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„Effects of a low-budget virtual reality system on mood,
enjoyment and perceived exertion during cycling in
healthy people.“

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Abstract

The use of virtual reality (VR) while exercising increases physical activity (PA) levels, enhances adherence and positively impacts mood states. However, scaling its use is directly related to VR affordability. Therefore, the objective of the study was to assess the effects of exercising with low-cost VR setup on perceived exertion, general mood, and well-being of healthy young people.

Fifteen participants (23 ± 1.6 years; 70.7 ± 13.2 kg mass; 172 ± 9.7 cm height) completed six 25-minute exercise sessions on a cycle ergometer at 75% of their maximum heart rate (143.9 ± 0.8 bpm) under two conditions: three with VR (using VR) and three without VR (not using VR). The total of six sessions were conducted in a random order. The VR solution utilised a modified version of the Google LLC Cardboard, which allowed for attachment of a smartphone to the head. Participants using VR were immersed in a 360°-view video simulation of an outdoor ride, available on YouTube. Before and after the exercise sessions, participants completed the BRUMS questionnaire to assess mood states, and after the session the PACES questionnaire was conducted to measure enjoyment. Perceived exertion (PE) was also measured before, during and after the sessions using the BORG scale.

Statistical analysis revealed that participants' perceived exertion was higher without VR (median [IQR]: 14[2]) compared to exercising with VR (12[5]; $U(189.5)$; $p = 0.001$). Regarding enjoyment, results indicated that the low-cost VR solution yielded higher scores for certain positive-worded items, while exercising without VR resulted in higher scores for certain negative-worded items. Participants' mood states did not significantly differ between the two conditions before or after exercising. However, when comparing mood states before and after exercising with VR, participants reported feeling less annoyed, confused, sleepy, tired, and nervous, and more active and livelier. After exercising without VR, participants reported feeling more active.

VR programs have already demonstrated effectiveness in increasing the frequency and engagement in PA. However, the scalability of VR for PA is crucial to obtain the benefits, and this study provides evidence that low-cost alternatives can effectively expand the use of VR.

Zusammenfassung

Der Einsatz von virtueller Realität (VR) beim Sport erhöht die körperliche Aktivität, fördert die Aufrechterhaltung und wirkt sich positiv auf die Stimmung aus. Die Skalierung der Nutzung von VR hängt jedoch direkt mit der Erschwinglichkeit von VR zusammen. Ziel der Studie war es daher, die Auswirkungen des Trainings mit einem kostengünstigen VR-Setup auf die wahrgenommene Anstrengung, die allgemeine Stimmung und das Wohlbefinden gesunder junger Menschen zu untersuchen.

Fünfzehn Teilnehmer ($23 \pm 1,6$ Jahre; $70,7 \pm 13,2$ kg Masse; $172 \pm 9,7$ cm Größe) absolvierten drei 25-minütige Trainingseinheiten auf einem Fahrradergometer bei 75% ihrer maximalen Herzfrequenz ($143,9 \pm 0,8$ bpm) unter zwei Bedingungen: mit VR und ohne VR. Die insgesamt sechs Einheiten wurden in einer zufälligen Reihenfolge durchgeführt. Für die VR-Lösung wurde eine modifizierte Version der Google LLC Cardboard verwendet, die es ermöglichte, ein Smartphone am Kopf zu befestigen. Jenen Teilnehmern, die VR nutzten, wurde ein 360°-Video einer Fahrt im Freien, das auf YouTube verfügbar war, gezeigt. Vor und nach den Trainingseinheiten füllten die Teilnehmer den BRUMS-Fragebogen aus, um den Gemütszustand zu bewerten. Nach der Sitzung wurde der PACES-Fragebogen zur Messung des Vergnügens durchgeführt. Die wahrgenommene Anstrengung wurde ebenfalls vor, während und nach den Trainingseinheiten mithilfe der BORG-Skala gemessen.

Die statistische Analyse ergab, dass das Anstrengungsempfinden der Teilnehmer ohne VR höher war (Median [IQR]: 14[2]) als bei den Einheiten mit VR (12[5]; $U(189,5)$; $p = 0,001$). Hinsichtlich des Vergnügens zeigten die Ergebnisse, dass die kostengünstige VR-Lösung höhere Werte für bestimmte positiv formulierte Items ergab, während die Einheiten ohne VR zu höheren Werten für bestimmte negativ formulierte Items führte. Die Stimmungslage der Teilnehmer unterschied sich nicht signifikant zwischen den beiden Bedingungen (mit VR und ohne VR) vor oder nach dem Training. Beim Vergleich der Stimmungslage vor und nach dem Training mit VR gaben die Teilnehmer jedoch an, sich weniger genervt, verwirrt, schläfrig, müde und nervös zu fühlen und aktiver und lebhafter zu sein. Nach dem Training ohne VR gaben die Teilnehmer an, sich aktiver zu fühlen.

VR-Programme haben sich bereits als wirksam erwiesen, wenn es darum geht, die Häufigkeit und das Engagement beim Sport zu erhöhen. Die Skalierbarkeit von VR für PA ist jedoch entscheidend für die Erzielung der genannten Vorteile, und diese Studie liefert Anzeichen, dass durch kostengünstige Alternativen VR häufiger zum Einsatz kommen kann.

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1 Introduction

Regular endurance training has a positive effect on the cardiovascular system (Blomqvist & Saltin, 1983). These effects can be observed even with a low number of minutes per week at moderate to high intensity. The World Health Organization (WHO) issues guidelines for proper levels of physical activity, in which significant health benefits can be obtained when exercising at moderate-to-vigorous intensity for 75 to 150 minutes/week (World Health Organization, 2020).

The levels of physical activity have decreased over time due to various reasons, such as digitalisation, lack of time, social support or health problems, which is associated to a variety of cardio metabolic diseases, especially in developed countries such as North America or Europe (Knight, 2012; Anderson & Durstine, 2019; Gomes et al., 2017; Lee et al., 2012; World Health Organization, 2020; Rütten et al., 2009).

As an example, digitalisation has been associated to have an impact on sedentary behavior, leading to higher levels of sitting time. Studies have shown that the digital development of country is related to sitting time, indicating that if countries become more digitally developed, sedentary behavior tends to increase (Moreno-Llamas et al., 2020). A reason for that is increased use of digital devices such as laptops, tablets and smartphones, which is resulting in an increase in screen and, therefore, sitting time (McLaughlin et al., 2021). This may lead to reduced physical activity and increased sedentary time (Christofaro et al., 2016; Delfino et al., 2017; Moreno-Llamas et al., 2020; Borle et al., 2021).

These occurring diseases could be avoided with increased level of physical activity. If this is a major problem in technology affine countries, then the available technology may be a tool to contribute to a solution for this problem.

Especially in recent COVID-19 times, physical activity was negatively impacted due to the restrictions implied by the government to limit the spread of the SARS-CoV-2 infections. Therefore, sport facilities, such as swimming pools, gyms or playgrounds were closed resulting in decreased mobility and time spend outdoors (Shahidi et al., 2020). The self-reported performance of physical activity decreased whereas the sedentary behavior increased (Woods et al., 2020; Park et al., 2022; Shahidi et al., 2020; Castañeda-Babarro et al., 2020; Lesser & Nienhuis, 2020).

To target the problem of decreased physical activity, different programs have been discussed. These programs have to be tailored to the respective region, population, and circumstances to yield effective results (Baumann et al., 2009). Generally, there are four

different approaches. The first strategy is to change individual 's behavior with programs or gadgets in terms of generating more movement. Secondly, the change of social norms with mass communication and marketing. The third strategy is to influence the physical and social environment so that physical activity is encouraged. The last approach is the development and a resulting implementation of national physical activity scheme, which include resources and timelines to evoke measurable change (Baumann et al., 2009). The use of virtual reality to promote physical activity would be an alternative for changing individual behavior. Virtual reality is reported to introduce people to physical activity, improve adherence and impact mood in positive way (McClure & Schofield, 2019; Ulas & Semin, 2021; Ng et al., 2019; Yasukawa et al. 2021; Murray et al., 2016). The use of virtual reality is often associated with an exciting experience. This in combination with a distracting factor can contribute to an increase in physical activity because of positive effects regarding well-being and perceived exertion. Furthermore, the location independence, which can be converted into a time factor when traffic arises, speaks for the use of this equipment. If people live in a city and would like to cycle by a lake, this could be done easily with a virtual reality goggle in the living room. Furthermore, the weather independence as well as not being bound to seasons may lead to regular sporty activity (Neumann et al., 2018).

However, literature so far has been exploring specific virtual reality solutions that are not necessarily intended for home use and/or are based on expensive technologies. These two points might influence the reach of virtual reality as a strategy to increase people's physical activity levels and effectively change this behaviour.

Thus, the goal of this master thesis is to contribute to the fast-growing research and application of virtual reality in physical activity, by presenting and testing a cost-effective virtual reality solution on perceived exertion, mood and enjoyment.

