auf. Aufgrund dessen und aufgrund einiger technischer Probleme zwischen verschiedenen Endgeräten und dem Sensor selbst, ist Equisense in seiner jetzigen Ausführung nicht für Persönlichkeitstests in der Wissenschaft verwendbar.

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9. List of Figures

10.List of Tables

Annex 1

Boxplots of absolute values for both methods

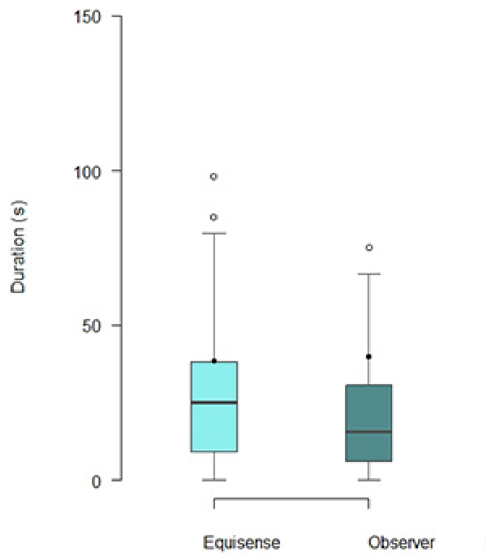

Figure A 1: Boxplot showing the duration of walk in seconds for the Equisense Motion Sensor (Equisense) and live observation (Observer). N=124

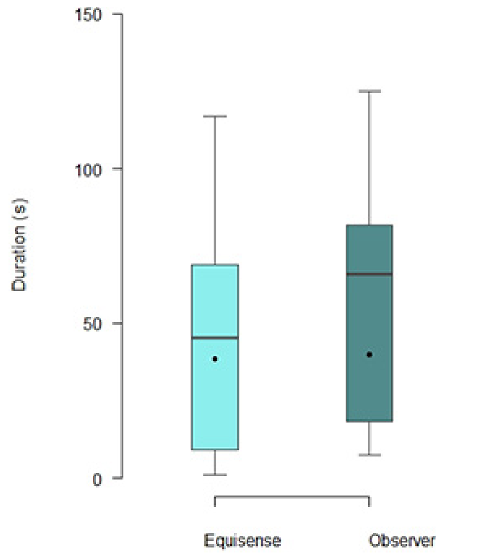

Figure A 2: Boxplot showing the duration of standing in seconds for the Equisense Motion Sensor (Equisense) and live observation (Observer). N=124

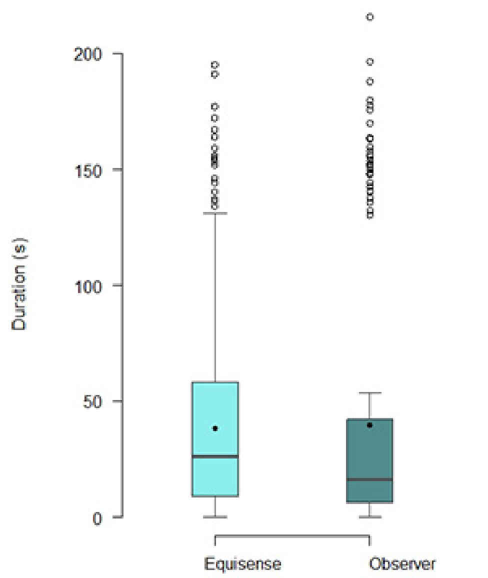

Figure A 3: Boxplot showing the duration of the total locomotion (TotalLoc) in seconds for the Equisense Motion Sensor (Equisense) and live observation (Observer). N=124

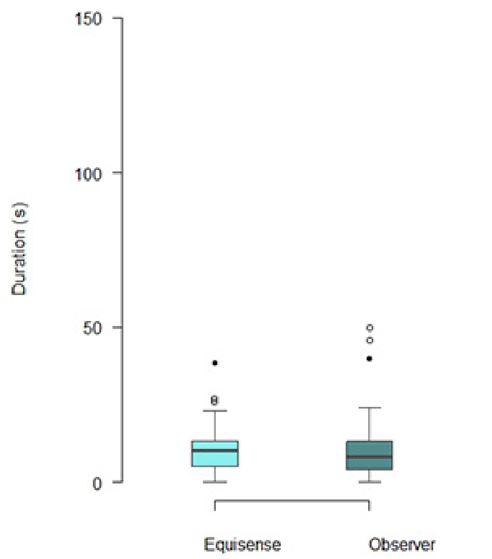

Figure A 4: Boxplot showing the frequency of transitions in seconds for the Equisense Motion Sensor and live observation (Observer). N=124

Annex 2

Scatterplots of standing during round pen, personality tests and within the sub personality tests

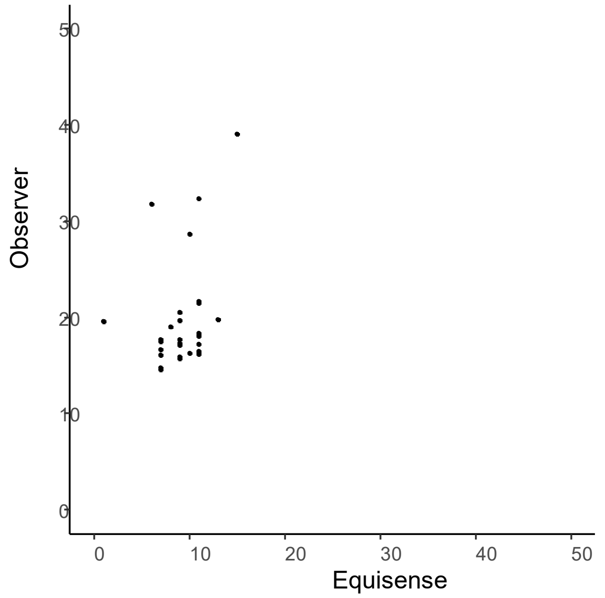

Figure A 5: Scatterplot of standing measured by Equisense Motion Sensor (Equisense) and live observation (Observer) during the round pen test. Pearson correlation coefficient was below 0.8 (r=0.289, n=30)

