Ghost Sweeper: Using a Heavy Passive Haptic Controller to Enhance a Room-Scale VR Exergame

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***Abstract*—Virtual Reality (VR) exergaming is a beneficial and promising approach resulting from the combination of physical activity with the high motivation and enjoyment immersive VR offers. However, exergames can often fail to reach suggested levels of exertion. We, therefore, integrated a heavy passive haptic controller into a VR exergame. We explore the impact of the passive haptic controller and different kinds of kinesthetic feedback resulting from different interactions on the player experience. Our results of an extensive study (N=82) suggest, that using a heavy controller can significantly increase the exertion without reducing the motivation in contrast to using an HTC Vive controller. We discuss this finding in the context of haptic feedback and the experience of presence and the resulting implications for further research and VR exergames.**

***Index Terms*—Virtual Reality, VR, Passive Haptics, Controller, Exergame, VR Exergame, Exertion, Motivation**

I. INTRODUCTION

Exertion games or *Exergames* are digital games focusing on physical exercising. The authors of [25] define exergames as digital games "*[...] where the outcome of the game is predominantly determined by physical effort*". Exergames can have positive effects on the player's mood and emotional well-being [13] and can be used to support physical rehabilitation, psychological therapy as well as to prevent and counteract obesity [2], [12], [13], [22]. Furthermore, exergames can offer social benefits [19] and can even increase cognitive performance [11] in contrast to sedentary games.

In the context of exergames, immersion seems to have a vital impact on the beneficial effects exergames offer. Increasing the immersion in exergames can beneficially impact the training's intensity and motivation [5], [10] as well as the player's feelings of energy [29], and can lead to a better performance [5], [26] and reduced perceived exertion [23]. The highest degree of visual immersion can be offered by Virtual Reality (VR) systems featuring a head-mounted display (HMD). Hence, we refer to the term VR exergames as exergames including an HMD. A variety of current studies has demonstrated that creating exergames for VR is a promising approach and can beneficially impact performance, motivation, and presence [5], [18], [35], [40].

Among the parameters that determine the degree of immersion is the range of sensory modalities [36]. Hence, providing haptic feedback in virtual reality can significantly increase the experience of presence [9], [17]. This increase can also be found in the context of exergames, where it can beneficially impact the players' motivation and enjoyment [34], [39]. Haptic elements can further be used to increase the exertion of the players if they apply an exerting force-feedback to the players. Since exergames can fail to increase the level of energy expenditure [28] or may not contribute towards the recommended daily amount of exercise [14], integrating haptic feedback may be a promising approach. Thus, the exertion, as well as the immersion, can be increased at the same time. However, the resulting interaction of increased presence and enjoyment on the one hand and increased exertion on the other needs further investigation. In this paper, we, therefore, target the research question, whether using a heavy passive haptic controller can increase the players' presence, enjoyment, and exertion at the same time.

Hence, we implemented a heavy everyday object as a passive haptic controller into a room-scale VR exergame. Thus, we aim at achieving two effects. On the one hand, we aim at increasing the exertion due to the controller that weighs 594 grams. On the other hand, to counteract a potential motivational reduction that may result from high levels of exertion we further aim at increasing the immersion due to the haptic feedback our controller provides.

Our results of a study with 82 participants suggest that the integration of a heavy passive haptic controller can significantly increase the perceived and actual exertion of the player in contrast to the standard HTC Vive controller. We have also found a descriptively observable similar trend for the experience of presence. Further, the players' motivation values were not affected by the heavy controller and suggest that our setup was able to increase the exertion without reducing motivation. We further evaluate which haptic feedback cues are of particular importance for a VR exergame. Our work contributes to the design of (VR) exergames that aim at providing high levels of immersion, exertion, and motivation.

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II. THE IMPACT OF IMMERSION IN EXERGAMES

Immersion can be defined as *"[...] the extent to which the computer displays are capable of delivering an inclusive, extensive, surrounding, and vivid illusion of reality to the senses of a human participant"* [38]. Hence, immersion can be seen as an objective characteristic of a technology, that describes the technical integration of a person into a virtual environment [36]. We distinguish between immersion and the user's experience of presence which can be seen as a direct consequence of immersion [37] and is often defined as *presence* or the feeling of "*being there*" [16]. In the context of exergames immersion has the potential to enhance the player experience.

