A Wall I Enjoy: Motivating Gentle Full-Body Movements Through Touchwall Interaction Compared to Standing and Sitting Smartphone Usage

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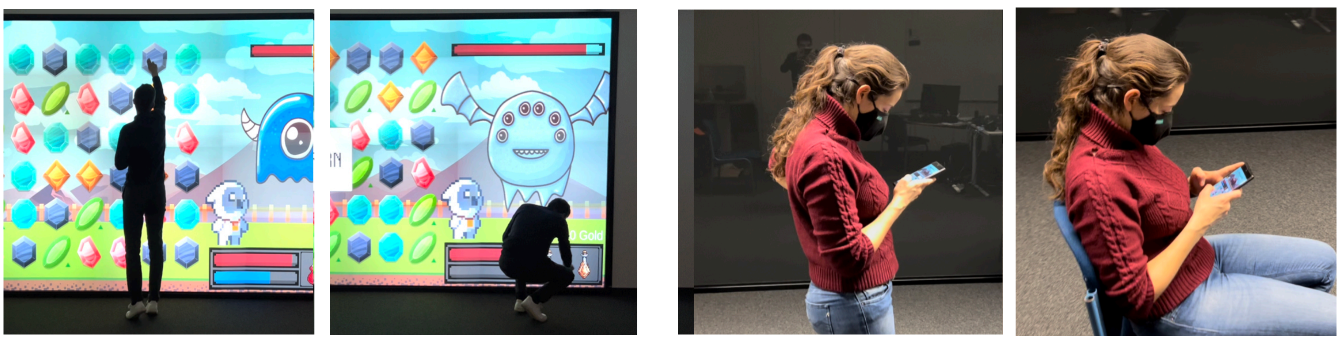

Touchwall Standing Sitting

Figure 1: Pictures of our Match-3-Monster game being played in all three conditions: full-body interaction on a larger-than-human touchwall; using a smartphone while standing, and using a smartphone while sitting.

ABSTRACT

Sedentary occupations and recreational activities carried out primarily while seated promote extended time periods spent in unhealthy sitting postures, contributing to physical and mental health issues. While apps and reminders can be effective, they often fail to sustain enjoyment and motivation or do not target stationary settings. In our work, we investigate whether sedentary waiting periods could be broken up through gentle full-body movements via full-body interactions on a large touchwall instead of remaining seated or standing. In a mixed-methods study (N=18), we compared a Match-3 game played (1) on a full-body touchwall, (2) on a smartphone standing, and (3) on a smartphone sitting, investigating user experience, performance, and acceptance. The touchwall game subtly motivated people to move, stretch and bend their bodies without performance loss while enjoying the game compared to the smartphone conditions. We suggest that full-body touchwall interaction has the potential to fill occasional waiting time while encouraging breaking up sedentary behavior.

CCS CONCEPTS

• **Human-centered computing → Empirical studies in HCI**;

KEYWORDS

gentle physical movement, gentle full-body interactions, touchwall, casual exergame, public display

IMX '24, June 12–14, 2024, Stockholm, Sweden

ACM ISBN 979-8-4007-0503-8/24/06
https://doi.org/10.1145/3639701.3656302

ACM Reference Format:
Jana Franceska Funke, Michael Wolf, Christian van Onzenoodt, Katja Rogers, Timo Ropinski, and Enrico Rukzio. 2024. A Wall I Enjoy: Motivating Gentle Full-Body Movements Through Touchwall Interaction Compared to Standing and Sitting Smartphone Usage. In *ACM International Conference on Interactive Media Experiences (IMX '24), June 12–14, 2024, Stockholm, Sweden.* ACM, New York, NY, USA, 18 pages. https://doi.org/10.1145/3639701.3656302

1 INTRODUCTION

Sedentary behavior and unbroken time spent sitting has well-known negative effects on physical and mental health [18, 29, 39, 47, 67, 73, 76, 77]. Further, we know that regular movement throughout the day (non-exercise activity thermogenesis, also called NEAT [50]) can improve long-term health even when the movement is performed in a very gentle manner [5, 15, 29]. Active breaks from sitting can facilitate cognitive activity [14, 55], and gentle full-body movements like stretching and bending help to improve blood flow [13, 82], neuronal responses [12], muscle stiffness [13], injury prevention [30, 54], coordination [31, 62], postural stability [69], and balance [71]. The nature of office jobs, as well as many leisure activities, is often heavily based on ubiquitous phone and PC usage, which amplifies unbroken sedentary behavior as a problem of great concern [47, 50]. Both researchers and companies at the intersection of health and human-computer interaction have attempted to encourage behavior change by using technology to motivate enjoyable physical activity and break up sedentary behavior.

Due to their ubiquity, smartphones initially seem like a useful choice to implement movement reminders, especially for short breaks and bridging waiting time, yet they also have downsides. Some application encourage and visualize movement or steps but potentially fail to sustain enjoyment and motivation long-term [85] or need an extensive movement range (e.g., [61]) and do not lend themselves well to waiting periods in stationary settings (e.g., at a bus stop, waiting room, or in short school or work breaks).

Additionally, smartphone use, in general, can have further negative effects on users' health. People tend to look down at their phones (while sitting, standing, and walking) because holding them at face height is too fatiguing for long periods of time. This not only leads to a stiff and forward-bent neck but often also to the whole back being bent [37, 48]. Pain and damage sometimes do not occur until years later, when it is challenging to treat and can reduce the quality of life [76, 78].

Alternative solutions to smartphone-based applications could thus be more promising to counteract posture and small screen health issues while motivating further health benefits through gentle full-body movements like standing, stretching/reaching, and bending/crouching. Applications have been developed that could potentially interrupt long sitting periods and motivate movement, such as arm stretches [24]. Building on such work, we believe that approaches that more explicitly incorporate fun or playful elements that the general population already enjoys may be more positive for user acceptance, uptake [52], and additional movement range would expand the benefits of gentle full-body movements.

In this work, we draw on the idea of a casual exergames [24] to explore a larger-than-human touchwall display to encourage gentle full-body movements through its touch-based interaction. This kind of technology could in the future be more commonly available in a public (e.g., at a bus stop) or semi-public/closed-public setting (e.g., in a waiting room) as display technology becomes cheaper. Current workplaces / schools already feature smartboards of slightly smaller sizes, which could implement applications of this type. Research like ours could help push for these future interactive displays to hang in more (semi)public spaces (e.g., waiting rooms) for multiple use cases. Early attention to the benefits can yield its importance to encourage implementing gentle full-body movements in display interaction [16]. However, prior to undertaking such efforts widely or long-term, we need to know whether this kind of touchwall-based interaction can effectively encourage stretching/reaching, bending, and moving, without negatively affecting player experience or performance compared to smartphone usage (thus hindering uptake).

For evaluation, we implemented a Match-3 game—a well-known, popular, and straightforward casual game genre [38]—for a large 2.58m x 3.88m touchable screen ("touchwall") and for the smartphone itself. The game's key mechanic consists of swapping colored symbols with neighboring ones in a 6 x 7 matrix to combine as many of the same colors as possible into a (vertical or horizontal) row to destroy the matched symbols and gain points. By transferring these game interactions from its conventional smartphone setting to a large display screen, it becomes a casual exergame that requires gentle full-body movements: moving a few steps back or to the sides, turning one's head and eyes in different directions, stretching/reaching and bending over to touch necessary symbols. In comparison, the same game can be played with a smartphone while sitting or standing but without any additional movements. The larger screen of the touchwall should motivate people to complete these gentle full-body movements while having a brief but enjoyable experience in a stationary setting.

We argue the game on the touchwall could be a healthier, more fun, and potentially even a more social and interactive option to spend time while waiting in comparison to using a phone in an unhealthy posture (sitting/standing). However, while in general large display usage in public settings can yield positive acceptance, e.g., in the context of a playful festival exhibit [84], we also need to find out whether users accept this kind of gameplay, i.e., fully use the given space for gentle full-body movements, without negative effects on player experience or game performance due to different screen sizes.

To evaluate these assumptions, we conducted a mixed-methods within-participants study with n=18 participants comparing the full-body interaction of the touchwall game (Figure 1 (a)) to smartphone variants while standing (Figure 1 (b)) and sitting (Figure 1 (c)).

After each playthrough, we assessed participants' interest and enjoyment (IMI), emotional valence, dominance and arousal (SAM), as well as fatigue and enjoyment, and recorded gameplay measures like click positions and item use (Part A). In a final interview, participants were then invited to provide more detailed insights into their experience, to which we applied a qualitative thematic analysis (Part B). While in part A), we were interested in the spatial extent of elicited movements, and whether this has negative effects on experience and performance. In part B), the interviews went beyond this comparison to gain contextual understanding of adoption for future research but also to expand the concept with new ideas.

Calculations of required movements, heatmap of touch input interaction, observations, and interviews with participants show that the touchwall successfully encourages gentle full-body movements compared to the smartphone conditions. Our results show that this encouragement of gentle full-body movements on the touchwall was subtle enough and not disturbing, even if participants recognized higher movement. In terms of enjoyment, the full-body condition yielded slightly higher scores. For game performance, the full-body condition showed no discernable difference compared to the smartphone conditions (based on the in-game metrics) and no obvious difference in screen usage (as shown by the heatmaps). Only performing interactions was faster for smartphone conditions, as users did not have to walk back and forth to see the whole layout. Regarding speculative user acceptance for public or semi-public spaces, we found that depending on suitable framing (i.e., the specific (public) spot, social situation, and application type, e.g., multiplayer), people would be interested in using the full-body touchwall interaction to fill or bridge waiting time. This provides a promising basis for further research concerning other application types and field studies.

With our findings, we contribute a lab-based proof-of-concept for the use of large touchwall displays for encouraging gentle full-body movements. They constitute a first step towards informing the design of an application for a full-body touchwall game, encouraging gentle full-body movements as one potential countermeasure against sedentary behavior and poor sitting/standing posture while, for example, waiting. Our findings that enjoyable gentle full-body movements on a touchwall could be an effective method against sedentary waiting behaviors are an empirical contribution in this context to encourage future applications or in-the-wild evaluation. We discuss the advantages and disadvantages of this approach and describe new approach ideas to inform future research into the application of casual exergames for breaking up sedentary behavior.