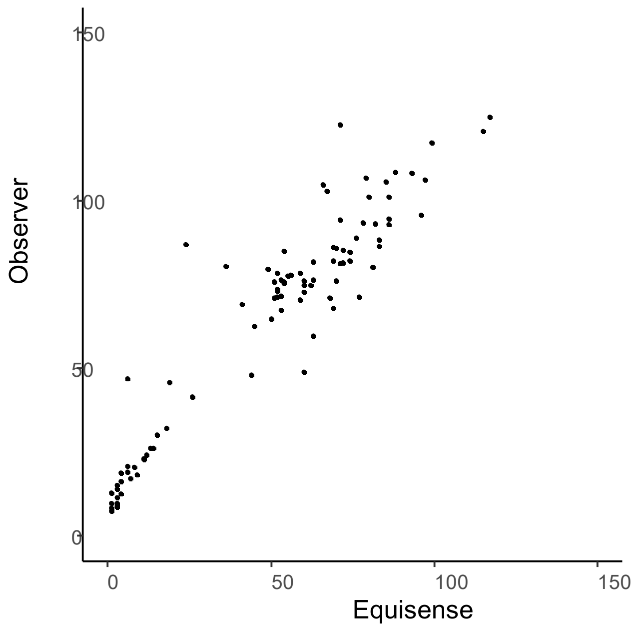

Figure A 6: Scatterplot of standing measured by Equisense Motion Sensor (Equisense) and live observation (Observer) over all personality tests. Pearson correlation coefficient was above 0.8 (r=0.909, n=101)

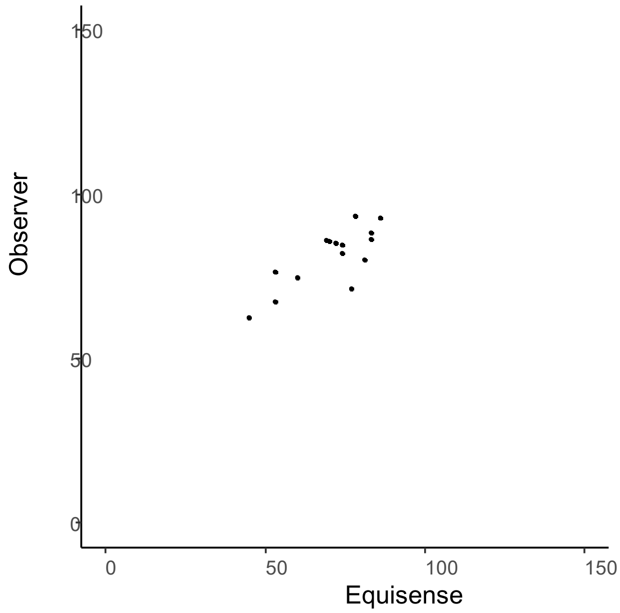

Figure A 7: Scatterplot of standing measured by Equisense Motion Sensor (Equisense) and live observation (Observer) during the passive human tests. Pearson correlation coefficient was close to 0.8 (r= 0.782, n=15)

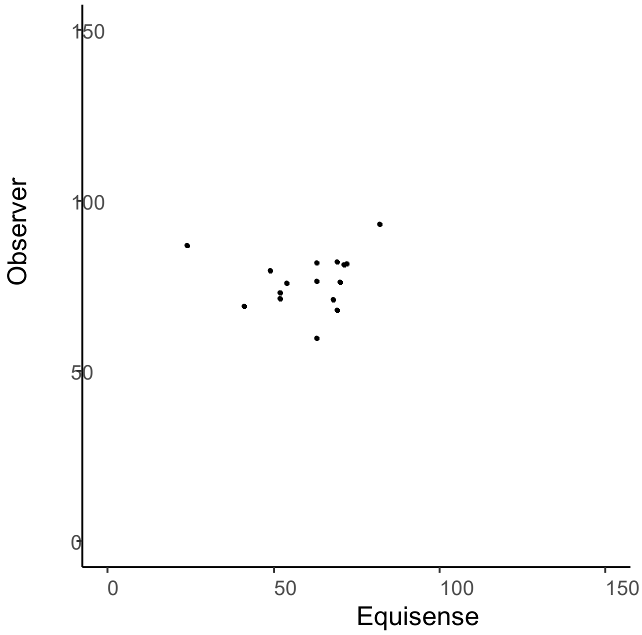

Figure A 8: Scatterplot of standing measured by Equisense Motion Sensor (Equisense) and live observation (Observer) during the novel object tests. Pearson correlation coefficient was below 0.3 (r=0.107, n=16)