The authors of [41] investigated the impact of an immersive VR-based exercise bike versus a traditional stationary exercise bike on the players' exertion, self-efficacy, and enjoyment. Their results reveal higher self-efficacy and enjoyment values for the VR condition. Since enjoyment is a vital actuator to act autonomously, it can maintain a long-term motivation [15] and is thus an important construct in the context of exergames. Further, the participants in the VR-exercise reported lower perceived exertion values though the physiological exertion did not differ between the groups. Hence, the VR condition acted as a distractor from the task and thus lowering the exertion while increasing the enjoyment. Similar results have been found by [3] who suggest that using an immersive 360-degree video with music while cycling has the biggest and most positive impact on the player compared to non-VR video and the exercise without any distraction. Furthermore, the authors of [1] have investigated to what extent VR can be used to enhance a rowing workout. For this, rowing athletes either trained with an HMD or traditionally without an HMD on a rowing machine. The results reveal that even for experienced athletes, the technique in VR could be improved and the VR condition was enjoyed more and resulted in higher distraction values for the athletes. These results are supported by the authors [32] who further suggest that using an HMD for rowing can enhance the workout more than using an immersive CAVE system.

Besides using VR as a distractor for monotonous exercises such as rowing or cycling, VR can also be used as a central part of the game. Here the required movements do not result from the training device but from the gameplay. The authors of [10] developed the immersive exergame *Astrojumper* that is played inside a three-sided stereoscopic cave system. The game does not aim at distracting the player from an exerting physical task but instead allows the players to focus on their body movements. The authors observed that high levels of motivation were accompanied by high levels of perceived exertion. Furthermore, the authors of [5] took a similar approach with their immersive exergame *Fit The Shape*. The authors systematically investigated the role of the output device, perspective, and tracking fidelity on the player experience. Their results suggest that in particular the output device (HMD) and perspective have the greatest impact on the player's motivation, presence, and performance. Further, the authors observed that the perceived exertion was not affected by any condition and concluded that the players' body awareness was not distracted by the game play setup.

A. Haptic Immersion

Among the parameters that determine the degree of immersion and thus the quality of experience is the range of sensory modalities [36]. Current VR exergaming research mainly focuses on the effects of auditory and visual stimuli [3], [5], [10], [32], [41]. However, so far, less research has been done on the effects of integrating haptics into exergames [21]. We distinguish between two types of haptic feedback. The *tactile feedback* describes the feeling of a touch that is perceived through the skin. *Kinesthetic feedback* describes a force acting on the body, which is measured by sensory cells or muscles [30].

The authors of [9] evaluated the effects of tactile cues on the player's presence by adding a fan and a heat lamp to their setup which were implemented meaningfully into their virtual environment. They found out, that the tactile cues had a great impact on the players and could significantly increase the experience of presence. Further, in [17] the authors enhanced a virtual environment with passive haptics. These objects which exist in the real as well as in the virtual world and thus can be touched were able to increase the experience of presence as well as the physiological arousal.

For non-VR exergames, the authors of [39] explored the impact of haptic feedback on the players' experience of presence. For this, they developed the exergame *Pedal Race* which was controlled by an exercise bike. The haptic feedback was provided by increasing the pedal resistance when the players entered a specific terrain in the game. The authors observed significantly higher presence scores for the haptic feedback condition and thus propose designers of future exergame should consider haptic feedback. In a more recent study [34] the authors evaluated the impact of haptic feedback on the players' performance, enjoyment, and motivation in a VR exercycle game. They integrated tactile feedback by adding a fan and kinesthetic feedback by increasing the resistance of the bike. The authors observed higher presence, motivation, and enjoyment scores for the tactile condition but only higher presence scores for the kinesthetic condition compared to a no-feedback condition. Yet, the authors did not assess the players' perceived exertion. However, integrating haptic feedback into VR exergames is a promising approach but has to be carefully considered with regards to the interplay of motivation and feedback type and the exertion resulting from it.