2 Aim

The present thesis aims to propose, apply and assess a low-cost virtual reality solution as a feasible alternative strategy that can be used to ensure proper levels of physical activity. Therefore, the solution set, comprised of cardboard goggles and a video streamed on a smartphone, will be used during exercise performed in a cycle ergometer. The rate of perceived exertion, mood and enjoyment parameters of young healthy people will be assessed. It is hypothesised that the use of a custom-built and low-cost virtual reality setup while exercising will enhance young healthy people general mood and enjoyment and also reduce perceived exertion, when compared to not using the virtual reality solution.

3 Organisation of thesis

The thesis follows the IMRaD scheme with an added literature review. First, a literature review was conducted and following keywords were used to search for relevant articles regarding the topic: „virtual reality“, „sport“, "exercise", "training", "rehabilitation“. These terms were also used in german language. The accounted articles were accessible via U:search (SURF, SPONET - Sports Science on the Web, SPORTDiscus and SPOWIS - Sports Science Literature). Furthermore, Google Scholar and Researchgate were searched. Preference was given to "peer-reviewed" articles and thus 123 articles could be recorded. After removing the duplicates, the number decreased to 78 articles and 41 more could be excluded due to an abstract analysis.

The selection of the studies, after they had already been sorted out by the keywords, began with the abstract analysis. It was important that only virtual reality and no augmented reality was subject in the studies. However, no distinction was made in the degree of immersion. Studies were also included, which work with an external screen and without glasses, i.e. a low degree of immersion. Furthermore, it was ensured that either perceived exertion, enjoyment and mood related topics were in the focus of the research. The different questionnaires used to collect the data were also screened. Less attention was paid to the design of the experiments conducted, meaning the different aerobic exercise was no exclusion criteria and different durations and frequencies was accepted. However, at least a group comparison has to be made to be included. No attention was paid to the age of the subjects. Articles that dealt with exergaming were excluded. For the remaining 30, a full text analysis was performed and finally 23 articles were included in this thesis.

Furthermore, the IMRaD scheme was followed. In the introduction, the lack of physical activity and its consequences are stated. Then virtual reality is proposed as a solution. In the literature review, the relationship between virtual reality and the effects on mood, enjoyment and perceived exertion that occur during physical activity is presented. In the methods it is explained how the effects were tested with this low-cost setup and the results are listed afterwards. These are lower rates of perceived exertion when cycling with virtual reality and the enjoyment questionnaire indicated that the low-cost virtual reality solution yielded higher scores for certain positive-worded items, while exercising without virtual reality resulted in higher scores for certain negative-worded items. Regarding the mood participants reported feeling less annoyed, confused, sleepy, tired, and nervous, and more active and livelier. After exercising without virtual reality, participants reported feeling more active. Finally, these

results are discussed and put into perspective in order to draw a conclusion. It is suggested that the distraction plays a key role in the measured results.

4 Literature Review

In the past decade several health authorities around the globe, especially the World Health Organisation (WHO), have been actively promoting the engagement in physical activity to promote various health benefits. The American Heart Association (AHA) recommends 30 minutes of aerobic exercise on five days a week with moderate intensity (50-70% of max heart rate). If the exercise is performed at a high level of intensity (70-85% of max heart rate), 25 minutes three times a week is sufficient to generate health benefits (American Heart Association, 2023). Between 2001 and 2016 the prevalence of physical inactivity was stable. Whereas 80% of younger generations and 25% of adults do not engage in physical activity (World Health Organization, 2020). The reasons for this are diverse and range from lack of time to digitalisation. Being physical inactive can be named as one of the main risk factors for non-transferable diseases, such as cancer (10% of colon cancers and 10% of breast cancer), type 2 diabetes (7%) or coronary heart disease (6%). This accumulates in an increase of 9% premature mortality rate (Lee et al., 2012). As a result, the costs for the health care systems are accumulating around \$53.8 billion (Ding et al., 2016). Lee et al. (2012) suggest that five hundred thousand deaths could be prevented annually if participation in physical activity would increase by 10%.

With the advancement of technologies, virtual reality is becoming more and more present and is making its way into the field of sports. The technology uses, among other, HMDs (head-mounted displays) and sensors to play images into the user's field of vision, which adapt to the movements of the head. In the case of virtual reality, the user sees only the computer-generated virtual or recorded world, and at the same time an attempt is made to block out impressions from the real world in order to create the greatest possible immersion. Immersion is understood as the effect that the user perceives the virtual environment as real (Neumann et al., 2018).

If the user reacts or acts with the displayed image, the movements are detected by the sensors and the displayed images align themselves accordingly (Ng et al., 2019). Thus, visual feedback is created. In more complex and expensive systems, it is also possible to integrate haptic, tactile or auditory feedback (Düking et al., 2018; Liu et al. 2019). A key aspect is, that the virtual reality environment can be manipulated and controlled in reproductive ways. Furthermore, it can be used to assess performances, gain feedback and/or practice specific skills repeatedly. It even goes so far, that another individual (coach, competitors, teammate,

fans, etc.) may be present in the virtual environment which can lead to higher levels of performance (Murray et al., 2016; Neumann et al., 2018).

As stated by Liu et al. (2019) during the late adolescence and early adulthood many physical activity habits are formed. So, if people are in this timeframe, it would be of great importance to perform regular physical activity, because it is more likely to stick for the rest of their life. To ensure this, the fact that the younger generations are very tech-savvy and video game based, virtual reality could be used to achieve acceptance and further regular physical activity.

Studies regarding the effectiveness of virtual reality enhanced exercise in comparison with traditional exercise are mainly examining two categories. Firstly, the physical activity in particular the duration, frequency and intensity. Secondly, the psychological outcome regarding the tiredness, calmness, enjoyment, energy and tension.

In the first category, Murray et al. (2016) have shown that virtual reality biking sessions have been more frequently attended by people than non-virtual reality stationary biking sessions. This is also shown by Liu et al. (2019) and Ulas & Semin (2021) with a study regarding motivation in virtual reality with full immersion. Thus, there is a tendency that virtual reality can promote physical activity as the motivation to regularly participate is higher (Ng et al., 2019). Furthermore, participants exercised longer distances and exerted more power while cycling in a virtual reality environment. Additionally, a higher heart rate was also measured while being in the virtual reality sessions.

Furthermore, it is demonstrated by research that exercise can be associated with various psychological benefits. These benefits include lowering anxiety, depression and stress. Therefore, regular exercise, especially aerobic based due to the reason that these types have the greatest health benefits, play a crucial role in both physical and psychological health (Ulas & Semin, 2021). There are different approaches why exercise benefits the psychological health. For example, it is suggested that the raise in body temperature, steroid and adrenalin activity stimulates a release of neurotransmitters (e.g. endorphin) which results in a boost in psychological parameters.

Another theory states that the perception of fitness results in a therapeutic and/or positive perception/suggestion if positive psychological outcomes is believed. Because people believe exercise is beneficial for health, the psychological outcome of these exercise is therefore enhanced. The perceptions and beliefs of humans have been proven as very powerful in affecting psychological and physical health and well-being (Plante et al., 2003).

Other authors indicate that exercise can be seen as a sort of distraction, psychological buffer, biofeedback and meditation. Baños et al. (2016) and Mestre et al. (2011) state that there is a possibility that the virtual reality produces the emerging effects because it distracts and/or diverts the participants attention away from the exercise/task performed, rather than because the elements of interactivity or a sense of presence in the environment. While the human body experiences several sensations every minute the human mind can only focus on a few or on one portion of the body. Lara (2018) suggests that a mind distraction during a workout may be the solution to dismiss negative bodily sensations and therefore enjoy the workout more (McClure & Schofield, 2019).

Also, a big effect on bodily sensations has the space and surroundings the person is currently in. Therefore, spatial and visual surroundings have significant effects on the sensation felt (McClure & Schofield, 2019). In a virtual reality environment these surroundings may be manipulated in a way that the bodily sensation for the person exercising benefits. It is added by Ijsselstein et al. (2004) that the degree of immersion can influence the outcome of the psychological effects. The higher the immersion the higher the measured effects, whereas the degree of immersion can be improved in different ways such as a more realistic environment (Neumann & Moffitt, 2018).

One main factor while exercising is enjoyment. Are high levels of enjoyment measured, is it more likely to stick regularly to the exercise performed (Ulas & Semin, 2021). Virtual reality could be a solution which tries to offer help to get more people to engage in physical activity or even maintain proper levels of activity. Thus, virtual reality offers an alternative when sports activities are affected by environmental factors such as light, weather and/or traffic. A particular reason for that is, that virtual environments may counteract the negative environmental influences regarding physical activity and enhance the subject's motivation to exercise (Plante et al., 2003). It also can create pleasure associated with natural environments while doing exercise conveniently in a studio, laboratory or home setting (Yasukawa et al. 2021).