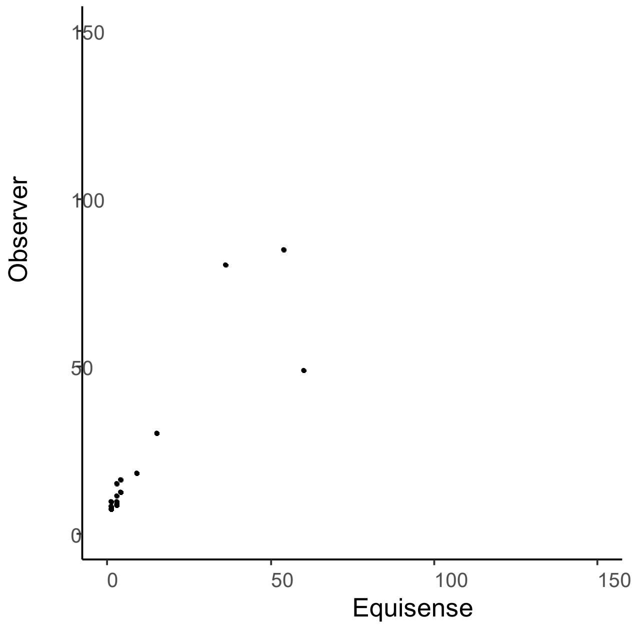

Figure A 9: Scatterplot of standing measured by Equisense Motion Sensor (Equisense) and live observation (Observer) for the unknown surface test. Pearson correlation coefficient was below 0.8 (r=0.598, n=15)

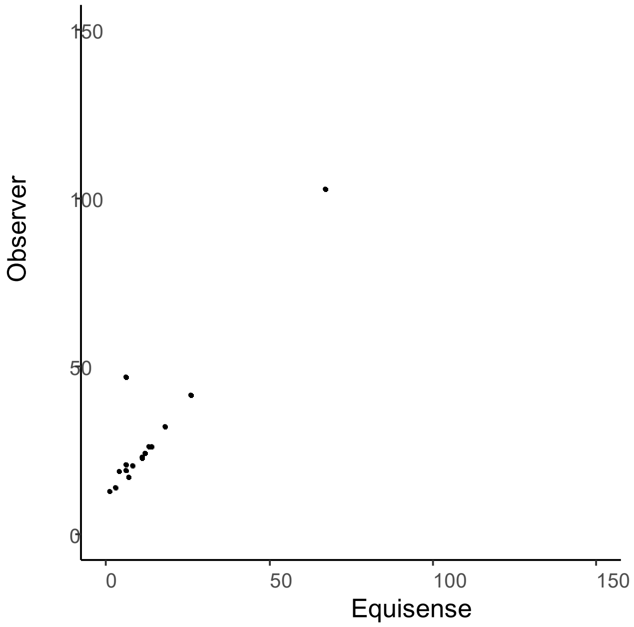

Figure A 10: Scatterplot of standing measured by Equisense Motion Sensor (Equisense) and live observation (Observer) for the surprise test. Pearson correlation coefficient was below 0.8. (r=0.936, n=16)

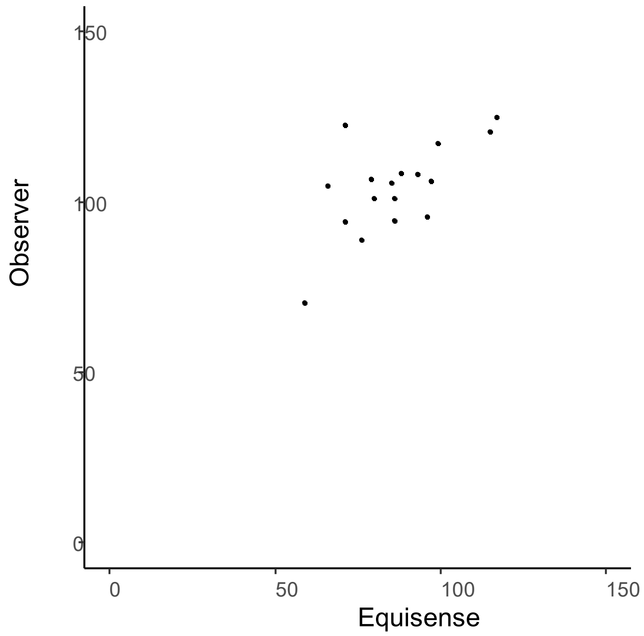

Figure A 11: Scatterplot of standing measured by Equisense Motion Sensor (Equisense) and live observation (Observer) for the ventilator test. Pearson correlation coefficient was below 0.8 (r=0.639, n=17)

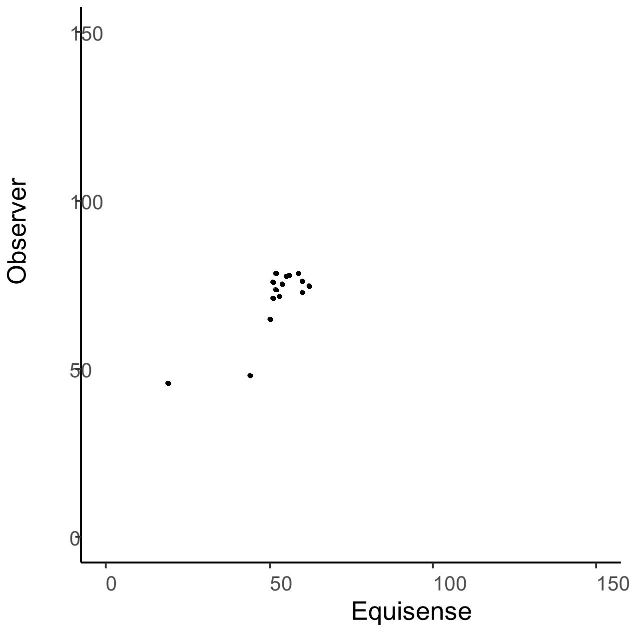

Figure A 12: Scatterplot of standing measured by Equisense Motion Sensor (Equisense) and live observation (Observer) for the noisy approach test. Pearson correlation coefficient was above 0.8 (r=0.827, n=15)