2 RELATED WORK

Using smartphones while sitting can affect not only health through bad posture and sedentary behavior but also the eyes. Kim et al. [43] and Jaiswal et al. [33] discuss indicators that handheld devices have effects on visual discomfort, especially when using them excessively. Further, a lot of research deals with questions regarding the link between health and physical activity. In order to narrow down the topic, we here mainly focus on gentle physical movement, sitting posture, and stretching the body. Research shows we can assume that already gentle physical movement can improve people's health [25] as well as break up time spent sedentary [15].

Adverse effects on posture are connected to the duration of smartphone usage, investigated by Jung et al. [37].In their study, a group that used smartphones for over 4 hours per day showed a significantly higher effect on bad posture and respiratory function. In a systematic review, Szczygieł et al. [76] found several negative effects coming from bad sitting postures like headaches, upper cross syndrome, postural pain syndromes, and balance disturbances.

Research suggests that stretching/reaching as a general activity over different time periods has positive effects on muscle stiffness, blood flow [13], arterial pressure decrease [45], arterial stiffness, and vascular endothelial function in middle-aged and older adults [42], and blood flow that could be related to oxygen availability and utilization [44].

Sitting thus seems to be very unhealthy, not only because of the posture but because of the lack of movement. In an analysis of 149,077 participants, Stamatakis et al. [75] found indications that sedentary behavior and lack of physical activity are associated with all-cause and cardiovascular disease (CVD) mortality risks. Dunstan et al. [18] not only argues about sedentary behavior but about *prolonged unbroken* sedentary behavior and its health risks. The authors conclude that even physically active people who have prolonged unbroken sedentary behavior are affected by health risks. A literature review from 2015 conducted by Benatti and Ried-Larsen [5] shows positive effects on health through breaking up prolonged sitting time with "light-intensity ambulatory physical activity." Similarly, a study by English et al. [20] found a decrease in systolic blood pressure through standing interventions and an even higher decrease through walking interventions every 30 minutes for stroke patients. The most effective break time and activity while having a break was evaluated in a study with 48 participants by Ding et al. [17]. They found muscle fatigue after 40 minutes of sedentary work. Comparing different break types ("passive break, an active break of changing their posture, and standing and stretching their body for 5 or 10 mins"), they reported standing and stretching for 5 minutes as the most effective break for muscle discomfort prevention. Furthermore, people are happier if they live an active life, where frequent light physical activity seems to be more helpful compared to vigorous physical activity [46]. Even on mental health, there can be positive effects [67, 73, 77].

In a study by Mazzoli et al. [55], researchers discovered that active breaks during classes in elementary school can facilitate cognitive activity. Productivity while using sit-and-stand workstations was investigated by Mengistab [57] and Rostami et al. [70]; no productivity loss appeared while performing tasks at a standing desk. Further, Jansen et al. [34] conducted a study to investigate the different effects on locomotion (moving and stationary) and screen overview (large wall display and small wall display). Their results show a significant effect on visual overview benefiting spatial memory. Locomotion itself had no significant effect on spatial memory, but the combination of both locomotion and overview performed best against all other combinations.

Besides social interventions (e.g., with school kids, initiated by teachers and/or parents [55, 81]), there are some technical approaches to motivate and remind people of gentle physical movement. Very common nowadays are wearable technologies that remind the user to break up time spent sedentary [74]. Looking for more enjoyment-based exercising, we can find a wide range of exergames (exercise-based games), although these must be treated with caution [40, 53]. Some of these can be classified as "casual exergames" that promote gentle physical activity: "effective technologies that may facilitate light- to moderate-intensity physical activity" [65].

Mandryk et al. [52] investigated anti-sedentary guidelines that "focus on re-introducing physical activity into daily routines": These include an easy entry into play, achievable short-term challenges, appropriate feedback on effort, individual skill-matching, supporting social play to increase motivation, a casual interaction, motivate for repetition and motivate to change sedentary habits. Further, Levine [50] focuses on all physical activity that isn't sports-like exercise (contributing to energy expenditure as "non-exercise activity thermogenesis, i.e., NEAT"), and states that an increasing level of NEAT could contribute to health benefits. Prior work has explored implementing a game to encourage increasing one's level of

NEAT [21, 22]. Looking for more sedentary time-breaking exercises in prior casual exergames, we built on work like the GrabApple intervention exergame [24]. With this, Gao and Mandryk [24] implemented a resistance exercise game in which users have to move, stretch, and bend to grab an apple. While having fun, their preliminary results showed that users' heart rate was elevated, and more calories were burned. The authors reported that these results met “recommended exercise intensity” and were “sufficient to provide health benefits when played a few times per day in 10-minute increments.” Isbister et al. [32] did not find higher enjoyment of games with higher physical activity than games with no physical activity, but they report a significantly higher level of energy when using physically active games. Nevertheless, Mueller et al. [59] motivates to use more of the “body as play”, referring to the body not only being a "thing" (Leib) but being a part of us that can and should be used in more different ways to create a more “humanized technological future”.

About ten years ago, Ojala et al. [63] reported their research on interactive public displays. In a nutshell, they warn of differences between laboratory and real-world settings, as well as novelty effects, which gradually decrease after a short period. Yet there are indications for older adults that technology-based exercise provides more enjoyment than traditional exercise programs [80]. Ardito et al. [3] report challenges for both users and designers. They mention the challenges of attracting diverse people in public spaces due to different ages, skills, and experiences with technology. A literature review by Alt et al. [1] suggests guidelines for the evaluation of public displays. They suggest controlling for validity (internal, external, and ecological), considering the content's impact, understanding the user through qualitative and quantitative data, and checking for common problems like social attention. They point out that lab studies have advantages like minimized external influences and fewer setup difficulties, but provide low ecological validity. A study from 2022 by Béraud-Peigné et al. [6] investigated user experience (UX), enjoyment, exertion, and heart rate of 38 healthy older adults playing a multiplayer interactive wall exergame. They report a "moderate-to-high" physical activity level, high perceived enjoyment, and high UX.

Since the global COVID-19 pandemic, new concerns have risen against public touch interfaces. In a user study by Emmanuel et al. [19], they try to avoid touching touchscreens with holographic projections. However, these use cases are very specific (e.g., traffic lights and ATM pin entry). Mäkelä et al. [51] tried to visualize and heighten awareness of hygiene on touch displays by highlighting fingerprint positions. Other approaches to avoid touching the surface of public displays could be the use of gestures as input [83] or the use of personal smartphones to interact with the public display [35]. Here, however, we would again use a small screen and lose the potential benefits of the bigger screen, like overview and the primary goal of gentle physical movement.

We note that there is not only research on large wall displays but also on large floor displays [28, 64], which can be implemented as floor exergames as well (see [41]). Floor displays avoid hygiene problems through touching, and still feature physical movement, but also need more space and may incur different acceptance issues.

Finally, the honeypot effect is a well-known issue when discussing interactive systems in public scenarios. It describes the effect of an attractive stimulus (the "honeypot"), e.g., the presence of other people already interacting with a system. This can motivate by-passers or observers to join an interaction. This effect was more closely investigated by Wouters et al. [84]. They believe the key factor is an activation loop consisting of information exchange, learning social norms, and interactive features by observing people. Something similar was investigated by Michelis and Müller [58], who observed 660 by-passers of a large display in a city center. Besides the honeypot effect, they observed different behaviors in groups and individuals. Moreover, they show the process in numbers: When 100% are by-passers, one-third started with subtle interaction of the display, most of them proceeded with more direct interaction, and two-thirds of them stayed and did multiple interactions. The same topic again was investigated by Brignull and Rogers [11], who suggest the main problem is the fear of social embarrassment, which makes the honeypot effect and seeing people playing already potentially very effective. There are indications that the honeypot effect can also work for being physically active and that observing other people's activity can be a motivating factor [79].

3 RESEARCH QUESTION

Our research focuses on the effects of gentle full-body movements (like moving side to side or front to back, stretching upwards to reach, and bending over/crouching) and how they can be elicited by a larger-than-human touchwall. In particular, we are interested in how these movements and interactions are perceived and affect gameplay compared to ubiquitous smartphone interactions that are mostly performed while sitting or standing.

We assume that the gentle full-body movements integrated into a casual game could positively influence enjoyment, cause greater movement (if using the full space of the wall) without noticeably increasing fatigue, and yield on-par performance compared to conventional smartphone interaction. Such factors (high enjoyment, low fatigue, on-par performance) would be necessary to induce and maintain users' motivation to actually use a touchwall full-body game in a (semi-)public area [7, 36, 52, 56, 60]. These were thus our primary dependent variables of interest.

Simultaneously, it is important to know if participants would use the given space to actually perform gentle full-body movements. We assess this by logging data of touch positions, observations, and individual perceptions of fatigue and calculation of the touchwall space. We opted to forgo physiological measures of exertion (e.g., heart rate) as we were more interested in full-body stretching and bending than in exercise heart rate levels.