Plante et al. (2006) suggest that psychological findings related to enjoyment and comfort may be manipulated if the environment is adapted to a person's liking. Therefore, social and environmental changes regarding the virtual environment may enhance the psychological effects anticipated during/after virtual reality exercise. Results indicate that higher enjoyment levels were measured and the ratings of perceived exertion were lower in the group which performed the exercise in the virtual reality environment comparing a control group (Murray et al., 2016; Zeng et al., 2017; Ulas & Semin, 2021; Kowal et al., 2021;

Sauchelli & Brunstrom, 2022; Bird et al., 2021; Annesi & Mazas, 1997). Also, Plante et al. (2003) measured the effect of virtual reality exercise regarding mood aspects on a stationary bike. They used the Activation-Deactivation Adjective Check List (AD-ACL) which includes, tension, tiredness, placid, fearful, quiet, sleepy, vigorous, energy and calmness. This check list was filled before and after the 30 minutes exercise session (60–70% maximum heart rate) by the 88 participants who were randomly assigned to three groups. The first one was an interactive virtual reality cycling experience on a computer. The second one was traditional cycling and the third one was playing a virtual reality computer cycling game without any actual exercise. Plante et al. (2003) observed that exercising in virtual reality resulted in the least tiredness and the most relaxation and joy (Mestre et al., 2011). On these findings Plante et al. (2006) researched 112 participants in three different conditions. These were an outdoor walk, an indoor walk on a treadmill with a virtual environment and no exercise while watch a virtual environment. Also, the short form of Activation-Deactivation Adjective Check List and PACES questionnaire was filled up by the participants. It is stated that exercising indoors and exercising outdoors boost different psychological effects. Furthermore, the combination of virtual reality with exercise had better psychological benefits than virtual reality alone. Interestingly, the outdoor environment was experienced as the most energizing and enjoyable but not the most relaxing. This could be due to the different factors one encounters when exercising outdoors such as other people, sounds, traffic, weather, etc. So, there could be a state of alertness regarding safety reason. Indoor exercise, on the other hand, was perceived as more relaxing. The reasons for this could be the secure and enclosed area. This difference could be used by exercising outside in the morning to get active and exercising inside in the evening for relaxation (Plante et al. 2006). Surprisingly, the rate of perceived exertion was the highest measured by Plante et al. (2003). They concluded that most of the psychological effects created by exercise were enhanced by using virtual reality while exercising. Yasukawa et al. (2021) were comparing different speeds of virtual reality while cycling. The results indicated that the effects on mood become larger the faster the visual flow is played comparing to slower visual flows.

Ng et al. (2019) demonstrated that virtual reality has, compared to traditional exercise, a large effect on physical activity whereas no effect was measured on the psychological consequences resulting of exercising in virtual reality. Zeng et al. (2019) counter these findings by measuring higher enjoyment and pleasure in the virtual reality sessions compared with traditional exercise. Zeng et al. (2017) investigated physiological and psychological effects comparing 20 minutes session of virtual reality (VirZoom) on a

stationary bike and a traditional stationary bike. All 12 participants were considered healthy and had to state their perceived exertion and enjoyment levels for the record. To ensure the same intensity all participants had to cycle in the range of 65% and 85% of age predicted maximum heart rate. The rating of perceived exertion was measured with the BORG scale and the enjoyment has been determined with a self-created five-point Likert-scale. The results show that participants experienced higher levels of exertion while cycling without virtual reality and a higher enjoyment was measured when cycling with virtual reality (VirZoom). Murray et al. (2016) tested rowing in a virtual environment with and without an avatar compared to non-virtual reality rowing. The participants rated their experience regarding enjoyment significant higher while rowing in a virtual environment despite the fact that increased performance was measured (distance and power output) in the virtual reality compared to traditional rowing. It was also pointed out that between running with an avatar and no avatar in a virtual environment, the results point towards the Köhler effect. Baños et al. (2016) underlined the higher enjoyment rates measured with an enjoyment scale, which was specially created for children, ranging, from 1- to 7-point. In some cases, higher tension was measured while exercising in a virtual environment. Plante et al. (2006) mention that this could be due to the apparatus the participants were wearing causing an uncomfortable feeling. In general, people who tend to have a higher susceptibility for experiencing motion sickness may are more likely to experience a state of discomfort while exercising in a virtual environment. Although it is assumed that the benefits which arise form virtual exercise outweigh these mentioned limitations (Plante et al., 2006).

Ng et al. (2019) go further and state that virtual reality-based intervention could be classified as primary intervention against physical inactivity, due to the fact that the benefits of virtual reality exercise surpasses the benefits of regular exercise. Furthermore, it was added, that the type of virtual reality stimulus did not emerge as a significant factor regarding the effectiveness of the measured outcomes.

When using virtual reality over a head mounted display (HMD) it is documented that simulator sickness also known as cybersickness or motion sickness may occur. The reason therefore is a conflict between the users' feelings and what the user sees (Kennedy et al., 1993; Koulieris et al., 2017). When viewing omnidirectional (360°) videos the likeliness of motion sickness is higher than viewing one directional video on a screen. A further explanation mentioned by Katsigiannis et al. (2018) could be the difference between computer generated images versus recorded images. The usual person is more accustomed to recorded images than computer generated images and therefore more likely to experience

motion sickness when viewing a digital virtual reality environment. Also, the users prior experience with a virtual reality environment is crucial on whether motion sickness arose. The users who had been in a virtual environment before, were significantly less affected by motion sickness. Interestingly, the quality settings of the virtual environment did not affect motion sickness scores (Katsigiannis et al. 2018).

The emergence of motion sickness may be crucial to whether a person is sticking to a virtual reality related exercise or not. This could therefore be a vital part whether a person is physically active or not. Katsigiannis et al. (2018) suggest that a familiarization period with shorter sessions to let the user accommodate to the new settings may be helpful before longer exercise is performed in virtual environment.

The key point to be drawn is the fact that the levels of physical activity should be increased and that virtual reality can provide a remedy. Most of the psychological factors are enhanced when virtual reality is used for endurance training. This means more enjoyment and better well-being as well as less perceived exertion is felt and this results in more frequent physical activity and in a higher likelihood in maintaining physical activity. A possible reason for that is the distraction the virtual environment provides.

These findings can be used to promote physical activity, but most virtual reality solutions are not ready for the masses. A low-cost virtual reality setup could be a solution for the masses if positive effects in terms of well-being, enjoyment and perceived exertion can be measured.

5 Materials and Methods

5.1 Sample

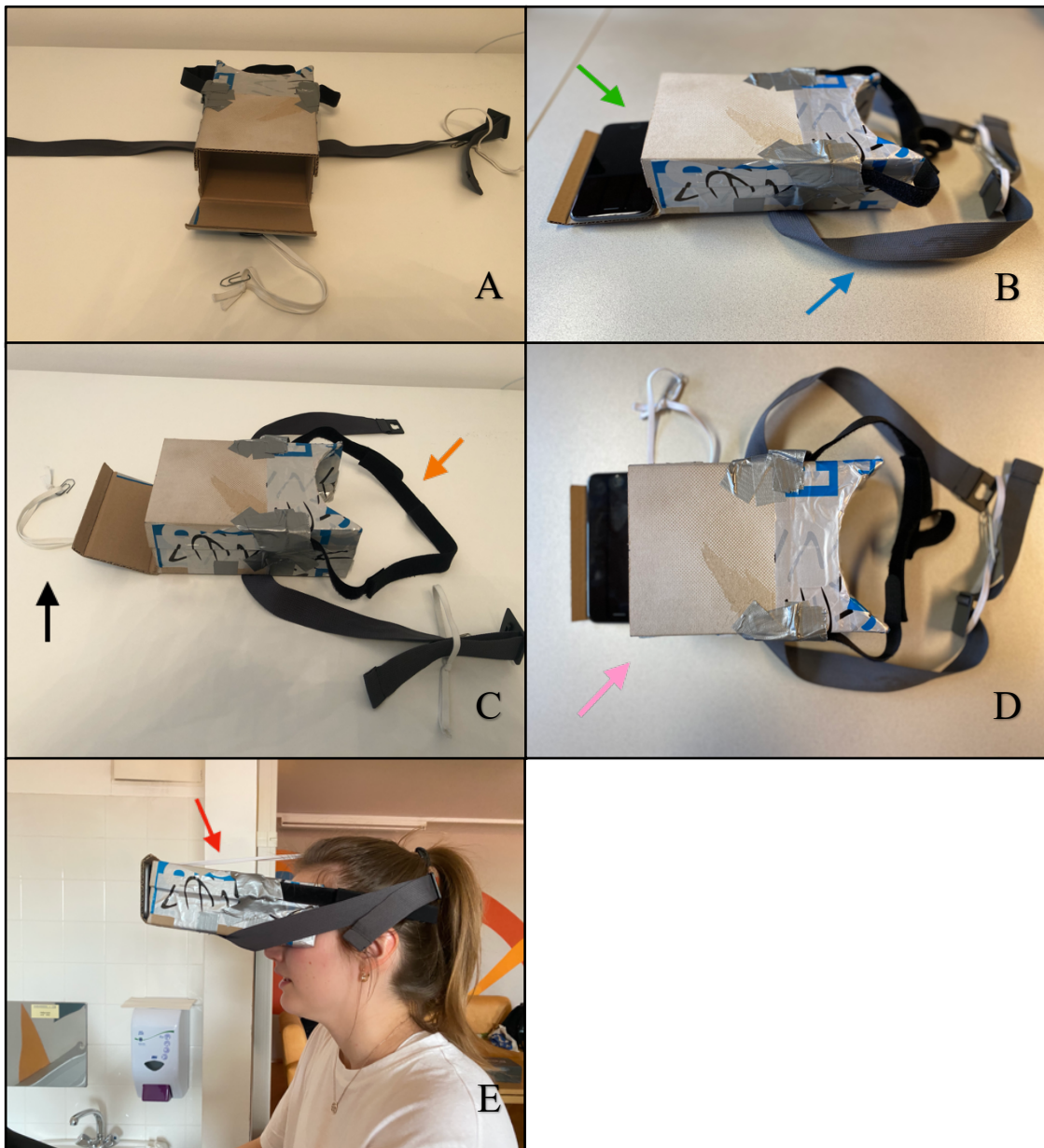
Fifteen participants (23 ± 1.6 years; 70.7 ± 13.2 kg mass; 172 ± 9.7 cm height) took part in this study. To be eligible, absence of any injury and disease that could impair their participation was required. The data collection was performed at the Center for Sport Science and University Sport of the University of Vienna.