Annex 3

Scatterplots of walk in round pen, personality and within the sub personality tests

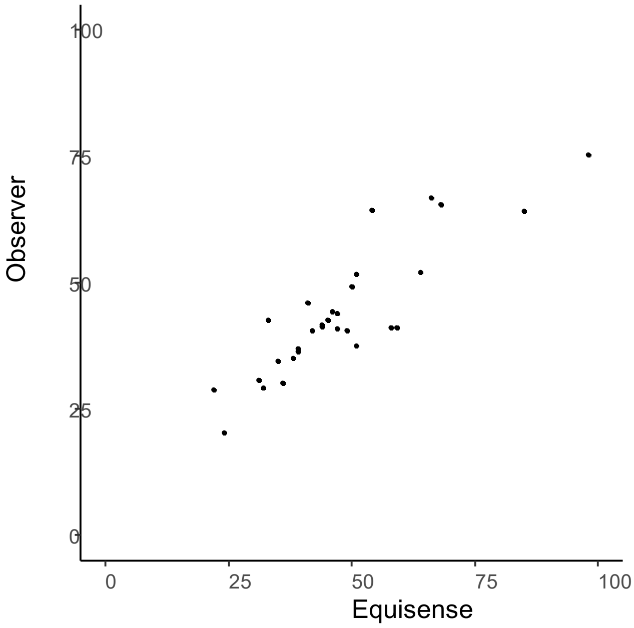

Figure A 13: Scatterplot of walk measured by Equisense Motion Sensor (Equisense) and live observation (Observer) for the round pen test. Pearson correlation coefficient was below 0.8 (r=0.879, n=30)

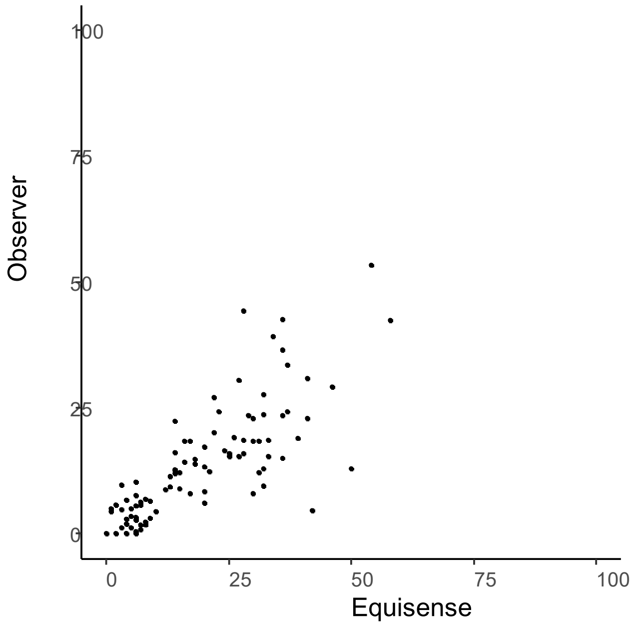

Figure A 14: Scatterplot of walk measured by Equisense Motion Sensor (Equisense) and live observation (Observer) for the personality test. Pearson correlation coefficient was below 0.8 (r=0.736, n=94)

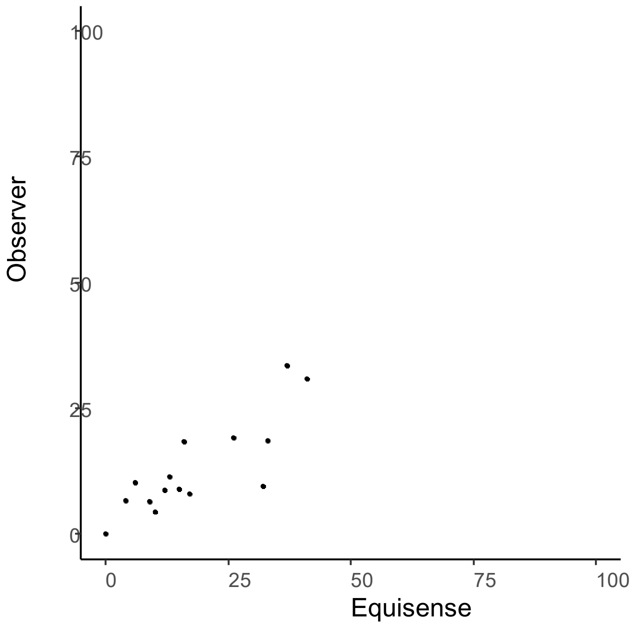

Figure A 15: Scatterplot of walk measured by Equisense Motion Sensor (Equisense) and live observation (Observer) for the passive human test. Pearson correlation coefficient was above 0.8(r=0.838, n=15)

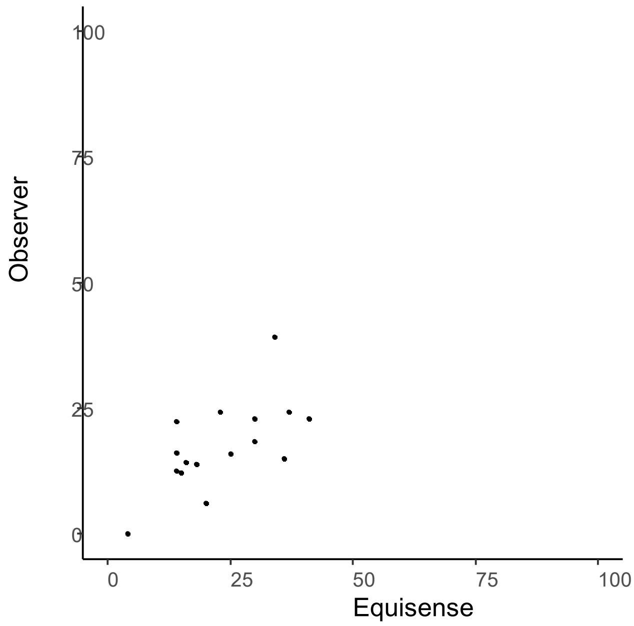

Figure A 16: Scatterplot of walk measured by Equisense Motion Sensor (Equisense) and live observation (Observer) for the novel object test. Pearson correlation coefficient was below 0.8 (r=0.645, n=15)