Additionally, large public displays have been explored a lot in previous work in real-world scenarios, showing that social acceptability is achievable when carefully designed: important factors to consider include context factors like location [63], system factors like usability and visibility of sensitive data [1], challenges with designing for a diverse user group [3], novelty effects [63], hygiene [19, 51], and overcoming initial hesitance [11, 84]. Relying on this prior work, we assume that our specific scenario could achieve similar acceptability with future design iterations. Therefore, we opt for a lab study due to unmovable hardware as a first proof-of-concept. We nevertheless asked our participants to speculate how

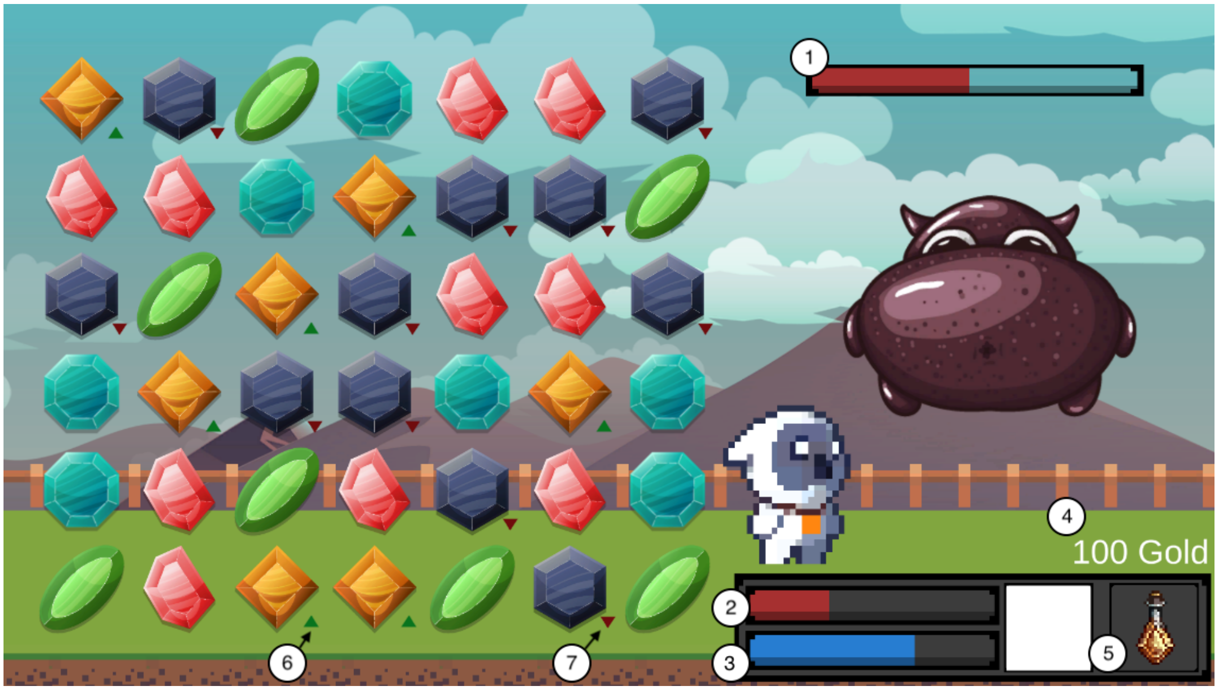

Figure 2: The picture shows the Match-3 game with the touchwall layout against the monster on the right. ① is the health bar of the monster, ② is the health bar of the player, ③ is the mana bar of the player, ④ is the in-game money the player has left, ⑤ are two potion slots were one is filled with a potion, ⑥ is the indication that this symbol will deal more damage, ⑦ is the indication that this symbol will deal less damage.

likely they would be to use the prototype in a real-world scenario to inform future work.

We aimed to compare effects on enjoyment, performance (including touch positions), and acceptance in players interacting with a Match-3 game played in three conditions[1]: on a larger-than-human touchwall (with a 2.58m x 3.88m sized display, necessitating reaching/bending movements), on a smartphone while standing, and a smartphone while sitting. The standing smartphone condition was used as an intermediate condition between sitting (no physical activity) and touchwall (full-body interaction[2]).

The research questions (RQs) driving our three-condition comparison study are as follows: *RQA1: Do participants actually perform our intended gentle full-body movements across the full touchwall space? RQA2: How does full-body interaction on a touchwall in the form of gentle full-body movements affect player experience, performance, and user acceptance in comparison to smartphone usage while sitting and standing?* In the pursuit of this research we constructed a third, more exploratory research question: *RQB: What impacts the acceptance and adoption of such touchwalls and how could we expand this concept with new ideas for future research?*

[1]While we also considered implementing a smartphone game variant that requires similar full-body interaction to the touchwall, we opted against this because the smaller display could result in disadvantages like eye strain [26, 27, 33, 66] or posture issues [37, 48], and full-body movement with a smartphone is less explored in terms of social acceptability. Additionally, the touchwall preserves potential future possibilities to design for large detailed overview screens or group interaction via the honeypot effect [84].

[2]Walking is partly involved in the full-body condition, but as we are aiming for example for waiting scenarios, we focus on in-place gentle full-body movements.

4 MATCH-3-MONSTER IMPLEMENTATION

To investigate our RQs, we designed a simple Match-3 game that could be used while waiting as described earlier. The goal of the player, represented by a little white owl-like character, is to defeat all evil monsters in order to free the owl’s hometown. The game consists of five different levels of Match-3 games. Each level is connected to a different monster. To win the game, all five levels and, therefore, five monsters have to be defeated. A Match-3 game consists of a matrix (in this case 6x7) filled with symbols (in this case 5 different colors). In each turn, one symbol can be swapped with a neighboring symbol. The goal is to create different patterns wherein symbols of the same color form a horizontal or vertical line. Patterns of three or more identical symbols are called a match and work towards the player’s goal of destroying symbols on the map: The matched symbols disappear and in doing so, deal damage to the monster. New symbols then appear and close the gap. The goal of the game design was to require regular use of the whole size of the Match-3 grid. With this interaction design, we try to subtly encourage gentle full-body movements in the touchwall condition by requiring players to stretch and bend in all the corners and move back and forth for overview.

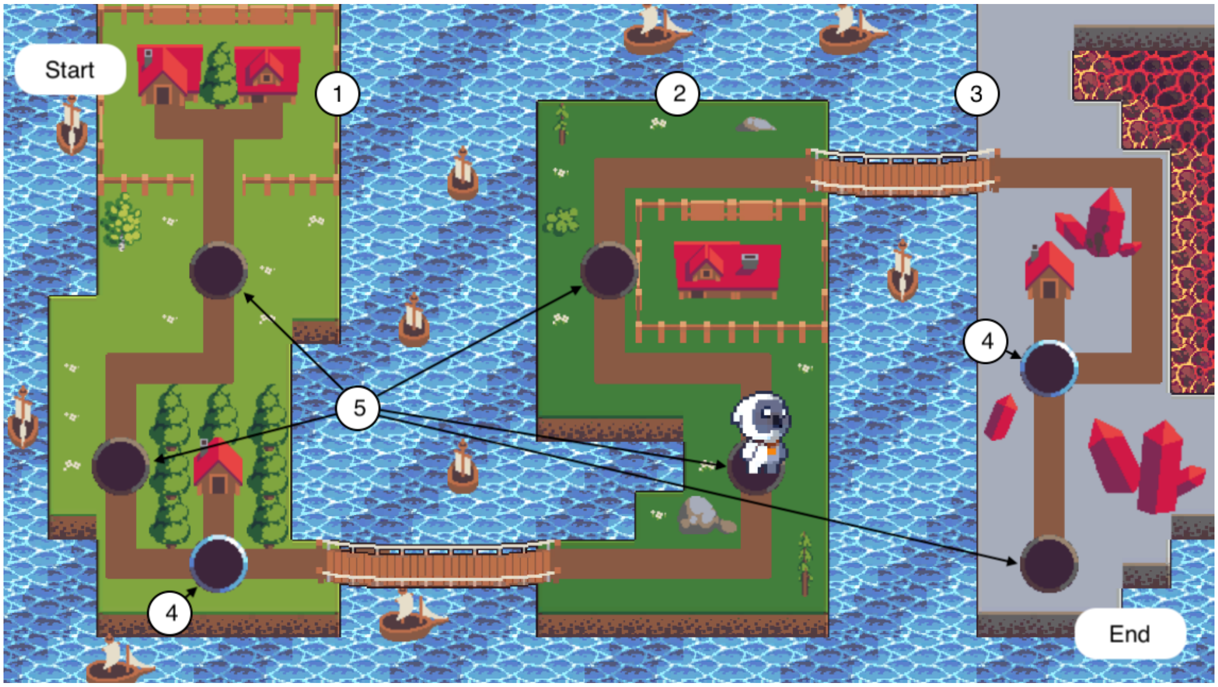

Figure 3: ①, ②, and ③ show the three different islands on the game map: each island has different monsters with different abilities. ④ marks the platinum-bordered nodes of the shop and ⑤ marks the bronze-bordered nodes of the Match-3 battles.

4.1 The Match-3-Monsters Game

Our game is implemented as a specific version of a Match-3 game. Each time symbols are destroyed through a combination, life points are subtracted from the opposing monsters' health bar. The loss of life points increases with the size of combinations, with every destroyed symbol dealing two damage each. The damage done to monsters can be optimized in a number of ways through specific combinations, as explained below. If the life points (see Figure 2 ①) of the monster reach zero, the monster is defeated and the player can progress to the next level on the map.

The player is equipped with a life bar (Figure 2 ②), a mana bar (Figure 2 ③: mana can be seen as the amount of power, or in this case, number of turns left to do something), two potion slots (Figure 2 ⑤ one is empty) and the number of in-game currency referred to as gold (also all shown in Figure 2 ④).

The life bar shows the amount of life points the player has left. A full bar is 100 life points. Life points are lost whenever an enemy monster attacks, which occurs whenever the player has no more mana left. The mana bar is used up after 3 swaps if no potions are used to replenish mana. The turn is not ended automatically to enable the use of potions before the enemy monster would attack. After an enemy attack, the mana bar fills up again and the next three swaps can be made. The mana bar is replenished between levels, while life points are not.

The two potion slots can be filled with a potion each, and then is removed permanently on use. However, new potions can be bought in a shop with gold, which is earned whenever a monster is defeated.

Combinations and Special Effects. The most basic match is a combination of three same-colored symbols in a line. Multiple combinations can be created with a single swap. If five symbols of the same color are matched, all visible symbols of that color disappear, resulting in a massive burst of damage.

The game's monsters have different weaknesses and resistances, relating to the different colors of symbols in the game. For example, a red monster takes double the damage from blue symbols (4 damage per symbol). These 'strong' symbols are denoted with a green arrow pointing upwards in the lower right corner (Figure 2 ⑥). In contrast, a red monster takes half the damage from green symbols (only 1 damage per symbol). Symbols that deal half the damage ('weak' symbols) are denoted by a red arrow pointing downwards in the lower right corner (Figure 2 ⑦).