Before all tests, the Physical Activity Readiness Questionnaire (PARQ) was applied to verify participants' health and fitness status and guarantee their eligibility for participation in the study.

The study was conducted according to the Declaration of Helsinki and was approved by the Ethics Committee of the University of Vienna (reference number: 00924).

5.2 Virtual reality solution

Figure 1. Virtual reality solution applied in the current study. A, B, C and D present front and side views of the proposed low-cost virtual reality solution with the slot for the phone. B and D shows the smartphone placement, which the green arrow points towards the flap that keeps the phone in place and the blue arrow points towards the belt band used to fixate the goggles in the user's head. E shows the virtual reality goggles mounted to the user's head. The red arrow pointing towards the elastic band which shuts the flap for the phone and goes over the person's head.

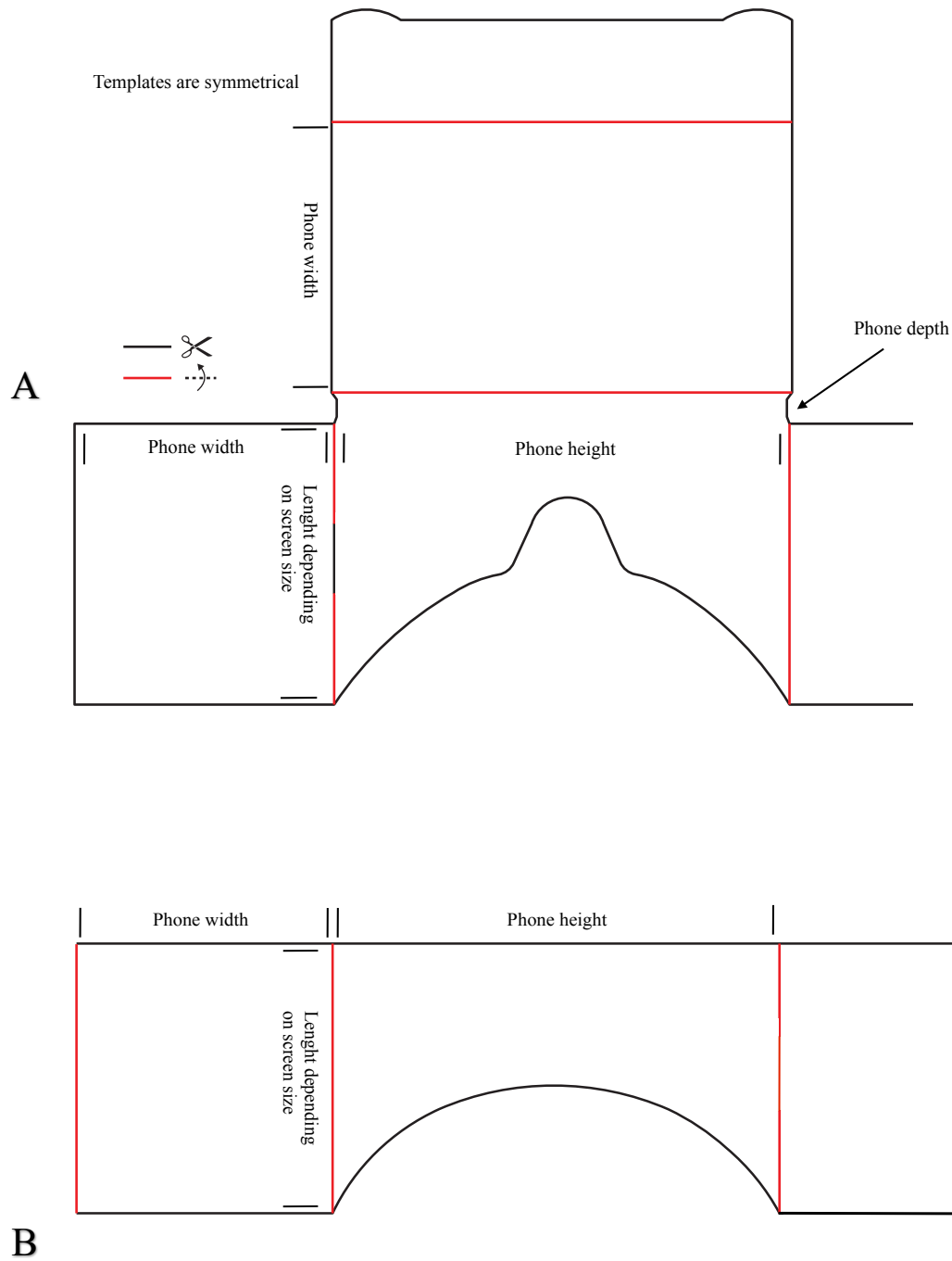


The aim for this study was to propose an affordable virtual reality alternative. In fact, there are several solutions available on the internet that allow the user to build different virtual reality goggles. The present study will apply a modified version of the Google Cardboard, which is a virtual reality option presented by Google LLC (Google LLC Cardboard, 2023) made from cardboards that can be found in shoeboxes, for example. Two characteristics of the Google Cardboard initiated the step to even simplify the concept. Number one was the required purchase of the lenses. Although these lenses are very cheap and a large selection is provided, there are different kinds of focal length. The focal length has to match your smartphone screen in a specific way to generate a smooth virtual environment without any distortion. The second reason for adapting the concept was that not every smartphone was able to execute the programs required, especially when using the YouTube application to watch 360° video. So, if lenses are used, the smartphone screen has to be divided into two screens. Every of the two screens has to compute a slightly different images with a distortion matching the lenses. The finished image is then created as the product of these factors. Unfortunately, not all smartphones are able to split the screen in the described way and therefore cannot generate the virtual environment.

These two reasons led to a concept without the use of spherical lenses that did not require an installation of external programs. To construct the adapted goggles, measurement of the iPhone 8 (height: 138.4 mm, width: 67.3 mm, depth: 7.4 mm) were taken into account and the dimensions of the goggles adapted to it (Figure 1). So, the new measurements were projected on a cardboard whereas the main shapes and forms of the Google Cardboard was copied and the distance between the eyes and the screen was increased up to 200 millimeters. Only the fixation for the lenses did not need to be constructed. After all the shapes were cut out, the two pieces were glued together. To fixate the goggles to the head two bands were attached with tape (Figure 1, C: orange arrow; Figure 1, B: blue arrow; Figure 1 D). One on each side of the goggles which was of elastic nature. The other one on the bottom of the goggles which had a fastener build in. With these two bands, it was assured that the goggles which weight 264 grams (98 grams construction + 148 grams iPhone 8) was fitted close to the person's head. To fixate the phone on front of the goggles another elastic band was attached to the flap which the intention to keep the phone in place (Figure 1, B: green arrow; Figure 1, D: pink arrow). This elastic band went over the head and was fixated on the band with the fastener on the back of the head (Figure 1, C: black arrow; Figure 1, E: red arrow). To ensure hygiene while wearing the apparatus, the places which come in contact with the persons face have been taped with duct tape. Furthermore, kinesiology tape was provided to

tape areas that caused discomfort. The templates used to create this setup are illustrated below (Figure 2). A 360° YouTube outdoor cycling video in the Newport Back Bay in Newport Beach, California which was running at 1080p was used as a virtual environment and displayed on the screen of the iPhone 8 to create an immersive environment (Dynamio 360, 2023). The virtual environment was initialized by the research assistant and put in place via the smartphone in the designed spot of the goggles (Figure 1, B and D). The movement of the head was detected by gyroscope sensors and the video was aligned accordingly. Therefore, a simple yet immersive environment was created.

Figure 2. Templates for the goggles. *A* shows the template for the lower piece of the goggles which can be cut out of a cardboard. *B* shows the template for the upper piece of the goggles which can be cut out of a cardboard. The measurements selected are according to the phone used.