B. Contribution

Though exergames show a great variety of beneficial effects they can also fail to increase the level of energy expenditure

[28] or may not contribute to the recommended daily amount of exercise [14]. Several studies focused on the question of how the exertion in exergames can be meaningfully increased. The authors have either increased the necessary movements of existing Wii games [24], made the visual appeal of the game dependent on the exertion [7] or improved the skills of the players' avatar if they trained in a corresponding heart rate range using a recumbent bicycle [20]. In our paper we take a different approach and make use of haptic elements. On the one hand we use a heavy passive haptic controller to increase the exertion. However, we do not want to reduce the players' motivation and thus leveling the reason for playing an exergame due to the high exertion. Hence, we further aim at increasing the immersion and hence the motivation by providing meaningful kinesthetic feedback on the other hand. We investigate the impact of our setup on the interplay of presence, motivation, enjoyment, and exertion to gain new insights on how haptics can be integrated into VR exergames.

III. GHOST SWEEPER

The exergame *Ghost Sweeper* serves as the basis for the study presented in this paper. *Ghost Sweeper* was developed using the game engine *Unity*. Since we want to systematically investigate the effects of an exerting passive haptic controller we implemented three different versions of the game each offering a different type of haptic feedback.

The basic gameplay is identical in each version. The player is located inside a haunted medieval castle. The player's goal is to defend the castle from the ghosts which haunt the castle. For this, the player is equipped with a special energy broom. As shown in figure 1 we have used a common corn broom to which an HTC Vive tracker is attached. Grip tape was wrapped around the broom handle to increase the grip. We then created a virtual replica of the original broom which serves as the interaction device and has the same dimensions as the real one. Further, all movements of the real-world broom are mapped to the virtual one. The player interacts with the game using only the broom. In total the broom and the attached components weight 594 grams and are thus twice as heavy as a common tennis racket. As the output device, we use the wireless version of the HTC Vive.

We have decided to use an everyday object as a passive haptic interaction object. On the one hand, we have thus focused on the integration of simple objects to show that complex technical setups are not required and games can be easily enhanced. On the other hand, due to the broom's soft end, the broom can be hit on the floor without risk. This makes it easy to realize kinesthetic feedback. With other sports equipment, such as tennis rackets or baseball bats, this would not have been possible without several risks.

The dimensions of the play area are 3 * 2.5 meters. Inside this area a green circle is displayed at the ground and serves as an energy field. To destroy a ghost, the player must perform a downward movement with the broom and hit the ghost on the head and then the green circle within the same movement. The interactions with the broom and the ghosts are only registered if the player hits the energy field after hitting a ghost. Thus, we can ensure that the player hits the ground in the real world and hence receives kinesthetic feedback. Further, the green circle acts as an indicator where the player can hit and thus reduces the risk of hitting real-world objects. Further, the players can also generate an energy shock by turning on their axes while pressing the broom to the ground. This shock will freeze the movements of all ghosts for six seconds and has a cooldown time of 20 seconds.

Fig. 1. **A** The real world broom has a length of 135 centimeters. An HTC Vive tracker is attached to the broom using a clamp. In total the broom weighs 594 grams. **B** The virtual broom has the same dimensions as the real one. A virtual tracker model is attached to the broom and acts as a visual indicator displaying whether the energy shock can be used (green light vs. red light).

There are four types of ghosts differing in their speed and number of hits they can withstand. As shown in figure 2, if a ghost gets destroyed it will shatter into pieces and the player receives a score based on the required effort to destroy the ghost. The player's score is displayed on a table inside the virtual environment. To avoid demotivating game elements, the player can not lose points nor lose the game. Each game lasts three minutes. Ghosts immediately start to spawn when the game begins. We deliberately chose a high spawn rate to ensure that the player is always busy and does not have resting breaks. Thus, the three minutes can be seen as a short high-intensity exercise.