The Map. To progress through the game, players make their way along a one-way path on a map that features all levels (see nodes with brown borders in Figure 3 ⑤) and shops (nodes with platinum borders, see Figure 3 ④). The map and its path is split into three distinct islands that are connected with bridges, and increase in difficulty. Monsters on the second, dark-green island (Figure 3 ②) are stronger (120 health and dealing 12% of the player's health as damage in each attack). Additionally, these monsters have both a weakness and a resistance, i.e., the level contains normal, strong, and weak symbols. The fifth and last monster on the grey island (Figure 3 ③) has 200 health and deals 12% of the player's health as damage in each attack. It has no resistance, only a weakness, but freezes symbols to add difficulty. Frozen symbols cannot be swapped anymore and can only be unfrozen by getting destroyed via a match.

After the monster in each level is successfully defeated, the player can progress on the map to the next node. After the last monster has been defeated, the game is completed.

Shop and Currency. The shop allows the player to buy three kinds of potions with different effects. One potion is a health potion that restores half of the player's maximum health. The second potion is a mana potion, (which allows the player to reset their mana bar and get the full set of turns back, or three turns if the bar is empty). The third potion is a damage potion (which instantly damages the monster, without interacting with the symbols in any way, dealing 30 damage). Health potions can be used in the shop and in battle, while the other two potions can only be used while fighting a monster. Potions can be bought with gold that is earned by defeating monsters.

4.2 Touchwall Calculation for Full-body Movements

To get an overview of the complete symbol matrix on the touchwall, users need to stand at a distance from the touchwall (see position P in Figure 4). To calculate the distance between such an overview position (P) and a position at which users can touch the touchwall, we used the length of the touchwall and the central field of vision (60 degrees)[3]. Our calculation resulted in an approximate distance of 2.23 m from the wall for a good overview of the matrix (P).

If we consider a participant of average height (173 cm)[4] with an arm length of up to 78.7 cm[5] standing at position P_0 with an outstretched arm (see right half of Figure 4), we can calculate the approximate distance a user has to overcome to select the target symbols in the four outmost corners. The approximate distances for the upper corner symbols are then 1.753 m, and 2.073 m for the lower corner symbols. To overcome this distance the participant is forced to take steps back and forth (this was also observed during the user study and can be seen in the paper's video figure).

4.3 Mobile Game vs. Touchwall Layouts

The game works similarly when presented on the 2.58 by 3.88 meter touchwall display or on a smartphone with an aspect ratio of 6:9. We note that there was an additional difference in layout to provide a comparative overview and usability: a horizontal orientation on the touchwall and vertical orientation on the smartphone (see Figure 5). Symbols could be swapped by either swiping across or tapping on two neighboring symbols: this interaction worked exactly the same way regardless of screen size or device.

5 USER STUDY

In order to find out how the full-body touchwall interaction with gentle physical movement in a Match-3 game affects player experience, performance, and user acceptance compared to smartphone usage, we designed a user study complied as far as possible with guidelines by Alt et al. [1]. As a comparable baseline, the same game with a smartphone in a standing and a sitting position was used. We chose standing and sitting as the two comparison settings with the smartphone because sitting would be a familiar position and level of physical activity while playing a casual game, and standing would be with the same device (a smartphone) but with a healthier posture (standing) inherent to the touchwall condition. This allowed us to better isolate the effects of gentle physical movements (as opposed to gentle physical movements *and* a standing position).

We chose a mixed-method approach for the study design. With the quantitative data (A) , we aim to measure and compare enjoyment and perceived exhaustion, while the in-game data was used to compare performance across conditions. The qualitative data (B) was used to inform our understanding of the quantitative data, and the speculative user acceptance of the full-body touchwall interaction if presented in a public scenario.

5.1 Conditions / Study Design

The participants were invited to play the Match-3 game in all three conditions (within-participants design). To avoid learning effects, the conditions were counterbalanced for each participant. All levels were played by each participant until the final screen appeared.

- *touchwall full-body interaction:* In this condition, participants played the Match-3 monster game on the touchwall screen (2.58m x 3.88m, Figure 1,).
- *smartphone standing:* In this condition, participants had to stand for the game duration while playing the same Match-3-Monster game on the smartphone (Figure 1,).
- *smartphone sitting:* In this baseline condition, participants were seated on a chair while playing (Figure 1,).

5.2 Participants

A total of 18 participants (9 female, 9 male, 0 non-binary or other genders; M_{age} = 31.16, SD = 14.54) took part in our user study. The youngest participant was 19, the oldest was 59. Most of them were students or university employees. Thirteen participants were known by the study conductor (we address this in limitations).

The participants were almost evenly divided into people who play video games a lot and people who play rarely (10 rarely; 8 often). Almost no one (2 of 18) played Match-3 games, but almost all of them generally knew the genre. Participants reported frequent physical activity; only two mentioned they were not physically active. They all said the full-body interaction on the touchwall was not or only slightly fatiguing.

5.3 Measures

In addition to a demographics survey prior to gameplay (age and gender), we employed three kinds of measures:

In-Game Metrics. While participants were playing the game, we logged in-game data. We measured several game-relevant information like overall timestamps (when the game starts and ends), timestamps and usage of potions, as well as information about the level and monster, the time and number of swaps, and detailed

[3] https://www.epd.gov.hk/eia/register/report/eiareport/eia_2522017/EIA/html/Appendix/Appendix%2011.1.pdf
[4] We assumed this average based on the average height of women and men in our general population https://www.worlddata.info/average-bodyheight.php
[5] The highest value for arm length in our general population based on DIN 33402 http://www.arsmartialis.com/technik/laenge/laenge.html

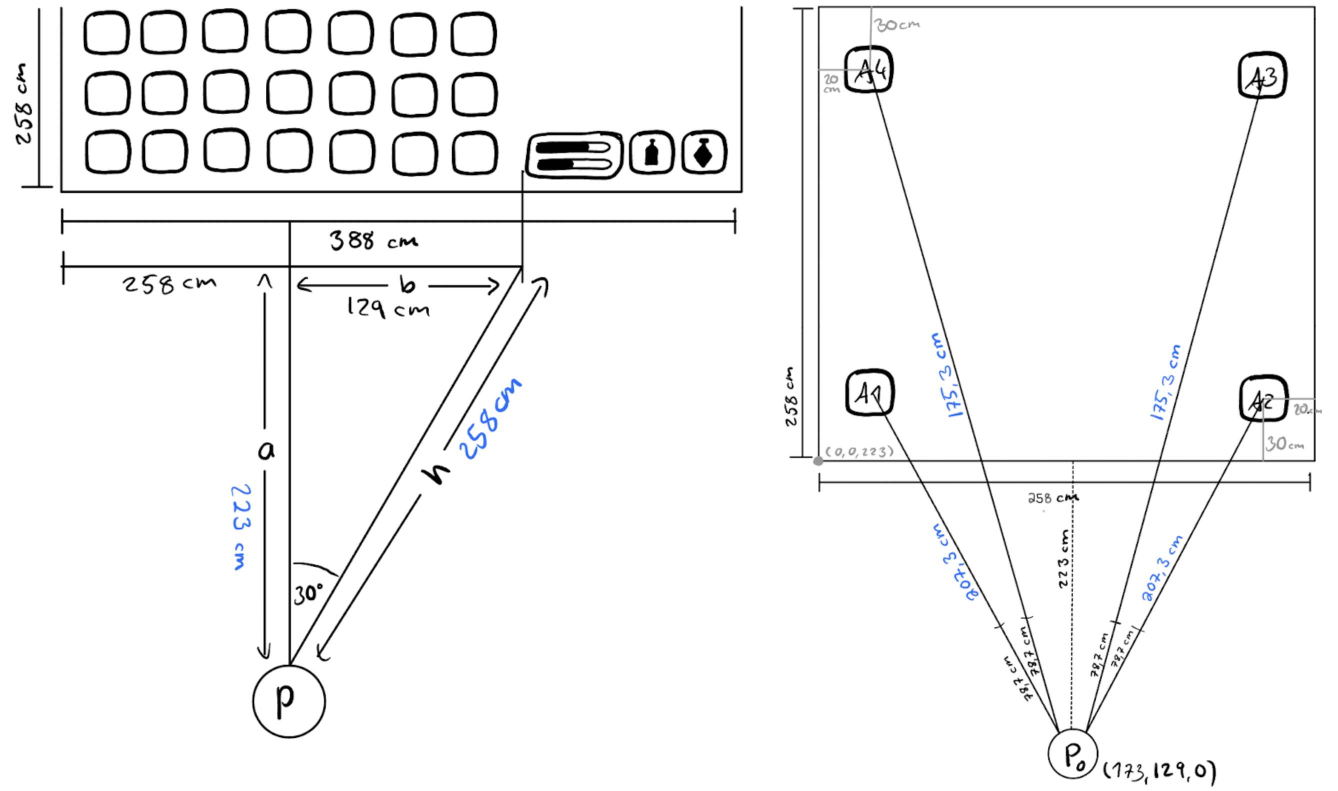

Figure 4: Calculation of the distances: On the left side, trigonometry was used to calculate the distance from the wall if the participant (P) wants to have a full overview of the symbol matrix in the game: *223cm*. On the right side, the approximate distance between the player's arm stretched out and the symbols furthest away is calculated. This calculation used geometry in a 3D space point. Point (0,0,0) is in the lower front left corner at the distance of the player P_0.The approximate length to be overcome between the outstretched arm and the corner symbols are *207.3 cm* (bottom corners) and *175.3 cm* (upper corners), respectively.