5.3 Experimental Protocol

Figure 3. *The image shows a participant from the current study exercising on the ergometer with the virtual reality goggles attached to the head.*



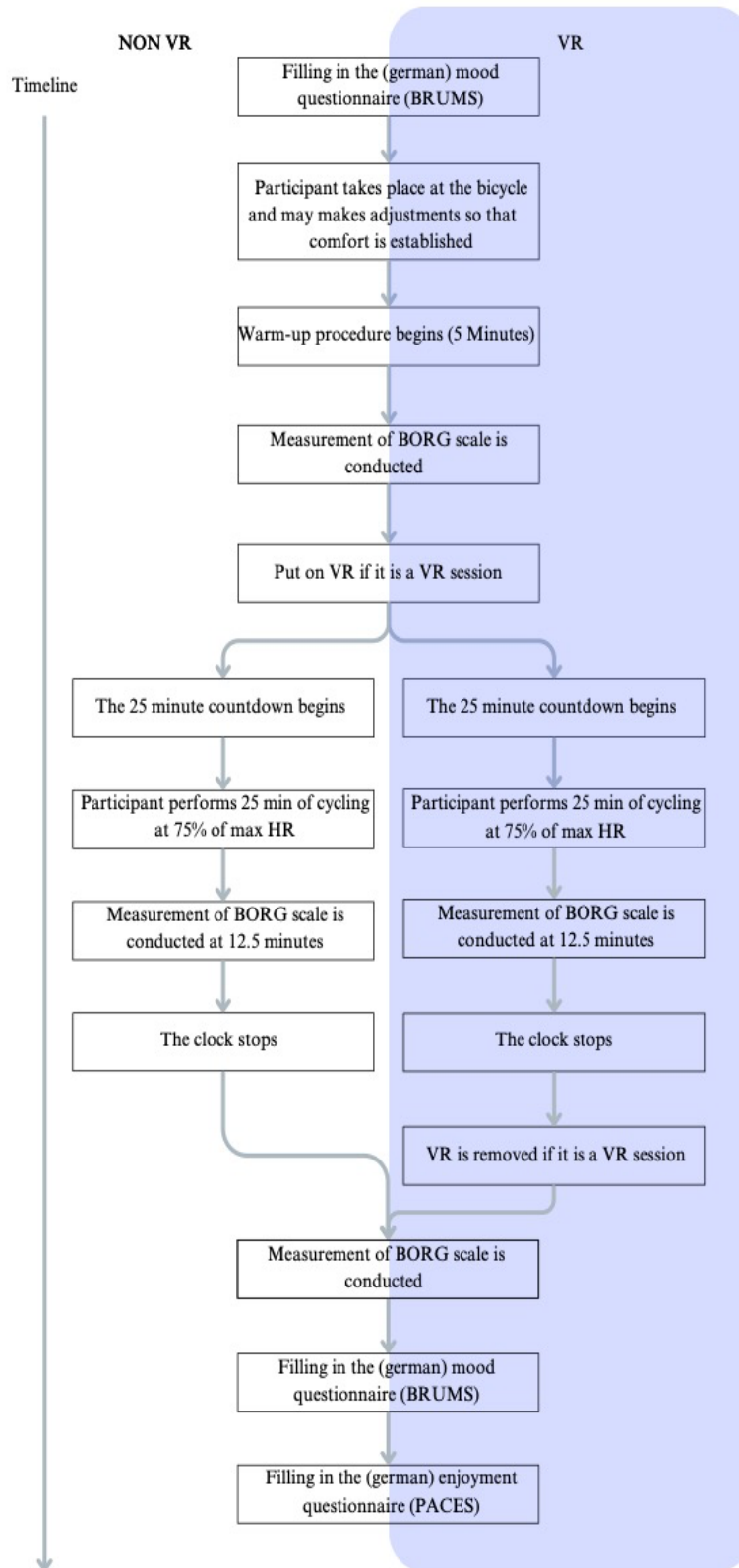
The protocol was designed according to the WHO guidelines for physical activity (World Health Organization, 2020), which states that adults should accumulate 75 minutes of moderate-to-intense exercise weekly. Thus, in the present study, participants performed exercise on a stationary cycle ergometer (BX70i, Cardiostrong, Germany) over three sessions of 25 minutes each, in two conditions: using the virtual reality solution (with VR) and without using virtual reality (without VR). The total of six sessions were conducted in a random order. The intensity the sessions was maintained at 75% of participants individual maximum heart rate, which was calculated according to Tanaka's formula (Nikolaidis et al., 2018):

$$208 - 0.7 \times \text{age}$$

Once the cycle ergometer had a built-in heart rate monitor on the handles, the intensity could be monitored by the researcher and the participant as well. Participants were asked and monitored to not fall under the threshold of 70% of the maximal heart rate, otherwise the

experiment would be interrupted. The seating position, the height of the saddle and the distance to the handlebars were adjusted accordingly to participants' comfort and anthropometrics (Figure 3). Participants were also allowed a 5-min warmup on the cycle ergometer before initiating the experiment, starting in a self-selected intensity, but aiming to reach the intensity corresponding to the one that the exercise would be performed in the experiment. All sessions were held with a minimum of 24 hours interval in between and the condition order was assigned randomly. The session in detail is listed below (Figure 4).

Figure 4. Session as a timeline. The image shows the session as a timeline step by step, progressing from the top down. The blue area indicating the use of virtual reality.



6 Measurements

6.1 Mood

To measure the mood states of the participants the Brunel Mood Scale Questionnaire (BRUMS) was conducted (Brandt et al., 2021, Brandt et al., 2016). This measurement was performed before and after sessions regardless whether virtual reality was used or not. The intention of this scale is to rate the participants mood at the current state. From this, a comparison can be made whether the cycling with virtual reality or without virtual reality made a difference regarding the participants mood.

The scale is a self-report and therefore subjective questionnaire containing 24 mood scale items, which have to be rated on a five-point Likert-scale (1 = Not at all; 2 = A little; 3 = Moderately; 4 = Quiet a bit; 5 = Extremely). For each question beginning with „I feel“ followed by a mood related adjective. The 24 items are made up of six dimensions with four questions each. These are tension (anxious, nervous, panicky, and worried), depression (depressed, downhearted, miserable and unhappy), anger (angry, annoyed, bad-tempered and bitter), vigor (active, alert, energetic and lively), fatigue (exhausted, sleepy, tired and worn-out), and confusion (confused, mixed-up, muddled and uncertain) (Brandt et al., 2021, Brandt et al., 2016).

6.2 Enjoyment

To reflect on the enjoyment regarding the physical activity just performed the Physical Activity Enjoyment Scale (PACES) was represented to the participants to fill out and assess how much people enjoy being physically active based on subjective feelings. (Mullen et al., 2011). Enjoyment is an important factor regarding exercise intention and contribute the the adherence of the activity. Therefore, a measurement of the enjoyment during cycling with virtual reality and without is necessary to draw conclusion.

The scale is divided into 18 questions („I enjoy it“, „I feel bored“, „I dislike it“, „I find it pleasurable“, „It's no fun at all“, „It gives me energy“, „It makes me sad“, „It's very pleasant“, „My body feels good“, „I get something out of it“, „It's very exciting“, „It's frustrates me“, „It's not at all interesting“, „It gives me a strong feeling of success“, „It feels good“, „I feel as though I would rather be doing something else“), each of which is to be answered with a five-point Likert-scale (1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = agree; 5 = strongly agree) (Kendzierski & DeCarlo, 1991; Mullen et al., 2011).

6.2 Perceived exertion

To record the rating of perceived exertion (RPE) all participants provided a subjective assessment of the current intensity. From these results a comparison could be made whether there is a difference in perceived exertion while cycling in virtual reality to cycling without virtual reality.

This measurement was conducted with the BORG scale which ranges from six (no exertion) to 20 (maximal exertion). A sheet with the scale was presented to the participants after the warm-up, 12.5 minutes into the session and the end. If virtual reality goggles were used the research assistant presented the scale vocally (Borg, 1998).

6.3 Motion sickness

Besides the BRUMS, PACES and BORG scale, emergence of motions sickness while cycling with virtual reality was also assessed with a question which participants could indicate yes or no.

7 Procedures

7.1 Data analysis

The dataset was averaged via the median because of the ordinal data the five-point Likert-scale produced. To compare the mood states of the participants between the conditions with virtual reality and without virtual reality the Mann-Whitney-U-Test was used. Hereby the mood states before and after the exercise were reviewed. To examine differences in-between the mood states of virtual reality and non-virtual reality sessions the Wilcoxon-Test was conducted. Hereby, the averaged sessions before and after virtual reality and the averaged sessions before and after non-virtual reality were analysed whether a difference occurred after cycling compared to the mood state measured beforehand. To compare the enjoyment between the virtual reality and the non-virtual reality sessions the Mann-Whitney-U-Test was performed for each variable of the PACES questionnaire. To compare the rate of perceived exertion between the virtual reality and the non-virtual reality the data was averaged with the median and then the Mann-Whitney-U-Test was conducted to screen for a significant difference. The level of statistical significance was considered $p < 0.05$ and all tests were conducted using IBM SPSS Statistics 25.0 (Armonk, USA).

8 Results

8.1 Data analysis

Table 1. *Descriptives (mean and standard deviation) of demographics.*

Characteristics	Mean	Standard Deviation
Age	23.0	1.6
Mass (kg)	70.6	13.2
Height (cm)	172.1	9.7
BMI (kg/m ²)	23.7	3.2
75% heart rate (bpm)	143.9	0.8
70% heart rate (bpm)	134.3	0.8

The main participant's characteristics are described in Table 1. The BMI classifying the group of participants, whereas 7 were female and 8 were male, as a normal weight regarding their age.

8.2 Mood state measurement

Table 2. Descriptives (median and interquartile range – IQR) and test statistic values (Wilcoxon Z scores and p-values) of healthy young adults' mood (BRUMS) scores related to anger when exercising with and without a virtual reality low-cost solution. b/a = before/after.

