

Auto-Paízo Games: Towards Understanding the Design of Games that Aim to Unify a Player’s Physical Body and the Virtual World

Most digital bodily games focus on the body as they use movement as input. However, they also draw the player’s focus away from the body as the output occurs on visual displays, creating a divide between the physical body and the virtual world. We propose a novel approach – the "Body as a Play Material" – where a player uses their body as both input and output to unify the physical body and the virtual world. To showcase this approach, we designed three games where a player uses one of their hands (input) to play against the other hand (output) by loaning control over its movements to an Electrical Muscle Stimulation (EMS) system. We conducted a thematic analysis on the data obtained from a field study with 12 participants to articulate four player experience themes. We discuss our results about how participants appreciated the engagement with the variety of bodily movements for play and the ambiguity of using their body as a play material. Ultimately, our work aims to unify the physical body and the virtual world.

Additional Keywords and Phrases: bodily games, movement-based play, wearable interaction, integrated play, hand games, electrical muscle stimulation

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Figure 1. A participant is playing “Elements”. The non-EMS hand (the player’s right hand) shows the “Water” symbol, while the EMS hand (the player’s left hand) shows the “Air” symbol caused by actuation and therefore closing the ring finger. The rules state that “Air” beats “Water”; hence the EMS hand wins.

1 INTRODUCTION

As a community, we are increasingly interested in creating digital bodily games using novel movement-sensing technologies, such as Nintendo Wii and Ring Fit (e.g., [4, 36, 38]). These games promote physical activity [5,

25 24], help develop bodily awareness [56] and foster knowledge of the inner self [42, 52]. However, while these
26 games utilise the body as input, visual displays typically provide output, creating a fundamental division between
27 the physical body and the virtual world [38]. As a result, it has been suggested that players continually shift their
28 focus, negatively impacting their overall bodily experience [32].

29 In response, game design researchers have called out the need for deeper integration of the human body
30 and computers to experience “the body as play” [35, 37]. The community responded by designing games that,
31 for example, use the body’s surface as an interactive screen [10] and allow users to play with their interior body,
32 such as their body temperature [28]. While these games begin closing the divide between the body and the
33 virtual world, the player still focuses on information external to their body, “using” their body to play “with” a
34 screen. In response, we asked ourselves: *How, then, can we design games that allow a player to focus solely*
35 *on themselves, where they “use” their body to play “with” the body?*

36 We propose a novel approach – the “Body as a Play Material” – where a player *uses* their body to play *with*
37 their body by using it as input and output by loaning bodily control to a computer. To showcase our approach,
38 we designed three novel bodily games called “Elements”, “Numbers”, and “Slap-Me-If-You-Can”, inspired by
39 traditional hand games like rock-paper-scissors. We call this suite of games “Auto-Paízo” (Self-Play in Greek)
40 games. Traditional hand games usually require two-players; however, thanks to our approach, such games can
41 also be played by a single player. In our games, a player plays with one of their hands (as input) against their
42 other Electrical Muscle Stimulation (EMS)-controlled hand (as output) (Figure 1). These games not only
43 showcase a novel way to experience bodily play, but could also be employed in the medical domain, for
44 example, for motor rehabilitation programs, where patients can engage with interactive games that facilitate the
45 recovery of motor skills [29, 41].

46 We obtained ethics from our institution to conduct a seven-day field study [21] of our games and interviewed
47 the 12 participants. We conducted a field study to allow our participants to experience the games outside the
48 lab’s environment (see participants’ engagement patterns in section 5), while also adhering to COVID-19
49 restrictions. By analysing the interview data using inductive thematic analysis, we articulated four player
50 experience themes: 1) loaning bodily control to a computer, 2) playfully engaging with the integrated computer,
51 3) playing with the ambiguity of the computer-controlled body parts, and 4) bodily awareness when loaning
52 bodily control to a computer to play. We found that our participants enjoyed engaging with the variety of bodily
53 movements for play and the ambiguity of using their body as a play material. This confirms prior theories that
54 varied bodily movements [32] and ambiguity [20, 51] are key concepts in the design of bodily games [32, 38].
55 We extend these theories by reflecting on our themes to articulate design considerations for designing bodily
56 games by using our approach. We make three contributions:

- 57 • A system contribution by presenting three games, adding to HCI’s collection of novel systems [56].
58 This contribution can inspire industry developers to utilise EMS through the lens of entertainment [30],
59 possibly to benefit the medical domain by creating engaging EMS experiences.
- 60 • An empirical contribution by presenting results in the form of four descriptive user experience themes
61 from our study. This contribution can be useful for user experience researchers who aim to understand
62 the potential of using the Body as a Play Material approach.
- 63 • A practical contribution by articulating design considerations by reflecting on our results to create future
64 games using our approach. This contribution can be helpful for game design researchers interested in
65 creating bodily play experiences that aim to unify the physical body and the virtual world.