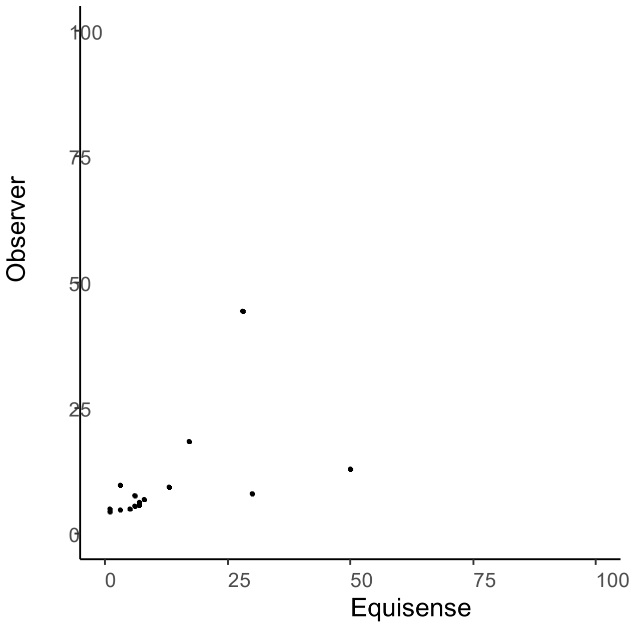

Figure A 17: Scatterplot of walk measured by Equisense Motion Sensor (Equisense) and live observation (Observer) over the unknown surface test. Pearson correlation coefficient was below 0.5(r=0.441, n=16)

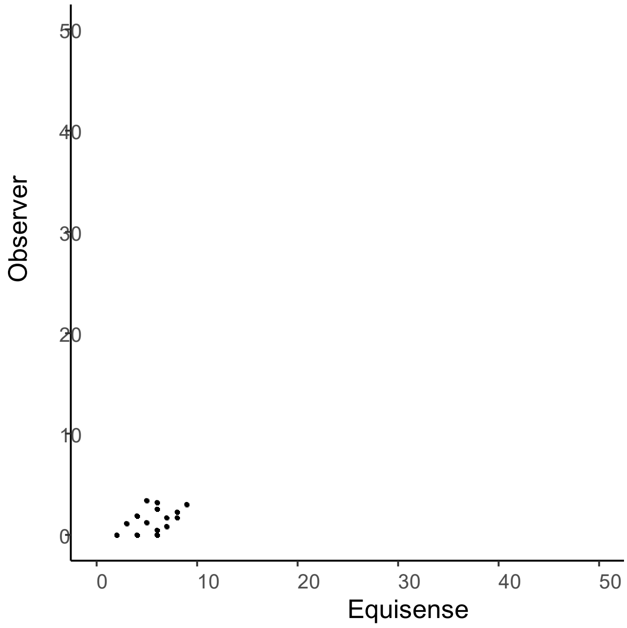

Figure A 18: Scatterplot of walk measured by Equisense Motion Sensor (Equisense) and live observation (Observer) over the unknown surface test. Pearson correlation coefficient was below 0.5(r=0.441, n=16)

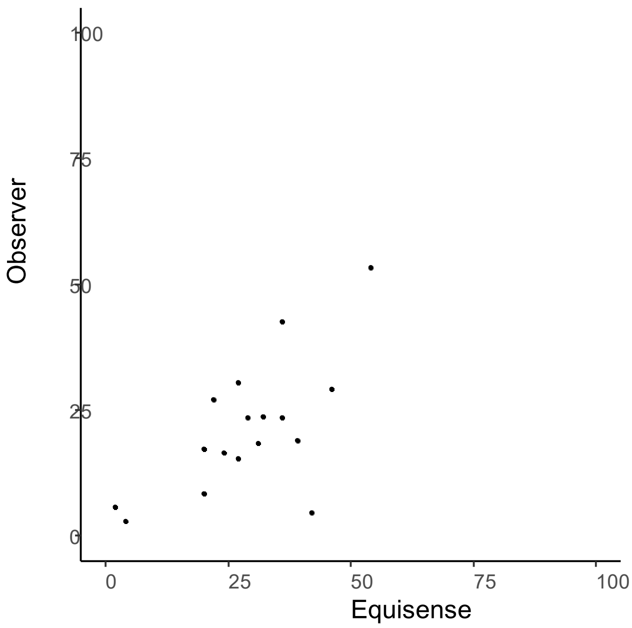

Figure A 19: Scatterplot of walk measured by Equisense Motion Sensor (Equisense) and live observation (Observer) for the ventilator test. Pearson correlation coefficient was below 0.8 (r=0.508, n=17)