Variables			With VR		Without VR		Comparison	Test statistic	p-value
			Median	IQR	Median	IQR			
BRUMS anger	I feel angry	before	1	0	1	0	b/a with VR	Z = -1.34	0.18
		after	1	0	1	0	b/a without VR	Z = -1,00	0.32
	I feel annoyed	before	1	1	1	0	b/a with VR	Z = -2.06	0.04*
		after	1	0	1	0	b/a without VR	Z = -0.58	0.56
	I feel bad-tempered	before	1	0.5	1	0	b/a with VR	Z = -1.89	0.06
		after	1	0	1	0	b/a without VR	Z = -1,00	0.32
	I feel bitter	before	1		1	0	b/a with VR	Z = -1.63	0.10
		after	1	0	1	0	b/a without VR	Z = 0,00	1

(*) significant difference between before and after in each condition.

Table 3. Descriptives (median and interquartile range – IQR) and test statistic values (Wilcoxon Z scores and p-values) of healthy young adults' mood (BRUMS) scores related to confusion when exercising with and without a virtual reality low-cost solution. b/a = before/after.

Variables			With VR		Without VR		Comparison	Test statistic	p-value
			Median	IQR	Median	IQR			
BRUMS confusion	I feel confused	before	1	0.5	1	0	b/a with VR	Z = -1.89	0.06
		after	1	0	1	0	b/a without VR	Z = -1,41	0.16
	I feel mixed-up	before	1	1	1	0	b/a with VR	Z = -2.12	0.03*
		after	1	1	1	0	b/a without VR	Z = -1.73	0.08
	I feel muddled	before	1	0	1	0	b/a with VR	Z = -1.63	0.10
		after	1	0	1	0	b/a without VR	Z = -0.58	0.56
	I feel uncertain	before	1	0.5	1	0.5	b/a with VR	Z = -1.41	0.16
		after	1	0	1	0	b/a without VR	Z = -1.41	0.16

(*) significant difference between before and after in each condition.

BRUMS is divided into six categories each representing a generic term associated to mood states. Relative to anger, the results showed only a significant difference in the construct “I feel annoyed”. Participants felt less annoyed after exercising with virtual reality (Z = -2.06; p = 0.04) when compared before exercising with virtual reality (Table 2.). The subject of Table 3. is confusion. The table shows that participants felt less mixed-up („I feel mixed up“) (Z = -2.12; p = 0.03) after the virtual reality exercise was done. Regarding the generic term depression no significant p-values were measured (Table 4.). Relative to fatigue, the outcome demonstrates that the participants felt less sleepy (Z = -2.45; p = 0.01) and tired (Z = -2.31; p = 0.02) when cycling with virtual reality (Table 5.). In Table 6. tension is represented yielding significant p-values regarding nervousness. „I feel nervous“ (Z = -2.45;

$p = 0.01$) in the virtual reality setting reported a reduction. The subject on Table 7. was vigor. Here, „I feel active“ was higher in both condition after the exercise with virtual reality ($Z = -2.332$; $p = 0.020$) and without ($Z = -2.810$; $p = 0.005$). Furthermore, the participants felt more lively in the virtual reality condition ($Z = -2.165$; $p = 0.030$).

Table 4. Descriptives (median and interquartile range – IQR) and test statistic values (Wilcoxon Z scores and p-values) of healthy young adults' mood (BRUMS) scores related to depression when exercising with and without a virtual reality low-cost solution. b/a = before/after.

Variables			With VR		Without VR		Comparison	Test statistic	p-value
			Median	IQR	Median	IQR			
BRUMS depression	I feel depressed	before	1	0.5	1	0	b/a with VR	Z = -1.86	0.06
		after	1	0	1	0	b/a without VR	Z = -1.41	0.16
	I feel down hearted	before	1	0.5	1	0	b/a with VR	Z = -1.60	0.11
		after	1	0	1	0	b/a without VR	Z = -1.41	0.16
	I feel miserable	before	1	0	1	0	b/a with VR	Z = -1.41	0.16
		after	1	0	1	0	b/a without VR	Z = -1.00	0.32
	I feel unhappy	before	1	0	1	0	b/a with VR	Z = -1.41	0.16
		after	1	0	1	0	b/a without VR	Z = -1.00	0.32
(*) significant difference between before and after in each condition.									

Table 5. Descriptives (median and interquartile range – IQR) and test statistic values (Wilcoxon Z scores and p-values) of healthy young adults' mood (BRUMS) scores related to fatigue when exercising with and without a virtual reality low-cost solution. b/a = before/after.

Variables			With VR		Without VR		Comparison	Test statistic	p-value
			Median	IQR	Median	IQR			
BRUMS fatigue	I feel exhausted	before	2	0	2	0	b/a with VR	Z = -1.00	0.32
		after	2	0	2	0	b/a without VR	Z = 0.00	1.00
	I feel sleepy	before	2	1	2	1	b/a with VR	Z = -2.46	0.01*
		after	1	0	2	1	b/a without VR	Z = -0.49	0.62
	I feel tired	before	2	1	2	0.5	b/a with VR	Z = -2.31	0.02*
		after	1	1	2	1	b/a without VR	Z = -0.75	0.45
	I feel worn-out	before	1	1	1	1	b/a with VR	Z = -1.19	0.23
		after	1	1	1	1	b/a without VR	Z = -1.41	0.16
(*) significant difference between before and after in each condition.									

Table 6. Descriptives (median and interquartile range – IQR) and test statistic values (Wilcoxon Z scores and p-values) of healthy young adults' mood (BRUMS) scores related to tension when exercising with and without a virtual reality low-cost solution. b/a = before/after.

Variables			With VR		Without VR		Comparison	Test statistic	p-value
			Median	IQR	Median	IQR			
BRUMS tension	I feel anxious	before	1	0	1	0	b/a with VR	Z = -1.00	0.32
		after	1	0	1	0	b/a without VR	Z = -1.00	0.32
	I feel nervous	before	1	1	1	0	b/a with VR	Z = -2.45	0.01*
		after	1	0	1	1	b/a without VR	Z = -1.00	0.32
	I feel panicky	before	1	0	1	0	bb/a with VR	Z = 0.00	1.00
		after	1	0	1	0	b/a without VR	Z = -1.41	0.16
	I feel worried	before	1	0	1	0	b/a with VR	Z = -1.34	0.18
		after	1	0	1	0	b/a without VR	Z = -1.00	0.32
	(*) significant difference between before and after in each condition.								

Table 7. Descriptives (median and interquartile range – IQR) and test statistic values (Wilcoxon Z scores and p-values) of healthy young adults' mood (BRUMS) scores related to vigor when exercising with and without a virtual reality low-cost solution. b/a = before/after.

Variables			With VR		Without VR		Comparison	Test statistic	p-value
			Median	IQR	Median	IQR			
BRUMS vigor	I feel active	before	3	1	3	1	b/a with VR	Z = -2.33	0.02*
		after	4	1	4	1	b/a without VR	Z = -2.81	0.01*
	I feel alert	before	2	0	2	0	b/a with VR	Z = -1.00	0.32
		after	2	0	2	0	b/a without VR	Z = -1.00	0.32
	I feel energetic	before	3	1	3	1.5	b/a with VR	Z = -1.47	0.14
		after	4	1.5	4	1	b/a without VR	Z = -1.90	0.06
	I feel lively	before	3	2	3	0	b/a with VR	Z = -2.17	0.03*
		after	4	1	4	1	b/a without VR	Z = -1.90	0.06
	(*) significant difference between before and after in each condition.								

8.3 Enjoyment measurement

Table 8. Descriptives (median and interquartile range – IQR) and test statistic values (Mann-Whitney U. and p-values) of healthy young adults' enjoyment (PACES) scores when exercising with and without a virtual reality low-cost solution.

	Variables	With VR		Without VR		Test statistic	p-value
		Median	IQR	Median	IQR		
PACES	I enjoy it	4	0.5	3	1	U(58.5)	0.02 [#]
	I feel bored	1	1	2	2	U(42.5)	0.00 [#]
	I dislike it	1	1	2	2	U(59.5)	0.01 [#]
	I find it pleasurable	4	1	3	1.5	U(67)	0.04 [#]
	It's no fun at all	1	0.5	2	2	U(63)	0.02 [#]
	It gives me energy	4	0	4	0.5	U(107)	0.80
	It makes me sad	1	0	1	0.5	U(89)	0.13
	It's very pleasant	3	1	3	1	U(75.5)	0.10
	My body feels good	4	0	4	1	U(93)	0.34
	I get something out of it	4	0.5	4	0.5	U(107)	0.80
	It's very exciting	4	1	3	1.5	U(67)	0.04 [#]
	It frustrates me	1	0	1	1	U(93.5)	0.26
	It's not at all interesting	4	1	2	1.5	U(57.5)	0.02 [#]
	It gives me a strong feeling of success	3	1	3	1	U(109.5)	0.89
	It feels good	4	0.5	4	1	U(81.5)	0.16
	I feel as though I would rather be doing something else	2	1	2	2	U(94)	0.42
(#): significant difference between the conditions With VR and Without VR.							