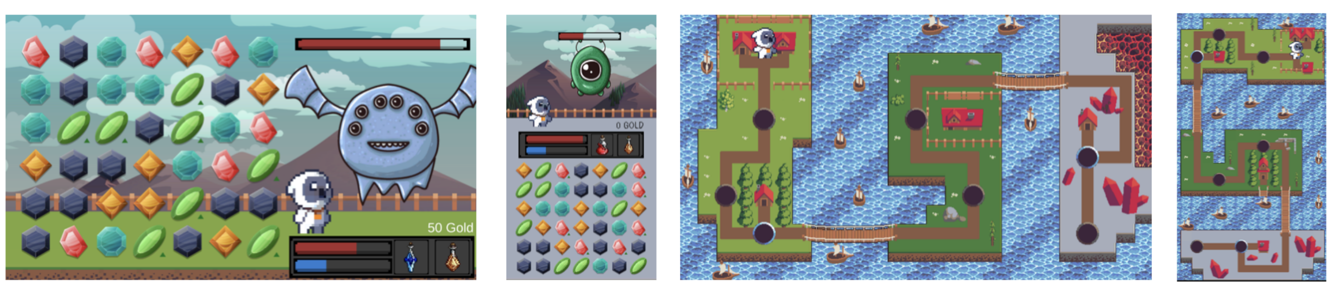

Figure 5: The game had two layouts: The horizontal versions (first and third picture) were shown on the touchwall, and the vertical ones (second and fourth) on the smartphone. The first two pictures are game screens, the second two are the map.

information about the swapped symbols and what damage they caused.

Post-Game Questionnaires. After each playthrough, participants had to fill out the interest and enjoyment subscale (7-point scale from 1="not at all true" to 7="very true") of the Intrinsic Motivation Inventory (IMI) [72], and the self-assessment manikin (SAM) [8] with subscales valence, arousal and dominance (5-picture scale). Two custom questions with a 7-point Likert scale (1=strongly disagree to 7=strongly agree) were added to ask about physical fatigue (exhaustion) while playing the game, and overall enjoyment of each game condition.

Interview. After all three conditions, we interviewed participants. The interview consisted of 14 questions (see supplementary materials) designed to gain insight into participants' game, exergame, and Match-3 prior experience, their experience and acceptance of the conditions during the study, and their speculative social acceptance of the full-body touchwall interaction in public scenarios. We followed the structure of the questions but deviated to clarify participants' answers with follow-up questions (semi-structured interview).

5.4 Procedure

Each participant was asked to sign a consent form allowing us to record, and publish their anonymized data, including demographics, usage metrics, questionnaire answers, and transcribed audio data. Afterward, the process of the study was explained and the participant was asked to fill out the demographics questionnaire. Participants were introduced to the game (mechanics and procedure) with a short instruction handout. If the participants had any questions, they were answered in detail to ensure a thorough understanding of the game before playing it for the first time and to minimize the learning effect between conditions. Participants were then asked to play the game, starting with the counterbalanced assigned start conditions. If questions arose during the game, they were again answered to minimize confusion on the participant's side and ensure a straightforward first game. The game ended either after finishing all levels and islands on the map or due to loss of life points, after which participants completed the post-game questionnaire. This cycle (playing and the post-game questionnaire) was completed three times (for each condition). The study ended with an audio-recorded semi-structured interview. Finally, participants were given 10 Euro as remuneration.

6 ANALYSIS & RESULTS

We first report the findings of our quantitative analysis, with details of significant results and effect size (Friedmans ANOVA for non-parametric results, Bonferroni correction for pairwise comparison and Kendall's w for effect size) in Table 1 and non-significant results in the appendix (Table 2). We then report the interview findings.

6.1 Quantitative Analysis

During analysis of the SAM scores, valence and dominance showed no significant differences. Arousal showed a significant effect between the three conditions, however, the post-hoc test with Bonferroni correction did not (see Table 1). Interest/enjoyment (IMI), while rated positively, did not differ significantly between conditions. Similarly, players' enjoyment rated with the custom question was overall rated high in all conditions (see Figure 6 (b)), but there was no significant difference between conditions for this item.

The custom question on participants' exhaustion showed a significant difference in exhaustion between the conditions *full-body* and *standing*, and *full-body* and *sitting*. While exhaustion was generally low, the sitting condition scored significantly lower on this item than both other conditions, see Figure 6 (a).

Gameplay Performance. There was no significant difference between conditions when analyzing the total number of swaps per game. However, the time between each swap in seconds did differ significantly: Post hoc analysis revealed that players took significantly longer for each swap in the *full-body* condition compared to the other two conditions *standing* and *sitting* (see Figure 6 (c)).

We found no significant difference when analyzing the number of strong hits (or weak hits per game), normalized by the number of total swaps, see Figure 6 (d).

As a measure of participants' actions, we grouped the individual input of each participant on the 6x7 symbol grid as an average and visualized this as a heatmap in Figure 7. Across all conditions, participants interacted with grid cells a minimum of four times, and a maximum of 84 times. We took a closer look at the outermost symbols in the full-body condition to calculate how often participants reached for symbols in the border regions, i.e., reaching "maximum" physical activity in the full-body condition. On average, each participant reached for the top cells (uppermost row) 6.72 times across all levels, about 7.0 times for the bottom cells, about 5.67 for the left-most cells, and 6.28 times for the right-most ones.

Condition	SAM Arousal		Exhaustion		Time Between Swaps	
	M	*SD*	*M*	*SD*	*M*	*SD*
full-body	3.17	0.86	3.33	1.46	14.37sec	11.44sec
standing	2.83	0.79	2.78	1.4	8.59sec	10.75sec
sitting	2.56	0.92	2.11	1.08	9.26sec	11.26sec
$\chi^2(2)$	6.34		9.41		274.61	
	p < .05		p < .01		p < .001	
	w=.18		w=.26		w=.18	
post hoc	full-body ↔ standing n.s.		full-body ↔ sitting p<.05		full-body ↔ standing p < .002	.01
	full-body ↔ sitting n.s.				full-body ↔ sitting p < .002	.01

Table 1: We report means (M), standard deviation (SD), and post-hoc pairwise comparisons with Bonferroni correction for all initially significant measures SAM arousal (5-point), exhaustion (custom 7-point likert), and time between swaps in seconds. The post hoc test for exhaustion yields significant differences between full-body and sitting as well as for time between swaps. Time between swaps is also significant between full-body and standing. Results for all measures can be found in Appendix.

6.2 Qualitative Analysis

Analysis Procedure. In total, we collected 2:28 hours of spoken interview data. For analyzing the transcribed interviews, we employed a hybrid thematic analysis approach, using elements from both reflexive thematic analysis (e.g., organic iterative development of themes) and a codebook-oriented thematic analysis (use of a codebook and consensus coding) [9, 10]. Interviews were transcribed and coded in Dovetail[6] in the original language (quotes presented in this paper were translated into English). We constructed four deductive categories *Enjoyment*, *Speed/Success/Performance*, *Physical Activity* and *Social Acceptance*, which drove our analysis as the guiding variables and factors we were interested in. We developed inductive codes within these categories based on a close inspection of the data.

[6]www.dovetailapp.com

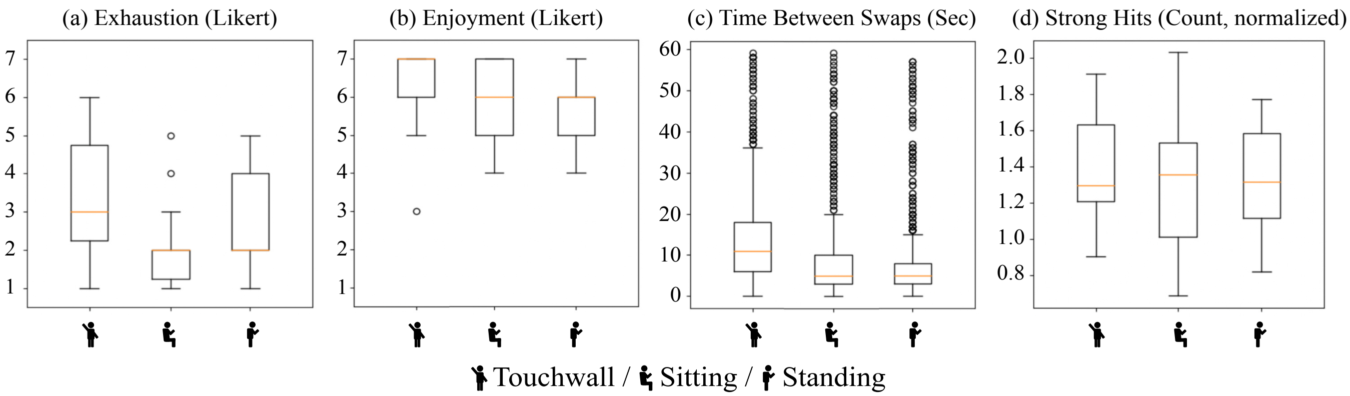

Figure 6: The sitting condition was rated significantly less exhausting than the full-body or standing conditions (a). The time between each swap in seconds took significantly longer in the full-body condition than in the other two conditions (c). All conditions were rated as enjoyable (custom item); while the *full-body* condition was rated most highly, this was not a significant margin (c). The total number of strong hits per game (divided by the overall number of swaps per game) did not differ significantly between conditions (d).

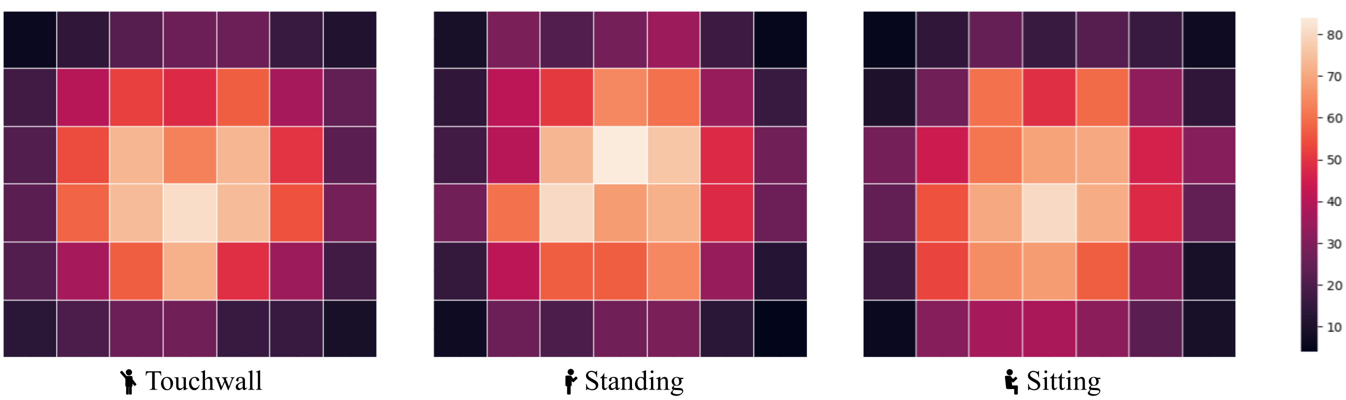

Figure 7: The heatmaps show the position of the Match-3 symbols for all three conditions. The more input a symbol of the 6x7 Match-3 matrix had, the brighter the coordinate block is depicted. The x- and y-axis denote the coordinates of each Match-3 matrix position. The scale on the right of each heatmap denotes how many total inputs each block had.