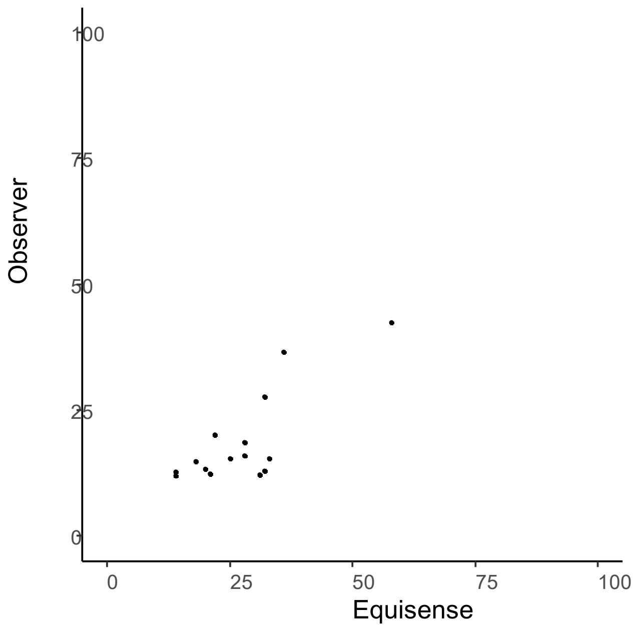

Figure A 20 Scatterplot of walk measured by Equisense Motion Sensor (Equisense) and live observation (Observer) for the noisy approach test. Pearson correlation coefficient close to 0.8 (r=0.789, n=15)

Annex 4

Scatterplots of transitions within the round pen, personality and sub personality tests

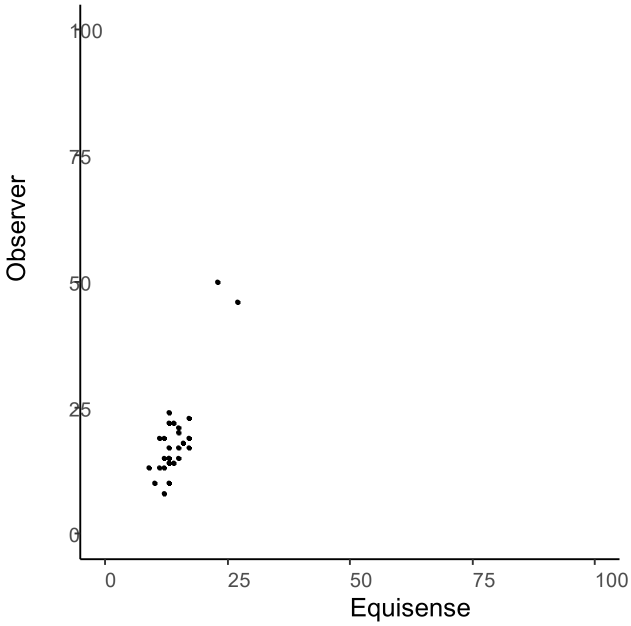

Figure A 21: Scatterplot of transitions measured by Equisense Motion Sensor (Equisense) and live observation (Observer) during the round pen test. Pearson correlation coefficient was above 0.8 (r=0.838, n=30)

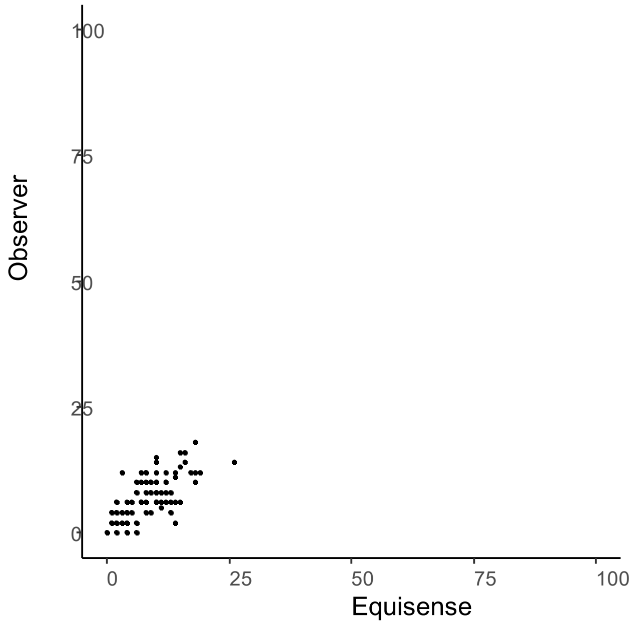

Figure A 22: Scatterplot of transitions measured by Equisense Motion Sensor (Equisense) and live observation (Observer) during the personality test. Pearson correlation coefficient was below to 0.8 (r=0.701, n=94)

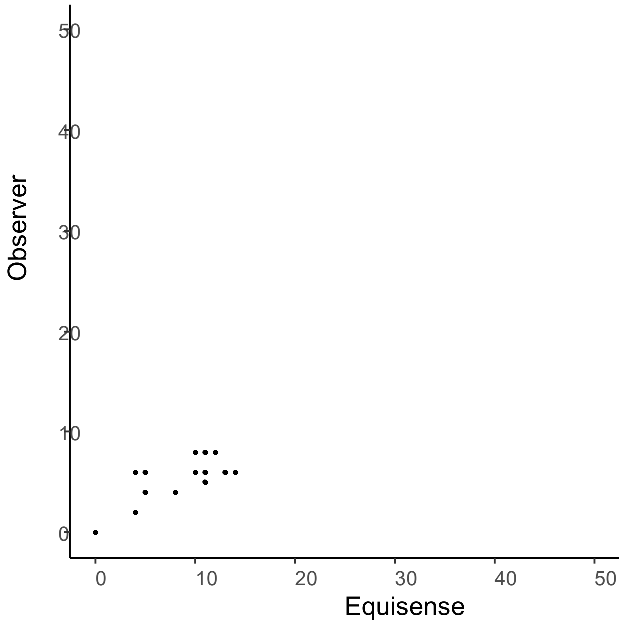

Figure A 23: Scatterplot of transitions measured by Equisense Motion Sensor (Equisense) and live observation (Observer) during the passive human test. Pearson correlation coefficient was below 0.8 (r=0.718, n=15)