To investigate which impact the haptic controller and the kinesthetic feedback resulting from the interactions have on the player, we implemented three different versions of the game, which are presented in figure 3. In the *Broom-Ground* condition, the player has to hit the ground using the real broom

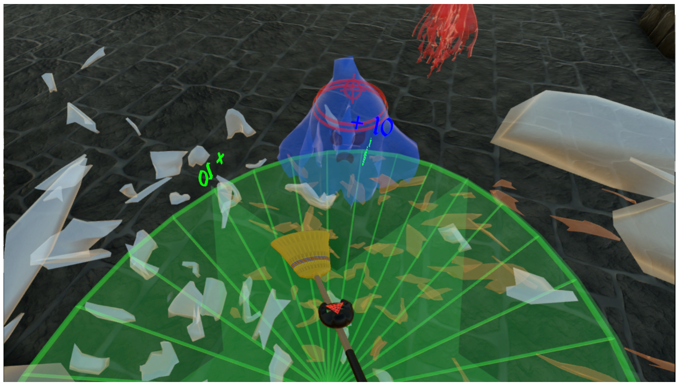

Fig. 2. *Ghost Sweeper* is played from a first-person perspective. In this screenshot the player just destroyed a ghost using the virtual broom. The red light on the virtual Vive tracker indicates that the player needs to wait until the energy shock can be used again.

to destroy the ghosts. Thus, the player experiences a force-feedback when the broom hits the floor. To investigate the impact of the haptic feedback which is provided by hitting the floor, we created the *Broom-Air* condition, in which the green energy field is moved up half a meter. Hence, the player does not need to hit the physical ground and thus does not receive the same force-feedback as in the *Broom-Ground* condition. To further investigate which impact the physical broom has on the player, we created a *Controller* condition, in which the player interacts using an HTC Vive Controller. In this version, we also use the virtual broom representation and display the green energy field on the ground. We deliberately neglected to implement a fourth version with an HTC Vive Controller and an energy field that is moved up since the player would not experience any force-feedback in both conditions.

IV. EVALUATION

We conducted a comprehensive study to investigate the impact of the passive haptic controller on the one hand and the impact of the force-feedback provided by hitting the ground on the other hand.

A. Method

We used the Borg Scale [4] to assess the perceived exertion. The scale ranges from 6-20 (none - very, very hard). The scale is based on the assumption that a person has a resting pulse of 60 beats per minute and that the perceived exertion correlates positively with the actual heart rate. Hence, the heart rate can be estimated by multiplying the Borg value with 10. The actual exertion was measured using the heart rate which we measured using the *Bittium Biosignals Ltd. Faros 180* pulse belt.

Furthermore, we measured the participants' dissociation and association to assess whether our setup distracted the players' attention. Congruent with the research of [23] association is defined by a focus on internal body stimuli whereas dissociation is defined by a focus on external stimuli and distance to internal body stimuli. This attentional focus could be rated on a scale from 0 (dissociation) to 10 (association).

We used the Intrinsic Motivation Inventory (IMI) to measure the players' motivation. The inventory consists of six subscales of which the *Interest/Enjoyment* subscale is considered the most significant since it directly measures intrinsic motivation [8]. The experience of presence was measured using the *IGroup Presence Questionnaire* (IPQ) [33]. The IPQ comprises the one-item subscale *General Presence* and three further subscales *Spatial Presence, Involvement, and Experiences Realism.*

Since the players' sportiness can moderate the assessment of the exergame, we used the International Physical Activity Questionnaire (IPAQ) [6] to assess the daily physical activities of the participants.

B. Design and Procedure

We used a between-subject design in our study. Hence, every participant played one of the three versions of *Ghost Sweeper*. The participants were assigned randomly to one of the conditions. The same dependent variables have been assessed in each of the conditions. Before the start of the experiment the participants gave their consent and put on the pulse belt while the instructor waited outside the laboratory. Afterward, demographic data, the IPAQ, and experiences with digital games and VR were assessed. Subsequently, the participants were asked to sit on a sofa for five minutes so that a resting pulse serving as a baseline measurement could be recorded. After finishing the resting period, the participants put on the wireless HTC Vive and received the controller. A short tutorial introduced the game world as well as the interactions and automatically started the actual game afterward. During the gameplay we recorded the heart rate of the participants to evaluate the physical exertion of the participants. The participants played the game for three minutes. Subsequently, the participants filled out the remaining questionnaires. After completing the last questionnaire, the subjects were debriefed about the experiment. The complete experiment lasted 45 minutes in total. The ethics committee of our university approved the experiment.