The enjoyment was measured with the PACES scale. All 16 subjects were measured after cycling with virtual reality and without. The comparison between those were calculated with the Mann-Whitney-U-Test.

Table 8. shows the subjects in the PACES questionnaire. The category „I enjoy it“ (U(58.5); $p = 0.02$) marks positive p-values demonstrating that the enjoyment was higher when cycling with a virtual environment. Furthermore „I feel bored“ (U(42.5); $p = 0.00$) was higher after cycling without the virtual environment. The same was for „I dislike it“ (U(59.5); $p = 0.01$). The virtual environment was found more pleasurable demonstrated by „I find it pleasurable“ and exiting „It's very exciting“ (U(67); $p = 0.04$). The category „It's no fun at all“ (U(63); $p = 0.02$) and „It's not at all interesting“ (U(57.5); $p = 0.02$) show that the exercise without virtual reality was found less fun and interesting.

8.4 Perceived exertion measurement

The perceived exertion was measured via the BORG scale and averaged for all runs with virtual reality (median [IQR]: 12[5]) and without (14[2]), showing a significant difference ($U(189.5)$; $p = 0.001$). The Mann-Whitney-U-Test indicates that less exertion is experienced when cycling with this virtual reality setup.

8.5 Motion sickness measurement

In two out of 45 runs motion sickness occurred. This equals 4.4 % of all runs in the virtual environment.

9 Discussion

The purpose of this thesis was to verify whether the presented low-cost virtual reality alternative influences mood states and enjoyment as suggested in the literature. Hereby, enjoyment, mood and perceived exertion are important parameters to evaluate (Liu et al., 2019). Furthermore, it was hypothesised that when exercising with virtual reality general mood, thus, well-being is enhanced.

The main results obtained from the experiment and stated in the results section regarding BRUMS are that participants reported feeling less annoyed, confused, sleepy, tired, and nervous, and more active and lively. After exercising without virtual reality, participants felt more active. PACES showed that the low-cost virtual reality solution yielded higher scores for certain positive-worded items, while exercising without virtual reality resulted in higher scores for certain negative-worded items. The measurement of BORG yielded results, demonstrating the fact that participants perceived exertion was higher without virtual reality when compared to exercising with virtual reality.

In five out of six categories regarding BRUMS significant p-values were recorded, an exception is the topic depression. Here, aligning with findings in the literature no link between virtual reality and depression is stated suggesting no negative effects regarding depression and mood can be attributed to the use of virtual reality while exercising. Although that can also be attributed to the performance of aerobic exercise (Ulas & Semin, 2021).

Regarding the topic anger the results demonstrate that participants felt less annoyed after cycling in the virtual environment. This may be attributed to the virtual environment used. A 360° YouTube outdoor cycling video in the Newport Back Bay in Newport Beach, California which was running at 1080p was used as a virtual environment (Dynamio 360, 2023). Thus, the virtual environment was not computer-generated but recorded. Neumann & Moffitt (2018) argue that there could be a difference in effects regarding the outcome (Plante et al. 2006). Although Neumann & Moffitt (2018) used neutral images presented on Microsoft Powerpoint instead of a video which was compared to a virtual environment running on the same apparatus. The authors suggest that looking at blank wall while exercising may lead to an increase of focus on the negative bodily sensation resulting in high level of perceived exertion or worse mood benefits. This is reinforced by Lara (2018) suggests that an occupied mind has lesser focus on the negative bodily sensation. Neumann & Moffitt (2018) compared 21-minute treadmill runs at 70% of Vmax (maximum velocity test) and measured forty-six participants regarding perceived exertion (BORG scale),

Physical Activity Affect Scale (PAAS) and Physical Activity Enjoyment Scale (PACES) among other criteria. The findings show a surprising effect of more enjoyment while running while watching neutral images played in the field of view of the participants. This is not attributable to a difference in the rate of perceived exertion which was statistically not significant. An explanation for this outcome may be the fact that there were different attentional processes during the two experimental runs. This was measured with the Measure of Attentional Focus (MAF) and the measurement shows that during virtual reality exercise the attention on bodily sensations was higher which may result in lesser enjoyment ratings compared with neutral images. As an alternative explanation it is also suggested that the virtual reality environment was missing elements that require a sufficient level of presence. This could be due to the fact that the virtual reality environment was fixed in position and followed the user's field of vision when movements of the head occur.

So, the study performed by Neumann & Moffitt (2018) has also limitations which are different from the present one. However, it must be noted that the runs, which were carried out without virtual reality, did not have any stimulus except from painted wall. However, this is also difficult to change, since cycling on the ergometer in laboratory conditions can only take place in a stationary position.

To summarize the connection of the present study and the article published by Neumann & Moffitt (2018), attention must be drawn to the different environments in which the opposed runs are performed and the outcome resulting in the different stimuli. It is suggested that further research is done in regarding this topic to clearly describe the differences resulting from different environments.

Regarding the generic term confusion the analysis presented that participants felt less mixed-up after the virtual reality bike session. This may be originating from the same reason as feeling less annoyed.

Regarding the topic fatigue the participants felt less sleepy and tired. At first, it might be thought that this is due to the aerobic exercise. However, if the same parameters are considered in the non-virtual reality runs, they do not show any significant differences. This suggests that these circumstances are probably again due to the distraction and the surroundings in the virtual environment showing the sundown in California (McClure & Schofield, 2019; Lara, 2018; Baños et al.; Mestre et al., 2011). The exposure to sunlight triggers an improvement of mood and energy (Bertani et al., 2021). Whether this could be stimulated with virtual reality and therefore tick the brain in releasing the same hormones (e.g. serotonin) should be topics in further studies.

Concerning the topic tension, the participants felt less nervous when cycling with virtual reality. This also could be due to the distraction provided (McClure & Schofield, 2019; Lara, 2018; Baños et al.; Mestre et al., 2011), but also to the fact, that cycling with virtual reality is exiting and thus nervousness is felt before virtual reality session. Afterwards the nervousness is gone which expresses itself through the reduction measured.

Regarding the generic term vigor, significant p-values are measured three times. Participants felt more lively when cycling with virtual reality. This condition may also be attributed to the realistic virtual environment used. Interestingly, „I feel active“ reported higher levels after the virtual reality and also the normal bike session, suggesting that these findings are attributed to the aerobic exercise itself.

The results of the PACES questionnaire suggesting that virtual reality bike sessions generated more enjoyment and the participants found it more pleasurable and exciting than sessions without virtual reality. These findings may be attributed to the fact that some kind of distraction in form of the 360° virtual reality environment was present. On the other hand, cycling without visual stimulus resulted in boredom and dislike. Furthermore these sessions were attributed with the terms „It’s no fun at all“ and „It’s not at all interesting“. A possible explanation for these circumstances may be the dichotomy the experimental setup brought to the table, comparing session with visual stimulus (virtual reality) to no visual stimulus. Generally speaking, because nowadays the people are used to constant visual stimulus, the time during no visual stimulus is present are classified as boring, no fun and not interesting. The perceived exertion measured was higher in session without the virtual environment. This may be attributed to the fact that while exercising in the virtual environment distraction is presented and therefore the mind is occupied resulting in lesser focus on the negative bodily sensation (Lara, 2018). The focus of further studies should be on the environment which generates the distraction and how the mood, enjoyment and perceived exertion varies if the visual stimulus changes.

Most of the time when exercising a sensory input is received. This is a combination of sound and visual feedback. In this particular experiment, only visual input was controlled through the video played over the virtual reality goggles. The feedback regarding sound was different each session due to the fact that the trails were held in the biomechanics laboratory at the USZII sports institute in Vienna. This laboratory is a larger room where people work, take courses and teach lessons. So, depending on the weekday and daytime the laboratory was producing different sensory feedback which may influenced the results.

The virtual environment in this study was a 360° YouTube outdoor cycling video running at normal speed of the video. The video speed depended on speed of the cyclist who recorded the video. On the basis of traffic, situations and environmental changes throughout the route the cycling speed changes accordingly. Therefore, the video speed does not match the pedaling speed of the participants. The reason for that is that the participants were cycling at a pedaling speed predefined by the 75% of the age-related maximum heart rate. Furthermore, there is no validity of the heart rate sensor which was built in into the handles of the stationary bike.

The intensity on the bike was adjusted accordingly throughout the session by the research assistant to cycle around 75% of the maximum heart rate. Therefore, the pedaling speed could vary and certainly would not match the video speed the whole session.

In general, the findings of this study align with the literature (Murray et al., 2016; Zeng et al., 2017; Ulas & Semin, 2021; Kowal et al., 2021; Sauchelli & Brunstrom, 2022; Bird et al., 2021; Annesi & Mazas, 1997; Zeng et al., 2019). The feelings of enjoyment and pleasure have been considered as a promoter to physical activity and the results indicate that these are enhanced (Liu et al., 2019). A circumstance that contributed to the measured effects may be the realistic environment and the degree of immersion presented, despite the fact that only a smartphone was used. This was due to the ability mimic the movements of the persons head and align the images accordingly resulting in a realistic immersive environment (Ijsselstein et al., 2004; Neumann & Moffitt, 2018). Furthermore, all voluntary participants were aged on average 23 ± 1.6 years. Therefore, the research group was very young. This could imply a technology and digital proximity contributing to the positive measured outcomes.