66 **2 RELATED WORK**

67 Our work was inspired and informed by how the body is the focus of play in many non-digital bodily games, how
68 the game design community is amplifying the human body's involvement in digital bodily games, and how the
69 body can be used as input and output with the help of Electrical Muscle Stimulation (EMS).

70 **2.1 Body as the focus of gameplay in non-digital bodily games**

71 In many traditional non-digital bodily games, such as rock-paper-scissors, the body is the focus of play. Here,
72 the body is the primary "play material," and game rules are crafted such that players must employ their bodies
73 interactively within the game and with other players [9, 23]. This pivotal role of the body gives rise to a wide
74 variety of bodily movements, from fine gestures (showing "scissors") that require precise motor control and
75 quick reactions to the opponent's movements [53], to more expansive gross motor movements, such as when
76 playing Hopscotch [11]. In other words, the player's body is central to play in these games [11, 53]. We note
77 that players benefit from having complete control over their body when playing such games, adding an element
78 of agency to the gameplay. However, there are also games where players loan bodily control to others. For
79 example, in the "Statues," one player becomes the "statue" and must hold a pose while other players try to
80 make them laugh or move in other ways [22]. In this game, the body of the "statue" is the focus, while the
81 "statue" player subscribes to the idea that they, at some point, will end up giving control over their body to the
82 other players. In "Statues", players do not have physical control over each other; however, in a three-legged
83 race, two players physically tie one of their legs together and run together, sharing their movements [49].
84 Similarly, in the game "Trust Fall," one player falls backwards and is caught by a group of other players, who
85 must work together to ensure the person's safety [15]. These examples demonstrate that while the player's
86 body is still the focus of gameplay, the control of it can be loaned to others, creating unique game experiences.

87 In summary, we learned that when simple rules engage with the player's physical coordination abilities and
88 reaction time, they can facilitate engaging experiences. Therefore, we also focused on simple rules that depend
89 on the player's physical coordination abilities and reaction time in our games.

90 **2.2 Amplifying the human body's involvement in digital bodily games**

91 When it comes to digital games, the role of the human body has been less central, with many games relying on
92 external input devices, such as a keyboard, mouse, or gamepad, to control virtual bodies, like avatars [38].
93 However, the emergence of movement-sensing technologies, such as those promoted with the Nintendo Wii
94 and Ring Fit, has enabled the game design community to integrate the body as the primary controller in digital
95 games. This amplified the role of the body in play (as input), while providing visual feedback on screens (as
96 output) [32]. For instance, in the game "Bounden", two players hold the same mobile device: they use their
97 synced movements to guide a ball through a series of levels, resulting in a dance-like experience [7]. The game
98 "Johann Sebastian Joust" uses PlayStation Move controllers to turn the players' bodies into the game controller,
99 with the controllers vibrating and lighting up when the player moves too quickly [33]. We learn from these games
100 that the player's movements and speed can be the primary input for bodily games, which we utilised in our
101 games. However, in both cases, the player's focus remains directed outwards, towards an external display.

102 To foster experiences where the player's body is the focus of play (which we are interested in), researchers
103 have been exploring ways to incorporate body practices into the experience [39]. For example, Life Tree [43] is
104 a virtual reality game incorporating deep breathing. The associated study showed that this breathing helped

105 them relax their muscles. Therefore, in our study, we asked participants to perform deep breathing before
106 playing the game to help them relax their muscles. We believe this could help reduce any anxiety or the
107 uncomfortable feeling that initial EMS experiences might cause [26].

108 In summary, many digital games use the body as a unique input source, while the output is typically relayed
109 through a screen. Although some games started to prompt players to look “inward”, the feedback is still mostly
110 presented externally, drawing focus away from the body. Interestingly, prior work proposed using Electrical
111 Muscle Stimulation (EMS) technology to use the body as input and output, explained in the next section.

112 2.3 Using the body as output by using EMS

113 To see our Body as a Play Material approach come to fruition, we utilised Electrical Muscle Stimulation (EMS)
114 technology. EMS has been employed to engage the body as an input and output medium [26, 31]. Users attach
115 electrodes to their skin, and when they loan bodily control to “it”, a small amount of electric current passes
116 through the electrodes, contracting their muscles and moving their body parts involuntarily [26]. We use the
117 word “loan” because the user can resist the electricity and regain control over their body movements.