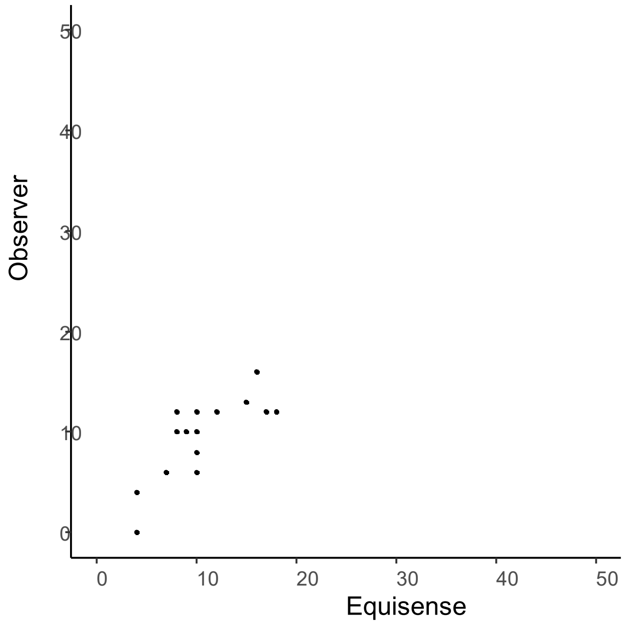

Figure A 24: Scatterplot of transitions measured by Equisense Motion Sensor (Equisense) and live observation (Observer) during the novel object test. Pearson correlation coefficient was close to 0.8 (r=0.786, n=16)

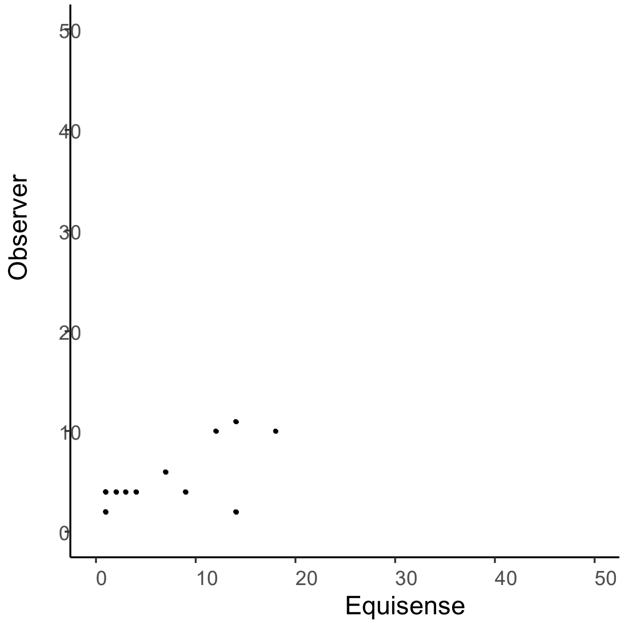

Figure A 25: Scatterplot of transitions measured by Equisense Motion Sensor (Equisense) and live observation (Observer) during the unknown surface test. Pearson correlation coefficient was below 0.8 (r=0.71, n=16)

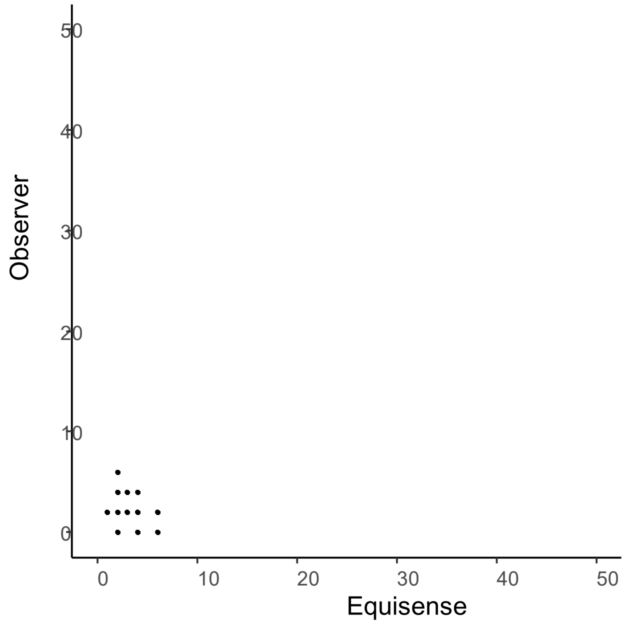

Figure A 26: Scatterplot of transitions measured by Equisense Motion Sensor (Equisense) and live observation during the surprise test. Pearson correlation coefficient was in the minus range (r=0.279, n=16)