C. Hypotheses

Based on the assumption, that the broom controller is heavier and provides more haptic feedback than the HTC Vive controller, we hypothesize that

I *Participants playing with the real broom show higher exertion and presence values than interacting with the Vive controller.*

We further assume, that the Broom-Ground condition provides the most haptic feedback and therefore hypothesize that

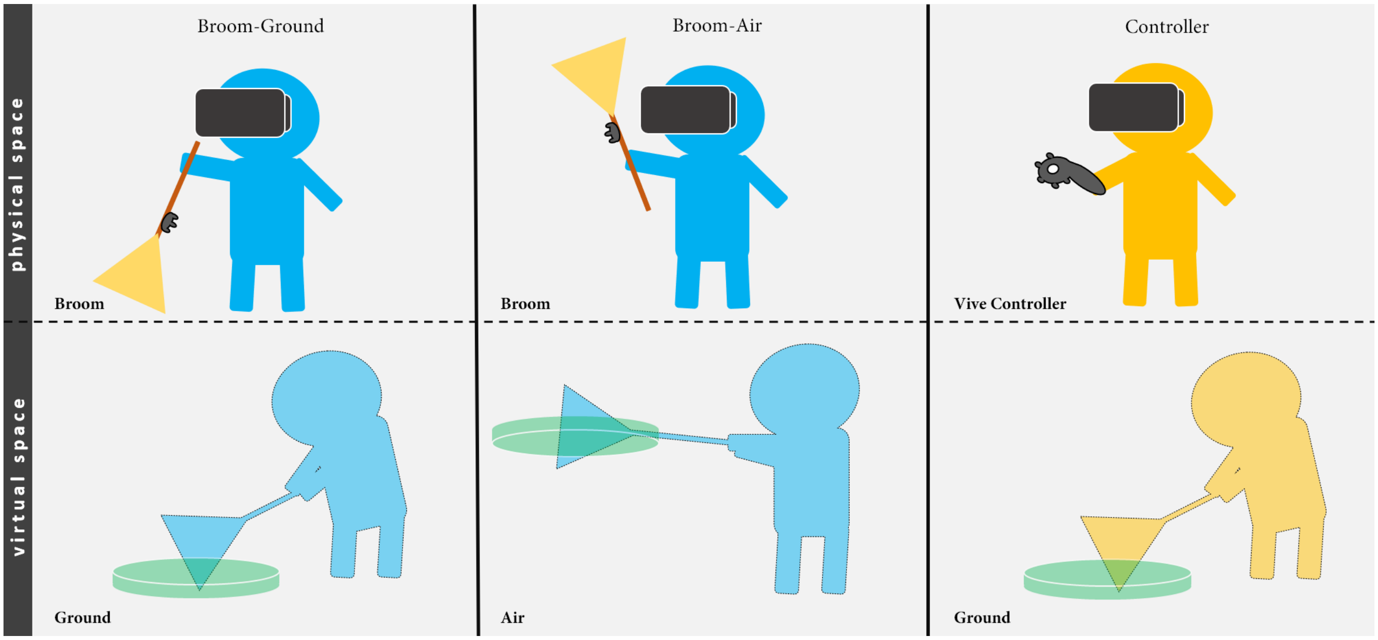

Fig. 3. Three different versions of the game were implemented which differ in the controller used and the position of the virtual ground. In the Broom-Ground condition the player interacts using a real broom. Here the virtual ground is at the same position as the real ground. In the Broom-Air condition, the player also interacts using the real broom but does not need to hit the real ground, since the virtual ground is moved into the air. In the Controller condition, the player interacts using a controller but sees a virtual broom. Here the virtual ground is also at the same position as the real ground.

II *Participants in the Broom-Ground condition show higher presence values than in the Broom-Air condition.*

Since current research showed that a strong connection between presence and motivation exists we further hypothesize that due to the higher hypothesized presence values between all conditions

III *The participants' motivation differs in all three groups and show the highest values in the Broom-Ground and the lowest in the Controller condition.*

D. Results

69 female and 13 male participants were included in the analysis $(N = 82)$. 28 subjects were assigned to the Broom-Ground condition and 27 each the other two conditions. The age ranges from $17 - 32$ years $(M = 21.24, SD = 3.29)$. 50% of the participants reported having played an exergame at least once. The VR experience can be rated low with 79% of the participants having no or just a little experience with VR systems. After removing outliners from the IPAQ the athletic activity of the participants was categorized. 9 participants were categorized as low, 48 as medium, and 19 as high.