118 The process of positioning the electrodes to actuate specific muscles and create certain body movements is
119 called calibration [26]. Research suggests that users can initially feel uncomfortable with the EMS sensations,
120 but this can be reduced by spending time during the calibration process [26, 31]. Moreover, due to differences
121 in users' muscle composition or changes in their body orientation, calibration can sometimes fall short, causing
122 unexpected and ambiguous modifications to EMS-actuated body movements [26]. Based on this knowledge,
123 we provided a detailed description of the calibration process to our participants in our pre-study session.

124 EMS has been used for many playful applications, particularly in the form of force feedback to make virtual
125 reality games more immersive by, for example, allowing players to experience their hands move involuntarily
126 when hitting a tennis ball [18] or to experience the pushback when touching a virtual wall [2, 18]. In these
127 applications, the player experiences EMS as complementary to the visual feedback. We note that these systems
128 do not indicate to the users when EMS is about to take control of their body. As we did not want to facilitate a
129 surprising experience with the EMS-controlled hand, we learnt from Benford et al. [4] who suggested informing
130 the user when a computer is about to take control. Therefore, we used sound in our games so that the player
131 knows when the EMS hand is about to get actuated.

132 EMS has also created movement-based games such as “Hot-Hands” [31], where players can play against
133 themselves, albeit to explore proprioceptive interaction [31]. Moreover, prior work by [authors] has explored
134 variations of these games, but in the form of a pilot study. Hence, we still do not entirely understand the design
135 and associated user experiences of *using* the body (as input) to play *with* the body (as output). Therefore, our
136 work aims to begin filling this gap by answering our research question: *how do we design games that allow a*
137 *player to focus solely on themselves, where they “use” their body to play “with” the body?*

138 3 DESIGNING GAMES THAT USE THE BODY AS A PLAY MATERIAL

139 We designed three Auto-Paizo games: “Elements”, “Numbers”, and “Slap-Me-If-You-Can”, to showcase that
140 our approach is not restricted to one instance. Moreover, having three games allowed us to gather wider insights
141 into user experiences associated with our approach. Our games are varied according to three previously
142 identified key characteristics of bodily games [38]: motor-movement [34], game outcome [24] and bodily
143 interference [36] (Table 1).

144

Table 1. Key characteristics of the three Auto-Paizo games.

Game name	Type of motor-movement	Game outcome	Bodily interference
Elements	Fine motor -movement	Psychological (Symbolic)	Non-interference
Numbers	Fine motor -movement	Psychological (Numerical)	Non-interference
Slap-Me-If-You-Can	Gross motor -movement	Physiological	Interference

145

- *Motor-movement* – does the game control fine- or gross-motor movement?

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- *Game outcome* – is the game outcome a psychological (symbolic, numerical) or physiological?

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- *Bodily interference* – does the game support interference play (where the EMS-controlled hands interfere with other body parts while playing) or non-interfering play (where the EMS-controlled hands do not interfere with other body parts while playing)?

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Figure 2. The EMS assemblage is given to each participant. It contains (A) a microcontroller device, (B) EMS instructions, (C) a GoPro

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action camera with a spare battery and charger, (D) and (E) game descriptions, (F) a mobile charger, (G) mobile phone, (H) spare

153

electrodes and lead cables, (I) EMS device, (J) and (K) electrodes for the games, and (L) hand glove for the mobile phone.

154

The following sections use the conceptual model of “describing games” [6]; first, we describe the hardware

155

and software (together called the “EMS assemblage”) and the gameplay preparation steps that are the same

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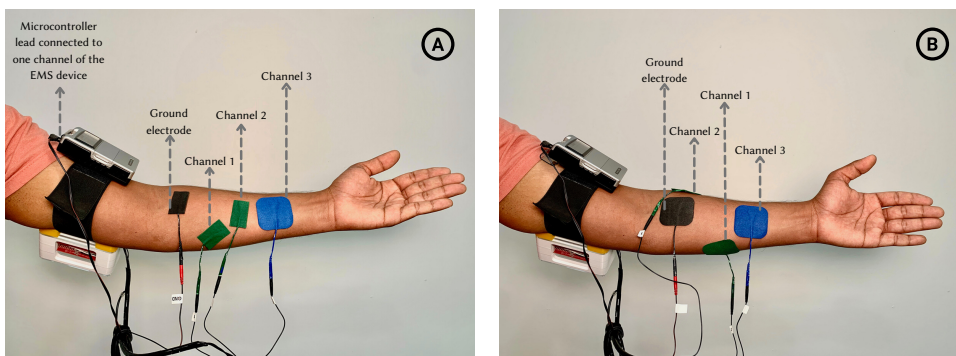
for all games, then we describe each game’s particular design features individually.