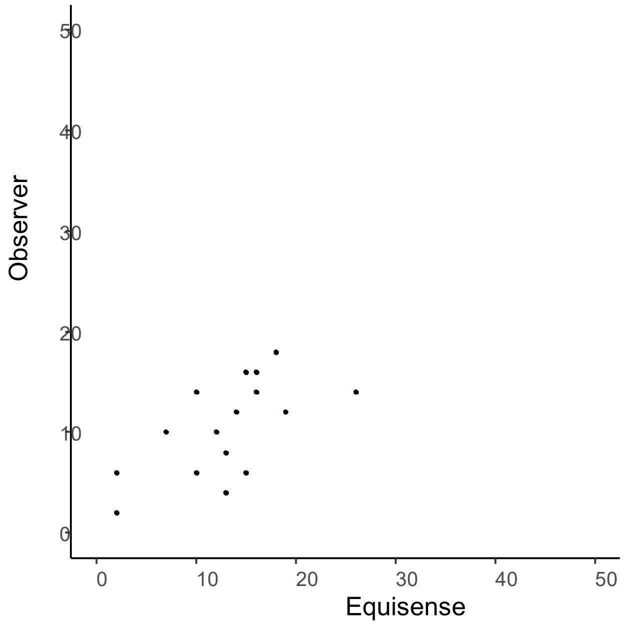

Figure A 27: Scatterplot of transitions measured by Equisense Motion Sensor (Equisense) and live observation during the ventilator test. Pearson correlation coefficient was below 0.8 (r=0.593, n=17)

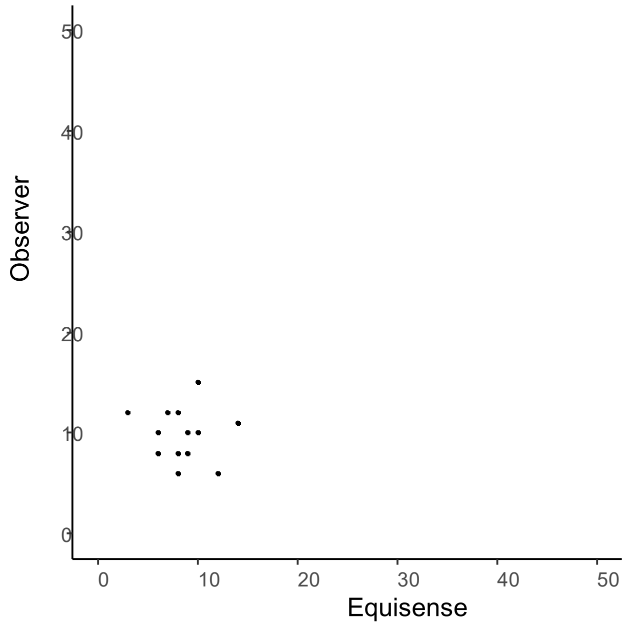

Figure A 28: Scatterplot of transitions measured by Equisense Motion Sensor (Equisense) and live observation (Observer) during the noisy approach test. Pearson correlation coefficient was in the minues range (r=-0.06, n=15)

Annex 5

Scatterplots of trot and canter during round pen test

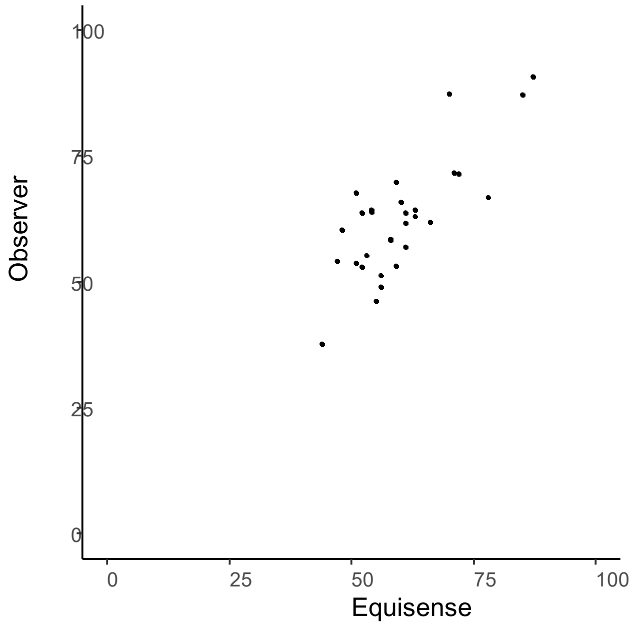

Figure A 29: Scatterplot of trot measured by Equisense Motion Sensor (Equisense) and live observation (Observer) during the round pen test. Pearson correlation coefficient was close to the threshold of 0.8 (r=0.784, n=30)

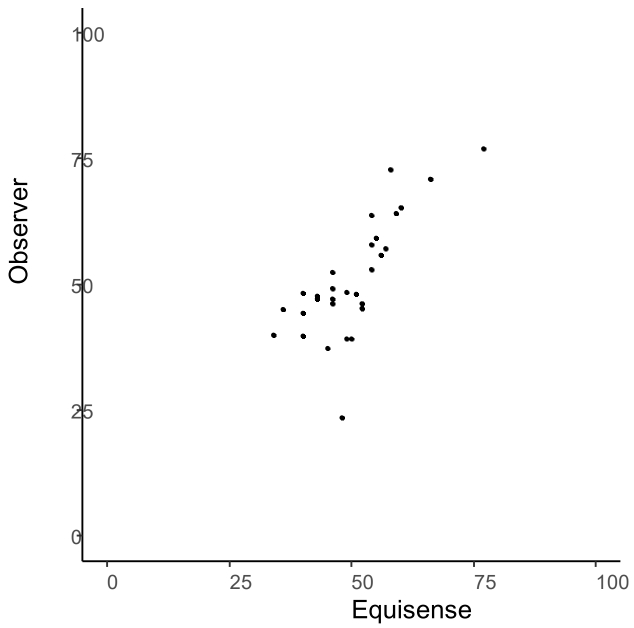

Figure A 30: Scatterplot of canter measured by Equisense Motion Sensor (Equisense) and live observation (Observer) during the round pen test. Pearson correlation coefficient was close to the threshold of 0.8 (r=0.762, n=30)