Two coders initially coded one interview separately and discussed the codes in a group with two additional researchers. Then two more interviews were coded by the same two main coders, and again discussed and compared with each other afterward, followed by the same process with three more interviews. Through this process, we developed and iterated on a codebook. After having coded and discussed six interviews, the remaining twelve interviews were split in half (six per coder) and the codebook that was developed based on the first six interviews was applied to the remaining ones. If coders felt that additional new codes were needed, they were coded in a different color and discussed in a final meeting after the first complete coding and were then added to the codebook if necessary. The first six interviews were re-checked to see if these new codes applied there, too.

The final codebook after the complete first round was used as the basis for developing themes within each of the deductive categories that represent our areas of interest. The themes were constructed in three meetings of the two main coders. In each meeting, the coders matched the themes to the interviews to make adjustments when necessary.

Participant Background. The participants were almost evenly divided into people who play video games a lot and people who play rarely (10 rarely; 8 often). Almost no one (2 of 18) played Match-3 games, but almost all of them generally knew the genre. Participants reported frequent physical activity; only two mentioned they were not physically active. They all said the full-body interaction on the touchwall was not or only slightly fatiguing.

6.2.1 Developed Themes.

Theme 1: While the touchwall lacked in overview, it made up for it with enjoyment and novelty. In comparison, the smartphone had a better overview and was familiar and comfortable. Many participants mentioned that gaining an overview of the touchwall was an issue compared to the smartphone. For example, one participant said *"on the board that was a disadvantage for me, because I lacked the overview. You always have to go back a step and look at the whole picture so that you can somehow recognize patterns, and on the mobile everything was compact." (P14).* Someone also mentioned a focus switch due to the big size of the wall: *"On the big screen [...] it was very confusing [...] I had to pay attention to the game on the one hand, which was on the left half, and then look to the right every now and then." (P1)* .

In comparison, the smartphone was perceived as having a better overview. For example, P18 said *"The advantage of the mobile part is that you can take it with you, that you can overlook everything at a glance." (P18).* This factor was named by another participant as why a *"cell phone is most suitable for such applications" (P16).*

While the full-body game on the touchwall was often mentioned as a novel interaction, the smartphone was often mentioned in terms of familiarity. One participant described: *"Of course, playing on the wall was unusual. I mean, normally you only know that you play it on your cell phone, and that's why it had an additional fun factor that you could also move around and that you experienced something new." (P12).* Similarly, the touchwall was perceived as *"most innovative" (P17)*, something *"special" (P7)* that *"fascinated" (P7)* them. Someone even described it as having *"an event character" (P3).* In comparison, the smartphone was a more familiar tool: *"on the cell phone you are more used to" (P13).* A few participants also mentioned a faster and more hasty play style with the smartphone: *"[on the] cell phone, I probably played faster and more fluidly." (P8)*, and *"on the cell phone I thought less strategically, but rather simply played" (P17).* One participant attributed their success in the seated smartphone condition to *"the habituation and the rest" (P16).* Nevertheless, one participant said *"but so to play once in a while or very rarely, the wall is just cooler." (P2).*

Theme 2: Most participants believed they could concentrate better while sitting than standing due to less distraction. Yet some felt concentrating was easier during full-body interaction. Participants had different opinions on the topic of concentration. Most participants mentioned they performed better and were more concentrated while sitting, compared to standing or moving at the wall. One participant said they were *"probably most successful on a cell phone and while sitting, because you're not concentrating on anything else." (P15)*; another one mentioned *When you're sitting, you can concentrate fully on the game. That's sometimes a bit difficult when you're standing, I think. (P5).* Another explained *"playing sitting down [...] yeah that's a little bit more relaxed than standing." (P4).*

On the other hand, some participants experienced the opposite. They felt that standing, moving, and stepping away heightened their concentration. For example, one participant said *"I guess I was most successful standing up. Then you are perhaps more concentrated" (P14).* Another described *"on the wall, I took a better look and thought strategically about the whole thing and was probably better for that reason." (P17).*

Theme 3: Although participants were aware of the full-body movements like walking, stretching, and bending, none of them were really fatigued by them. .

Participants were aware of the fact that they had to move more on the touchwall than while sitting or standing: *"I'm constantly walking so I can keep track, you have to go back and close to the wall again" (P8).* Another mentioned being aware of the stretching: *"I think it's good that sometimes you have to stretch" (P10).* Some participants highlighted the movements as being enjoyable—e.g., *"But on the screen, it was fun, because when you were moving, it was fun." (P1)*—or as exciting: *"Because somehow by having to move around more and be more involved in the game yourself, it was more exciting than typing something on your phone." (P15).*

Two participants mentioned that the height of the person could have an effect on the physical experience: *"The wall is too big for me. I can't reach everywhere." (P8).* In contrast, being tall had effects too: *"it was no problem for me to reach the top. But I had to bend down to reach the stones at the bottom, and that might be exhausting in the long run" (P3).*

One participant felt that gentle movement is more pleasant than only standing:*"standing around apathetic is the most uncomfortable. Just standing sometimes on the left, sometimes on the right foot was a bit uncomfortable. But when you stand at the wall like that, you move a bit and it's not noticeable that you're moving a bit more" (P9)*

While no one experienced the full-body interaction on the touchwall as really tiring, some were aware of it: *"you don't notice that you're moving because you're just so immersed. [...] I could imagine I would do that, simply because you are moving." (P10)* or *"I didn't necessarily perceive it as strenuous, but of course I kind of felt afterwards that I was active and on my feet." (P9).* One participant did find it more fatiguing: *"I found it more tiring compared to the other variants, because you have to stay attentive all the time and somehow put more energy into it than when you play it on your phone." (P4).*

Theme 4: Participants had different opinions regarding social acceptance, depending on the public scenario and place itself, who was already playing, and how well they think they would perform themselves. In general, our participants felt such an interactive touchwall would improve public spaces: *"[...] such a screen looks extremely forward-looking, futuristic, and yes, it really spices up a bus stop." (P2)*, one participant said. Another explained in more detail *"[... it's] something to keep people busy [...] They're also a little bit maybe more modern [...] So for me, that would definitely have a positive effect and I would definitely tell people: Hey, it's really cool there, you can do that there." (P9).*

While some participants would rather prefer a closed public space like a waiting room, they explain: *"[In a] waiting room, like if I'm really killing time and I know it's going to be another half hour, I'd be more likely to go for it." (P7)* One participant mentioned *"You can play a game on your cell phone relatively quickly, [...] But you don't have a wall like that yourself. So you don't own it, but if it's in the waiting room or I can imagine it in the office when you have to wait or something. I think I would have fewer worries there." (P4).* On the other hand, some would prefer playing at a bus stop (but unfortunately did not further explain why); others would not care if it was a closed public setting (e.g., a waiting room) or a fully public open one (e.g., a bus stop).

In contrast, some had issues with *any* public setting. The main factor is the feeling of being watched and the possibility of performing poorly in front of others: *" you feel like you're being watched. In the beginning, you might not be used to it and then you consider it funny when someone plays on the wall." (P14).* Another participant explained *"Unless I was super good or super trained, then maybe. Um,* *uh, if I'm alone, definitely. I could imagine that." (P10).* A participant thought critically about performing full-body movements in public: *"[...] especially when you're in a waiting room like that, you also need more space, and if you have to stretch and bend over like that all the time, it might be a bit awkward." (P13)* or seeing children as a target group: *"I think that's where the target audience tends to be younger than me. So I think kids would tend to do it more than me." (P1).*

The honeypot effect [84] resulting from participants watching others and being enticed to play themselves or helping and joining the game, also was perceived by participants: they saw the touchwall as a conversation starter. They stated they would help others playing: *"I think so, because maybe that's how you get into conversation. [... Something] you don't usually do in the waiting room or at the bus stop. And so you can then maybe already come into the conversation and you ask what exactly that is or what is happening there." (P4).*

Further, several participants–even those who initially seemed averse—mentioned that they would enjoy watching other participants play and that it would probably create the desire to play themselves. Summarized by P10: *"as a viewer, of course it would be cool if someone played it and you had something to watch [...] likely I would want to do that, too." (P10).* There were however also differing opinions on helping others play: it would *"[...]depend on the person. If they give the impression that they are not that interested in [me] being involved, then probably not." (P15).* Some stated it would depend on whether the other person was making mistakes: *"Yes, maybe if the person somehow makes a mistake or overlooks something that might help him now."(P11).* Alternatively, they might help if they were really *"bored" (P12).* Multiplayer games—*"strategically [playing] together" (P17)*—were also suggested in this context.

Finally, a few participants raised concerns about the unknown time frame users would have while waiting— *"It has to be designed in such a way that you can stop at any time and still have a sense of achievement." (P18)*—as well as hygiene: *"At the moment, this hygiene issue is so big that you have to think carefully about which surfaces you touch now and which not." (P11).* One participant suggested switching to *"gestures, [so] that one must not really touch the wall" (P3).*

7 DISCUSSION AND LIMITATIONS

We first discuss how well the touchwall worked to induce gentle full-body movements without noticeably affecting fatigue as a kind of manipulation check. Subsequently, we discuss the effects of the different conditions on enjoyment, performance, and (speculative) acceptance, respectively.