One-way ANOVAs were calculated for the following comparisons of the dependent variables between the groups. According to [31] if the groups consist of $N \geq 25$, ANOVAs are robust against violations of the normal distribution, which is why we did not check for normal distribution. Furthermore, variance homogeneity according to the Levene test was given for all dependent variables. If significant differences between the conditions were found, Bonferroni post hoc tests were calculated. The descriptive values for all dependent variables are shown in table I. The results of the inferential statistical evaluations are presented in the following subsections.

TABLE I
MEANS AND STANDARD DEVIATIONS OF THE DEPENDENT VARIABLES

Subscales	Broom-Ground M *(SD)*	Broom-Air M *(SD)*	Controller M *(SD)*
Exertion			
HR gameplay	133 (*17.5*)	123 (*16.4*)	111 (*17.6*)
HR difference	44.5 (*17.1*)	38.4 (*12.3*)	27.7 (*13.6*)
Borg	13.3 (*1.65*)	12.9 (*1.42*)	10.5 (*1.93*)
Attentional Focus			
Diss-&Association	5.32 (*2.75*)	5.56 (*2.90*)	3.15 (*2.52*)
IPQ			
General Presence	4.71 (*1.05*)	4.70 (*1.14*)	4.04 (*1.29*)
Spatial Presence	4.63 (*0.90*)	4.67 (*0.99*)	4.25 (*1.13*)
Involvement	4.36 (*1.01*)	3.52 (*1.07*)	3.50 (*1.31*)
Experienced Realism	1.95 (*0.83*)	2.12 (*0.78*)	1.70 (*0.62*)
IMI			
Interest/Enjoyment	5.83 (*1.00*)	6.02 (*1.07*)	6.00 (*0.90*)
Perceived Competence	4.43 (*1.11*)	4.33 (*0.99*)	4.91 (*0.78*)
Effort/Importance	5.26 (*1.01*)	5.50 (*0.85*)	4.93 (*0.99*)
Pressure/Tension	4.34 (*1.12*)	4.27 (*1.03*)	3.21 (*1.11*)
Perceived Choice	5.16 (*1.08*)	4.95 (*0.95*)	5.20 (*0.96*)
Value/Usefulness	4.30 (*1.22*)	4.23 (*1.30*)	3.48 (*1.41*)

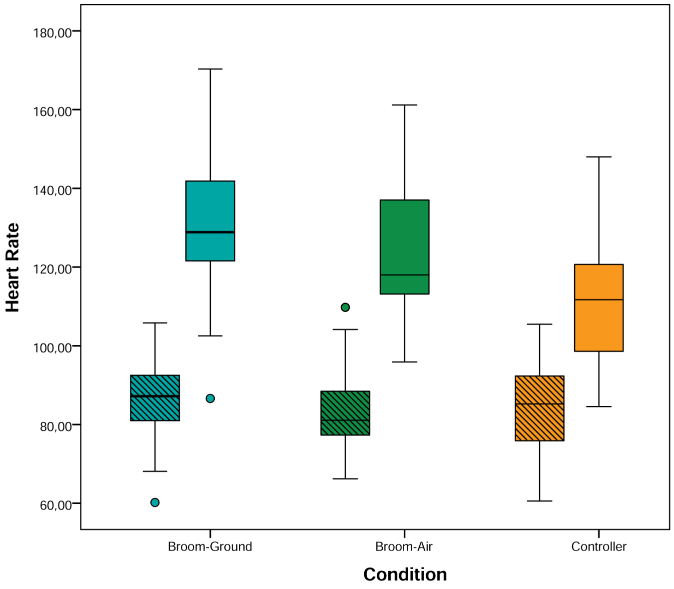

Fig. 4. The hatched areas represent the respective heart rate baseline measurements. The unhatched areas represent the respective average heart rates during the gameplay.