This low-cost virtual reality setup brings mood and enjoyment benefits and lowers the perceived exertion as shown in the literature. Therefore and because of the cost effective and easily accessible setup (cardboard, virtual environment via YouTube) this solution may help many people to become and stay physically active and meet the WHO recommended guidelines.

However, further studies should incorporate a larger and more diverse sample and study the long-term effects of virtual reality use.

10 Conclusion

This experimental study proposes, applies and assess a low-cost virtual reality setup which appears to generate positive the effects regarding mood, enjoyment and perceived exertion as stated in the literature. Therefore, the scalability of this solution could be a vital part in the help for people to maintain proper levels of physical activity. This is the first report of a low-cost virtual reality setup looking into the effects virtual reality in combination with exercising produces. Therefore, more studies in this field are needed to verify the results obtained. Especially larger studies in different ages groups should be on the agenda.

11 Literature

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12. Appendix

On the following pages the Physical Activity Readiness Questionnaire (PARQ) and the Questionnaire for the participants (including BRUMS, PACES, BORG) are listed.

PAR-Q Fragebogen Gesundheit

Der nachfolgende Fragebogen (Physical Activity Readiness Questionnaire) soll Ihnen helfen herauszufinden, ob Sie vor Beginn einer sportlichen Aktivität einen Arzt aufsuchen sollten.

Bei einem Alter über 35 und unter 60 Jahren ist eine sportärztliche Vorsorgeuntersuchung sinnvoll. Bei einem Alter über 60 Jahren sollten Sie in jedem Fall eine solche ärztliche Untersuchung vornehmen lassen.

Beantworten Sie die untenstehenden Fragen nach bestem Wissen und Gewissen. Falls Sie eine oder mehrere Fragen mit JA beantworten, sollten Sie einen Arzt aufsuchen und sich untersuchen und beraten lassen, bevor Sie sportlich aktiv werden.

1.	Hat Ihnen jemals ein Arzt gesagt, Sie hätten „etwas am Herzen“ und Ihnen Bewegung und Sport nur unter ärztlicher Kontrolle empfohlen?	Ja	Nein
2.	Hatten Sie im letzten Monat Schmerzen in der Brust?	Ja	Nein
3.	Haben Sie in Ruhe oder bei körperlicher Belastung Probleme mit der Atmung?	Ja	Nein
4.	Sind Sie jemals wegen Schwindel gestürzt oder haben Sie schon jemals das Bewusstsein verloren?	Ja	Nein
5.	Haben Sie ein Knochen- oder Gelenkproblem, das sich unter körperlicher Belastung verschlechtern könnte?	Ja	Nein
6.	Hat Ihnen jemals ein Arzt ein Medikament gegen hohen Blutdruck oder wegen eines Herz- oder Atemproblems verschrieben?	Ja	Nein
7.	Ist Ihnen ein weiterer Grund bekannt, warum Sie ohne medizinische Kontrolle nicht sportlich aktiv sein sollten (z.B. früherer Herzinfarkt oder Rhythmusstörungen, Herzerkrankung von Familienmitglieder die jünger als 60 Jahre sind oder gewesen sind, Lungenerkrankung, etc.)	Ja	Nein



0% completed

Mood/Enjoyment Questionnaire

Answer the questions about your current status in relation to the activity you currently performed.

When I am physically active...

1. ID number

2. Please choose your sex:

☐
Female

☐
Male

3. Please state your age in years:

4. Please state your weight in kg:

5. Please state your height in cm:

6. 70% of maximum heart rate:

7. Is this questionnaire filled up before or after a session:

☐
Before

☐
After

8. Is it a VR session?

☐
Yes

☐
No

9. I feel annoyed

☐
Not at all

☐
A little

☐
Moderately

☐
Quite a bit

☐
Extremely

10. I feel bitter

☐
Not at all

☐
A little

☐
Moderately

☐
Quite a bit

☐
Extremely

11. I feel angry

☐
Not at all

☐
A little

☐
Moderately

☐
Quite a bit

☐
Extremely

12. I feel bad tempered

☐
Not at all

☐
A little

☐
Moderately

☐
Quite a bit

☐
Extremely

13. I feel confused

☐
Not at all

☐
A little

☐
Moderately

☐
Quite a bit

☐
Extremely

14. I feel mixed-up

☐
Not at all

☐
A little

☐
Moderately

☐
Quite a bit

☐
Extremely

15. I feel muddled

☐ Not at all ☐ A little ☐ Moderately ☐ Quite a bit ☐ Extremely

16. I feel uncertain

☐ Not at all ☐ A little ☐ Moderately ☐ Quite a bit ☐ Extremely

17. I feel depressed

☐ Not at all ☐ A little ☐ Moderately ☐ Quite a bit ☐ Extremely

18. I feel downhearted

☐ Not at all ☐ A little ☐ Moderately ☐ Quite a bit ☐ Extremely

19. I feel unhappy

☐ Not at all ☐ A little ☐ Moderately ☐ Quite a bit ☐ Extremely

20. I feel miserable

☐ Not at all ☐ A little ☐ Moderately ☐ Quite a bit ☐ Extremely

21. I feel worn-out

☐ Not at all ☐ A little ☐ Moderately ☐ Quite a bit ☐ Extremely

22. I feel exhausted

☐	☐	☐	☐	☐
Not at all	A little	Moderately	Quite a bit	Extremely

23. I feel sleepy

☐	☐	☐	☐	☐
Not at all	A little	Moderately	Quite a bit	Extremely

24. I feel tired

☐	☐	☐	☐	☐
Not at all	A little	Moderately	Quite a bit	Extremely

25. I feel panicky

☐	☐	☐	☐	☐
Not at all	A little	Moderately	Quite a bit	Extremely

26. I feel anxious

☐	☐	☐	☐	☐
Not at all	A little	Moderately	Quite a bit	Extremely

27. I feel nervous

☐	☐	☐	☐	☐
Not at all	A little	Moderately	Quite a bit	Extremely

28. I feel worried

☐	☐	☐	☐	☐
Not at all	A little	Moderately	Quite a bit	Extremely

29. I feel lively

☐	☐	☐	☐	☐
Not at all	A little	Moderately	Quite a bit	Extremely

30. I feel energetic

☐ Not at all ☐ A little ☐ Moderately ☐ Quite a bit ☐ Extremely

31. I feel active

☐ Not at all ☐ A little ☐ Moderately ☐ Quite a bit ☐ Extremely

32. I feel alert

☐ Not at all ☐ A little ☐ Moderately ☐ Quite a bit ☐ Extremely

33. After the session:**34. I enjoy it**

☐ strongly disagree ☐ disagree ☐ neutral ☐ agree ☐ strongly agree

35. I feel bored

☐ strongly disagree ☐ disagree ☐ neutral ☐ agree ☐ strongly agree

36. I dislike it

☐ strongly disagree ☐ disagree ☐ neutral ☐ agree ☐ strongly agree

37. I find it pleasureable

☐ strongly disagree ☐ disagree ☐ neutral ☐ agree ☐ strongly agree

38. It's no fun at all

☐ strongly disagree ☐ disagree ☐ neutral ☐ agree ☐ strongly agree

39. It gives me energy

☐ strongly disagree ☐ disagree ☐ neutral ☐ agree ☐ strongly agree

40. It makes me sad

☐ strongly disagree ☐ disagree ☐ neutral ☐ agree ☐ strongly agree

41. It's very pleasant

☐ strongly disagree ☐ disagree ☐ neutral ☐ agree ☐ strongly agree

42. My body feels good

☐ strongly disagree ☐ disagree ☐ neutral ☐ agree ☐ strongly agree

43. I get something out of it

☐ strongly disagree ☐ disagree ☐ neutral ☐ agree ☐ strongly agree

44. It's very exciting

☐ strongly disagree ☐ disagree ☐ neutral ☐ agree ☐ strongly agree

45. It's frustrates me

☐ strongly disagree ☐ disagree ☐ neutral ☐ agree ☐ strongly agree

46. It's not at all interesting

☐ strongly disagree ☐ disagree ☐ neutral ☐ agree ☐ strongly agree

47. It gives me a strong feeling of success

☐ strongly disagree ☐ disagree ☐ neutral ☐ agree ☐ strongly agree

48. It feels good

☐ strongly disagree ☐ disagree ☐ neutral ☐ agree ☐ strongly agree

49. I feel as though I would rather be doing something else

☐ strongly disagree ☐ disagree ☐ neutral ☐ agree ☐ strongly agree

50. I experienced motion sickness while cycling with VR

☐
Yes

☐
No

51. Rating for BORG Scale 1 (Sheet is represented by the instructor.)

☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12 ☐ 13 ☐ 14 ☐ 15 ☐ 16 ☐ 17 ☐ 18 ☐ 19 ☐ 20

52. Rating for BORG Scale 2 (Sheet is represented by the instructor.)

☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12 ☐ 13 ☐ 14 ☐ 15 ☐ 16 ☐ 17 ☐ 18 ☐ 19 ☐ 20

53. Rating for BORG Scale 3 (Sheet is represented by the instructor.)

☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

Next