Movement and Fatigue. Our interviews and observations indicate that many participants moved noticeably a lot more while doing the full-body touchwall interactions compared to the sitting and standing conditions. Participants also were aware of the stretching/reaching up and bending down to reach symbols that were not close by. They also mentioned that the large screen resulted in a lack of overview that required them to take steps backward. This matches with our calculations in Section 4 that shows that people needed to move, stretch and bend to reach all the corners. It can be seen in the heatmap of logged touches that all areas are covered, even the borders (though not as much). We see this as confirmation that participants *actually* used the space and therefore were walking side to side, stretching/reaching upwards, and bending downwards, which as discussed increases NEAT [50] and can have beneficial effects on blood flow, muscle stiffness, posture, etc. [12, 13, 13, 30, 31, 54, 62, 69, 71, 82]. We note that the degree of movement will differ between participants depending on their height and arm span, as this affects how much they have to move to reach all positions on the wall. However, we leave such more specific details open to address in future work.

While none of the conditions were perceived as very fatiguing, sitting was definitely perceived as most comfortable, with standing smartphone use and full-body touchwall interaction considered slightly less relaxing comfortable but still not tiring. This aligns with our expectations and also matches prior research: while unhealthy, sitting is more comfortable than standing or stretching [17]. These findings indicate that games on large touchwalls could be a feasible and not too tiring option to break up sedentary periods that would otherwise probably be spent using a phone with a small display, thereby potentially avoiding neck or posture issues [37, 48].

The amount of gentle exercise provided through stretching and bending at the full-body touchwall could contribute to meeting current guidelines about avoiding sedentary behavior. It indicates that such a touchwall could prevent people from sitting in times of waiting, without leaving them uncomfortable due to too much exercising and while also offering an enjoyable pastime.

Enjoyment. As expected, and as suggested in research exploring other time-bridging (casual) exercise games [24, 52, 65], participants accepted the gentle full-body movements that is part of our casual exergame and also enjoyed it. We did find slightly higher enjoyment between gameplay with gentle full-body movements and non-active gameplay but it was not statistical significant, which is a similar result as in a study by Isbister et al. [32]. Like Isbister et al. [32] we did not find significant differences between physical active and non-active gameplay probably due to small effect size probably due to small effect size. We emphasize that the slightly higher enjoyment in the full-body condition cannot be noted without considering novelty effects; their connection to enjoyment is referred to in related work [63] and was also indicated by our participants. We cannot exclude that the higher enjoyment of the touchwall would decrease to the same level if full-body interaction touchwall were omnipresent in public spaces. Nevertheless, we believe that when having a full-body interaction touchwall at specific places like airports or waiting rooms, where people normally are not very often, novelty effects might remain and yield positive effects longer. Moreover, considering that devices like the Xbox Kinect[7] which successfully motivates full-body movements, we believe that—if such a tool became omnipresent in the distant future—it could even be integrated into the selection of ubiquitous digital devices in consumer homes that are used for gaming or information presentation like tablets. To investigate these effects, long-term and in-the-wild studies will be required in future work [63].

Performance. Our results concerning participants' performance indicate no significant difference between touchwall interaction and either of the smartphone conditions. Strong and weak hits were

[7] https://en.wikipedia.org/wiki/Kinect

equally balanced in all conditions. These results coincide with the ones from Mengistab [57] and Rostami et al. [70] who found no performance difference between standing and sitting at a desk. The only difference we discovered was the time participants needed between swaps, which probably has to do with the steps back and forth to gain an overview. This phenomenon of stepping back to gain a better overview is commonly observed with large displays [2, 4, 49], and suggests that games leveraging spatial memory and overview affordances would be interesting to further investigate performance effects with the touchwall. Previous studies suggest that setups like our touchwall condition (large display combined with letting users move around in front of it) can benefit tasks that require spatial memory [34, 68]. Despite no impact on performance (except duration), our participants noted the lack of overview and having to step back and forth with a slightly negative connotation. In the future, alternative applications ways could be considered of allowing users to interact with the touchwall while still motivating gentle full-body movements.

Additionally, we note that other game designs—e.g., ones that require fast-paced movements like a rhythm game or reaction-based mechanics similar to BeatSaber [23]—might of course show significant effects on performance with our compared conditions. However, such mechanics would also likely push the game away from *gentle* physical activity and the *casual* exergame.

Acceptance. Public display interaction and social acceptance are a very common problem [1]. Our participants had very different opinions on public scenarios they would prefer for touchwall interaction. This matches prior work that suggests that social acceptance with public display depends on a lot of different factors relating to diverse user characteristics like age, gender, interests, body height, extra-/introversion, etc. [3]. Some participants expressed disliking social scenarios remin general, primarily due to the remfeeling of being watched and fear of social embarrassment, which is one of the many problems in social scenarios according to Brignull and Rogers [11]. However, others shared this fear only in open public scenarios (e.g., bus stops) but not so in closed public scenarios (e.g., waiting room), perhaps because this suggests the presence of fewer people or, at some times no people at all. After participants were asked about helping others, many were more willing to join even in (semi-)public scenarios. Many of our participants This can be described as an effect that amounts to the honeypot effect [84], which is a very well-known effect when interacting in social scenarios. Like Brignull and Rogers [11] suggest, only one person is needed to attract others which is similar to the role model effect for being physical active [79]. This was confirmed by our participants and probably would be the main hurdle in achieving social acceptance.

This also suggests that multiplayer movement-based touchwall games might have different social acceptance than single-player ones as also proposed by Mandryk et al. [52]. Multiplayer aspects should be further investigated in future work for touchwall games featuring gentle full-body movements, too. A full-body interactive touchwall could feature not only an entertaining casual exergame but moreover become a conversation starter and a social hub.

Now that pandemic regulations seem to be loosening, we hope to investigate the acceptance of our game with touchwall interaction in a real-world scenario (e.g., a bus stop or a waiting room) in the future, as lab study findings and people's own assessments can vary when confronted with them in the field [63]. However, we note that given prior results on acceptance of large displays in the field and our interview findings, similar results for our prototype should likely occur [58, 84].

Public touchscreens can also pose a hygiene problem like it has been investigated by Mäkelä et al. [51]. Some participants mentioned experiencing discomfort since the COVID-19 pandemic when touching surfaces that many others have already touched.

Gestures instead of direct touch input was a solution proposed by one of our participants. For gestures on public displays, there is already some promising research by Walter et al. [83]. Gestures instead of direct input could keep the whole-body movement and contribute to emphasizing the "body as play" [59] while solving the hygiene problem, and additionally could solve the problem with participants of different heights. This makes it an interaction technique worth looking into in future work. However, social acceptance must be taken into account here as well.

Takeaway: Feasibility of the Touchwall with Full-Body Interaction. Summarizing the different advantages and disadvantages between the three conditions, it seems clear that there is no obvious "best" variant. In terms of enjoyment, all conditions were rated positively. The full-body touchwall condition was rated as somewhat more exciting (based on the SAM arousal scores), but took participants longer to complete actions—although this did not impact performance.

In terms of our goal to elicit gentle full-body movements, the touchwall worked well: participants did not avoid the border regions and so had to bend, stretch, and reach to play the game. This resulted in higher physical fatigue for players, but not overly so.

Participants' speculation regarding the social acceptability in a waiting scenario can be classified as mixed for the full-body touchwall variant—thus worse than the seated smartphone experience but better than the standing smartphone condition. In summary, we believe a touchwall game that encourages gentle full-body movements is a first approach to close the gap for *enjoyably* counteracting sedentary behaviour in *stationary contexts*. Moreover, it combines positive effects of *gentle full-body movements* like stretching and bending while counteracting *bad posture* and sitting behaviour.

From this, we conclude that the smartphone sitting condition is the most comfortable and time-effective option. The touchwall condition was similarly enjoyable while successfully eliciting gentle full-body movements—which is less comfortable but has health benefits. In contrast, the standing with the smartphone condition combines most of the disadvantages. Overall, our findings suggest that the touchwall could potentially counteract sedentary behavior and motivate gentle full-body movements while still providing a comparably enjoyable experience. This indicates that the idea is feasible for the context of waiting periods in public or semi-public spaces.

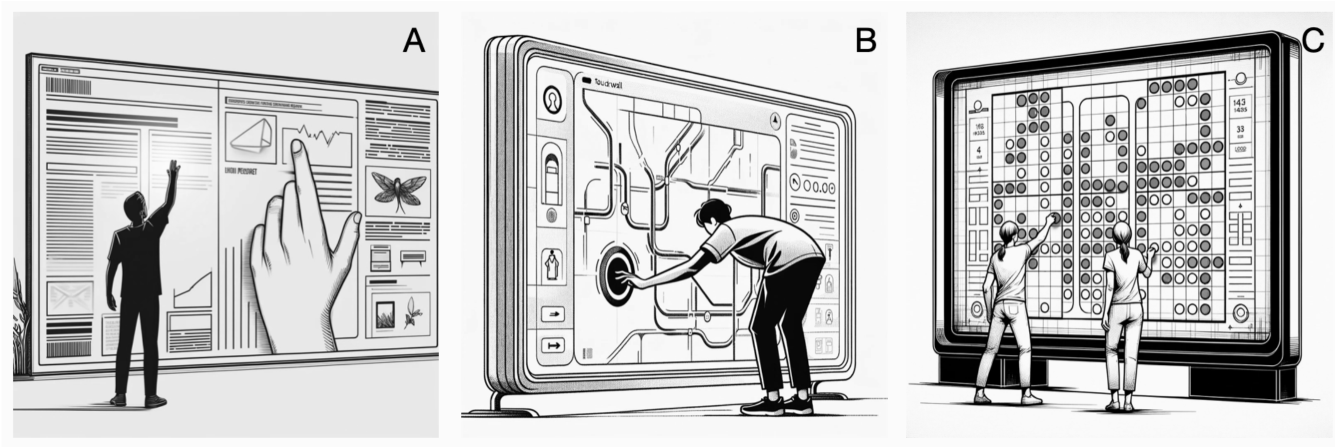

Figure 8: The three sketches show the possible other future applications that were suggested by participants. Picture A shows a human scrolling a huge newsletter, Picture B is showing a person bending over a public transport city map, and Picture C is showing two people playing a joint game together. Pictures generated with DALL-E 3.