1) Exertion: To compare the physical exertion which is presented in figure 4 we calculated the heart rate difference for each participant between the average heart rate during the gameplay and the average heart rate during the baseline measurement. We found a significant difference for the resulting value between the groups $F(2,79) = 9.29, p < .001, \eta_p^2 = .19$. Post hoc comparisons revealed a significant difference between the *Broom-Ground* and *Controller* condition ($p < .001$) as well as between the *Broom-Air* and *Controller* condition ($p = .025$). No significant difference between the Broom conditions was found. Regarding the perceived exertion, the results suggest a similar tendency as for the physical exertion. A significant difference for the Borg value between the groups was found $F(2,79) = 21.91, p < .001, \eta_p^2 = .36$. Post hoc comparisons indicate significant higher scores in the *Broom-Ground* condition compared to the *Controller* condition ($p < .001$) and in the *Broom-Air* condition compared to the *Controller* condition ($p < .001$). No differences were found between the Broom conditions. The Borg values for both Broom conditions indicate a somewhat hard exertion whereas the values for the Controller condition indicate a fairly light exertion.

In a next step, we calculated the individual percentage of the maximal heart rate by dividing the heart rate during the gameplay by the individual maximal heart rate (220 - age). If we compare the individual relative heart rate with the relative Borg value (Borg value divided by the maximal Borg value) no significant difference is observable. This indicates, that the participants were able to rate their perceived exertion precisely. Further, in the *Broom-Ground* condition 60% , in the *Broom-Air* condition 30% and in the *Controller* condition 22% of the players reached a moderate or high intensity level according to the intensity levels of the ACSM [27]. The findings are further supported by the the results regarding the dissociation and association values which reveal a significant difference between the groups $F(2,79) = 6.44, p = .003, \eta_p^2 = .14$. The players in the *Broom-Ground* condition ($p < .012$) and in the *Broom-Air* condition ($p < .005$) had a significantly higher associative focus compared to the *Controller* condition.

2) Presence: A significant difference for the *General Presence* subscale was missed $F(2,79) = 3.04, p = .053, \eta_p^2 = .07$. Descriptively considered, however, a dichotomy can be identified with higher values in both broom conditions than in the *Controller* condition. Further we have found a significant difference for the *Involvement* subscale $F(2,79) = 5.17, p = .008, \eta_p^2 = .12$. A post hoc comparison revealed higher values for the *Broom-Ground* condition compared to the *Broom-Air* ($p = .022$) condition and compared to the *Controller* condition ($p = .019$). No other significant differences were found for the remaining subscales of the IPQ.

3) Motivation: The overall results of the IMI show high average values in all subscales. Especially the values for the most significant subscale *Interest/Enjoyment* are very high but do not differ between the conditions. Overall ANOVAs revealed significant differences for the *Pressure/Tension* $F(2,79) = 9.18, p < .001, \eta_p^2 = .19$ and *Value/Usefulness* $F(2,79) = 3.31, p = .042, \eta_p^2 = .08$ subscales. However, post hoc comparisons only revealed significant differences for the *Pressure/Tension* subscale with higher values for the *Broom-Ground* condition compared to the *Controller* condition ($p = .001$) and *Broom-Air* condition compared to the *Controller* condition ($p = .002$). We have further observed interesting correlations between the *Interest/Enjoyment* subscale and the subscales of the IPQ. The *General Presence* $r(82) = .325, p = .003$, *Spatial Presence* $r(82) = .462, p < .000$, and *Involvement* subscale $r(82) = .247, p = .025$ highly correlate with the *Interest/Enjoyment* subscale of the IMI and thus indicate, that presence and motivation are linked closely. Surprisingly, we have found no correlation between the actual exertion and perceived exertion with the *Interest/Enjoyment* subscale.

4) Sportiness as a confounding variable?: To investigate whether the participants' sportiness is a confounding factor, we calculated correlations between the *IPAQ* score and all subscales of the *IMI, IPQ, BORG*, and the heart rate difference. We found no significant correlations. Hence, the results seem independent of the physical activity of the participants.