7.1 Potential future applications

Based on our interviews, we present some new ideas for applications with gentle full-body interaction. We show some potention sketches of them made with DALL-E 3[8] in Figure 8.

A: Newsletter. A potential interesting application could be a news or book application where pages need to be flipped or the content has to somehow be moved around. Here, gentle full-body movements could be used for large swiping movements or buttons on the far corners.

B: Public Transport Overview. It can be used to show public transport maps, where the corners and edges can be used to move the map towards a new space in this area. Full body zooming movements (pinch and stretch both hands) can be used to change the level of overview. Buttons on different outer positions could guide to subviews of a bus line or the departure view of the current bus station (if positioned on a bus stop)

C: Games. Many different kind of games would possible, some for single player but others for multiplayer were suggested. Furthermore, the games should be short or round based and easy to understand. Some mentioned thinking games better would be better than extreme action games for (semi-) public setting. Mentioned examles: Tick-Tack Toe, 4 wins, Pong, sudoku, Ludo or Parcheesi, Battle Chess, Card Games, Mini Metro, Memory, crossword puzzle, skill or fast reaction games.

7.2 Limitations

We note some factors relating to our implementation and study design that may have affected the results somehow. For example, the input on the touchwall was sometimes not recognized due to the hardware setup itself. Therefore participants occasionally had to repeat touch input, leading to annoyance. This may also have contributed to the longer times between swaps on the touchwall.

Further, the additional COVID-19 measures made it hard to find participants, so our number of 18 participants is relatively small. Still, the reported significant differences, even showing small effect sizes, present indications that are further supported by our qualitative findings. The fixed wall also hindered us from conducting a field study in a public or semi-public setting or re-creating social scenarios with larger groups in our in-lab study, which would have helped increase ecological validity [1]. As a result, however, the study conductor knew several participants (13) personally, at least as an acquaintance. This could have affected their answers, although likely more so in the interview.

In terms of analysis and measures, we note that one of the main coders involved in the thematic analysis had no prior experience with this methodology, while the other main coder has a strong exercise motivation which could have influenced their reading of the transcripts and the construction of themes. Additionally, in retrospect, we would have liked to also measure participants' body height and each participant's physical exertion through physiological measures (e.g., heart rate) while playing.

From our perspective, a noteworthy limitation is that the novelty of the full-body touchwall interaction may have been a strong factor in its enjoyment ratings. We cannot say with certainty whether their enjoyment of the touchwall would be lessened if it were pervasively available and used frequently. Our findings suggest that the touchwall may be able to introduce a healthier posture and gentle full-body movements into sitting and waiting periods in public spaces. This works to motivate a field study; this kind of future work will be able to explore the social acceptability of such a touchwall scenario with greater validity.

8 SUMMARIZING CONCLUSION AND FUTURE WORK

With our Match-3 monster game implementation, we designed a prototype to investigate whether a touchwall application actually

[8]https://openai.com/dall-e-3

induces the expected can induce gentle full-body movements including stretching and bending. In a mixed-method study, we compared (1) full-body interaction on a larger-than-human touchwall with two smartphone conditions, (2) standing and, (3) sitting. We found that participants perceive the difference in physical movement, use the full space of the wall for full-body movements while not feeling overly fatigued, and overall enjoy the full-body touchwall interaction and its novelty. While we found no difference in success or game screen usage, there were mixed opinions towards speculative usage of the touchwall in public spaces (like a bus stop or a waiting room). In future work, our findings for full-body interactions on a large-sized touchwall should have to be validated directly in a public scenario like a waiting room or at a bus stop, possibly taking different wall sizes, applications or touch-free gestures into consideration. The greatest possible use of interaction and public display space should be taken into account in the design process to encourage healthy posture and counter possible unhealthy behavior with gentle full-body movements. Our positive results towards gentle full-body movements can work towards large-sized touchwalls being considered in future planning of (semi)public spaces and product design.

ACKNOWLEDGMENTS

We used DALL-E 3 to generate the illustrations in Figure 8 with the following prompts: 1) "Can you create a graphical sketch in the same style where a person is standing in front of a larger than human touch wall and stretching to scroll through a newsletter." 2) "Can you create a graphical sketch in the same style where a person is standing in front of a large than human touch wall and bending to scroll through a Public Transport Overview map", "Can you adjust so that the person has to bend down to press a button". 3) "Can you create a graphical sketch in the same style where two persons are standing infront of a large than human touch wall playing '4 wins'".

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A SUPPLEMENTARY MATERIALS

Table 2: Mean values and standard deviation for all measures.

Condition	SAM Pleasure		SAM Arousal		SAM Dom.		IMI Int/Enj		Exhaustion		Enjoyment		total#Swaps		timeBetwSwaps		normStrHits	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
full-body	4.3	0.77	3.17	0.86	3.22	0.88	5.93	0.78	3.33	1.46	6.22	1.11	43.39	6.02	14.37	11.44	1.38	0.27
standing	4.1	0.58	2.83	0.79	3.44	0.78	5.68	0.79	2.78	1.4	5.78	0.88	42.94	6.99	8.59	10.75	1.33	0.3
sitting	4.0	0.73	2.56	0.92	3.67	0.69	5.63	0.84	2.11	1.08	5.89	1.02	42.67	9.04	9.26	11.26	1.32	0.35
$\chi^2(2)$	2.62		6.34		4.13		4.55		9.41		3.64		2.32		274.61		1.44	
	n.s		p < .05		n.s.		n.s.		p < .01		n.s.		n.s		p < .001		n.s.	

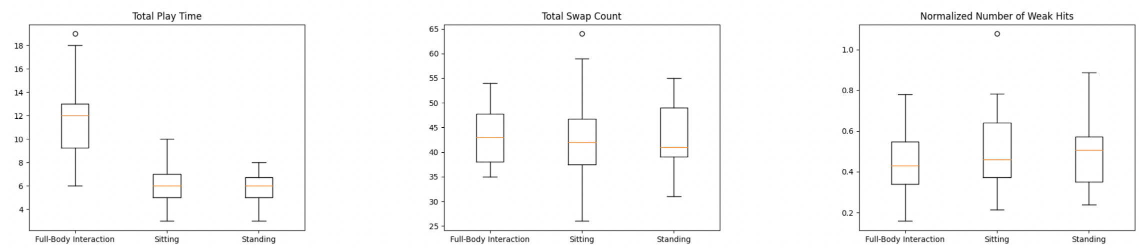

Figure 9: This figure shows boxplots of total playtime of the total swap count and normalized weak hits.

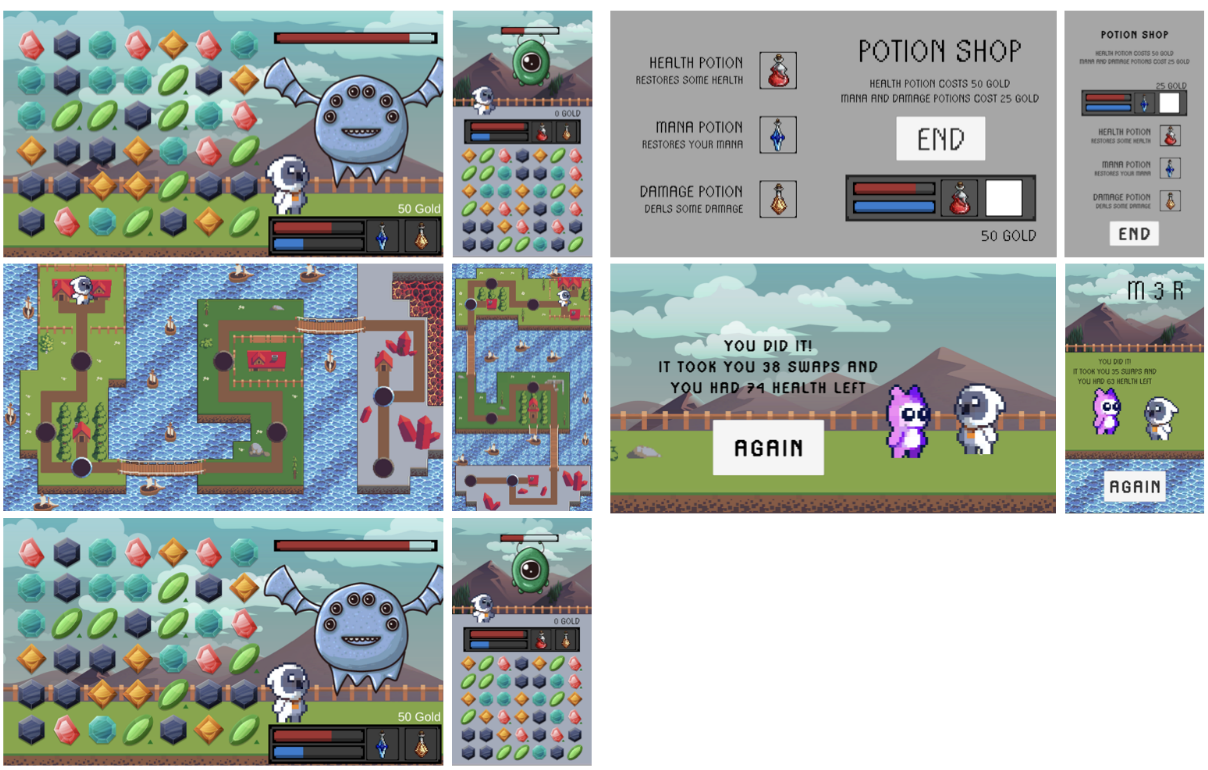

Figure 10: This figure shows all the different screens on the game. On the horizontal view on the right was the touchwall view, while the vertical view next to it on the left, was the view of the mobile phone.