V. DISCUSSION

Our approach was to increase the exertion in an exergame in such a way that the motivation and enjoyment are not reduced. Our results reveal that the integration of an exerting passive haptic controller can significantly increase the perceived and physical exertion in contrast to an HTC Vive controller. In the Broom-Ground 60% of the participants reached a moderate or high-intensity level and thus twice as many as in the Broom-Air condition and nearly three times as many as in the Controller condition. Since the ACSM and world health organization guidelines suggest to train at least 150 minutes a week at a moderate intensity or 75 minutes at a high intensity especially the Broom-Ground condition can contribute to reaching these goals. We further aimed at increasing the players' presence by providing rich haptic feedback. Our results indicate that there is a tendency towards higher general presence values in the broom groups. Hence, our first hypothesis can be confirmed for the exertion part but only partly confirmed for the presence part.

We have found significantly higher *Involvement* values for the *Broom-Ground* condition compared to both other conditions. This finding is interesting since it could be an indication of a confirmation of our second hypothesis. We assumed that the kinesthetic feedback resulting from striking the ground is more intense and thus provides a higher sense of presence than hitting in the air. However, no other subscale shows the same tendency as the *Involvement* subscale. Thus, we have to reject our second hypothesis. The difference in the kinesthetic feedback between the broom conditions is so marginal, that it seems to have only little influence. In addition, it happened that also in the *Broom-Air* condition, the players hit the real ground.

Surprisingly we have found no difference between the conditions for the *Interest/Enjoyment* subscale. Hence, we reject our third hypothesis. However, the enjoyment values for all conditions are really high. Thus regardless of the version, the participants enjoyed the game. Further, though the broom conditions show higher exertion values, the motivation in these conditions has not been reduced. Hence, we achieved our initial goal to increase the exertion without negatively affecting motivation. In this context the *Pressure/Tension* values are interesting since they reveal higher scores in both broom conditions compared to the controller condition. Since this subscale is theorized to be a negative predictor of intrinsic motivation [8], we see our assumption that a higher exertion can have a negative motivational impact to be confirmed.

However, as we found no difference in the motivation between the groups and no correlation between the *Interest/Enjoyment* subscale and the participants' exertion, the negative influence of the exertion on the motivation seems to have been compensated. We assumed that a higher sense of presence due to the kinesthetic feedback resulting from the broom controller and the related interactions would counteract a potential motivational loss. Since we have found positive correlations between three subscales of the *IPQ* and the *Interest/Enjoyment* subscale of the *IMI* the assumption that a higher sense of presence leads to higher motivational values seems to be confirmed. However, we have found no significant differences between the broom conditions and the controller condition for the IPQ subscales. Thus it is possible that the descriptively observable difference in the presence values influenced the motivation, though no statistical difference was found.

The values of the attentional focus further indicate that the participants had a stronger body perception with increasing exertion. As planned, our application, therefore, did not distract from the actual exertion. In line with [10], high exertion values are accompanied by high motivation. Thus, using room-scale VR setups for exergaming is a promising approach for future developments to achieve high levels of motivation that seem to be independent of the exertion.

Although our results are promising and can be used for the design of future exergames we have to discuss some limitations. We observed, that the participants in both broom conditions tend to report that interacting with the broom in both conditions led to uncomfortable postures. Although this does not seem to influence the motivation, future developments should choose a more posture pleasant interaction. Further, the game only lasted for three minutes. This period may be too short for a meaningful assessment of the perceived exertion. Future developments should aim at evaluating whether the high motivation values are also observable for longer gameplay or more consecutive rounds. However, 83% of the participants in our evaluation would have liked to continue playing the game and even 48% of the participants would have liked to play for another five minutes. Furthermore, using a common broom to interact in a VR game is simply something new and could, therefore, trigger the novelty effect.

VI. CONCLUSION

Our study indicates that integrating an exerting passive haptic controller into a VR exergame can significantly increase the perceived and actual exertion without reducing the motivation. The haptic feedback provided by the passive haptic controller could not increase the experience of presence significantly, though a positive trend is observable. Since the exertion tends to increase the pressure and tension of the player but did not reduce the motivation and since we found positive correlations between the players' motivation and the experience of presence, we nevertheless assume, that a potential motivational loss due to the higher exertion was counteracted by the rich haptic feedback the passive haptic controller provides.

Our work contributes to the future design of VR exergames which aim at providing high levels of exertion and motivation/enjoyment at the same time. Furthermore, since room-scale VR gaming becomes increasingly popular, our approach serves as an easy realizable possibility to expand current games which then can offer an increased exertion mode.

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