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158 **3.1 Game hardware**



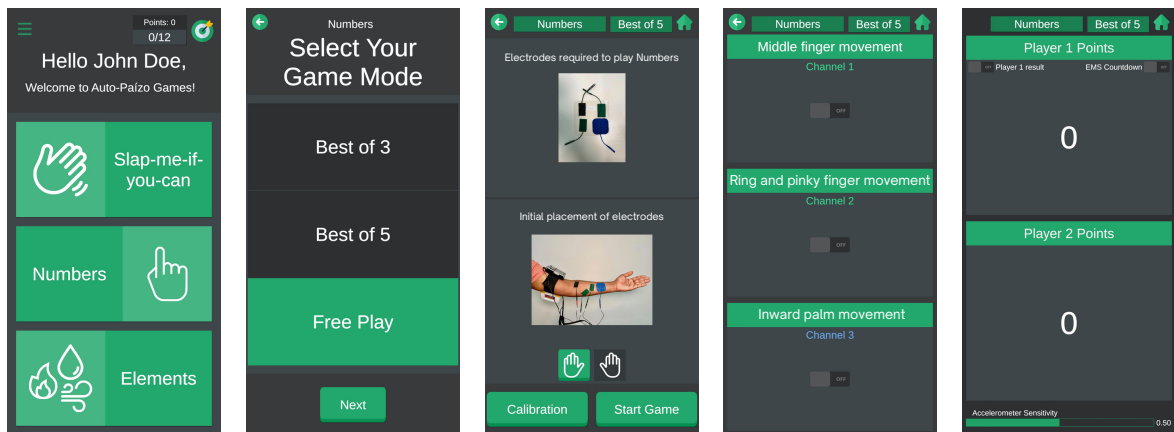
159
 160 Figure 3. A participant is wearing the hardware to play “Numbers”. The participant chooses their non-EMS right hand to be “odds”,
 161 and the EMS left hand to be “evens”. The with their right non-EMS hand shows a “2”, and their left EMS hand shows a “5”
 162 simultaneously, making the sum odd ($2 + 5 = 7$). Therefore, the player’s right non-EMS hand wins.



163
 164 Figure 4. (A) shows the electrodes’ position for Elements and Numbers, and (B) shows the position of the electrodes for Slap-Me-If-
 165 You-Can. The size of channels 1 and 2 are smaller in (A) to target muscles for fine motor-movements and larger in (B) to target
 166 bigger muscles for gross motor-movements.

167 The hardware consisted of a microcontroller, an EMS device, and electrodes worn on one arm (the EMS hand),
 168 while the non-EMS hand has a mobile phone in a custom-made hand glove (Figure 3). A commercial EMS
 169 device was used to increase players’ sense of safety [26, 31]. The software used the phone’s accelerometer
 170 sensor to trigger the microcontroller, which actuated the right combination of three electrodes to move the
 171 player’s EMS-controlled hand involuntarily to play the games. The system was designed to be small and mobile,
 172 weighing about 400 grams, with a microcontroller that splits the EMS output into three controllable channels.
 173 The microcontroller was placed in a 3-D printed case attached to the arm and the EMS device via a lead. While
 174 the hardware was the same for all three games, the electrodes used for each game differed (Figure 4). We
 175 conducted basic tests such as a drop and shake test and checked how long it takes for the battery to run out
 176 (lasted for more than seven days without charging) [50].

177 **3.2 Game software**



178

179 Figure 5. The screens for game and mode selection, calibration instructions, calibration switches and score-keeping.

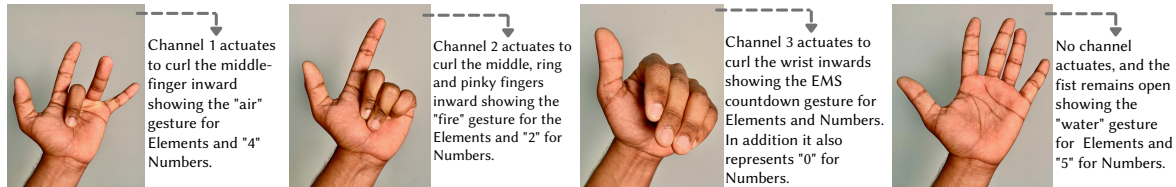
180 We developed a phone application that communicates with the microcontroller through Bluetooth. The
181 minimalistic software interface (Figure 5) was designed to keep players focused on their body movements rather
182 than the screen. The application supports four key actions: logging in, selecting a game and game mode,
183 calibrating the EMS, and tracking the score. Players log the result after each round of play on the score-keeping
184 screen. The application also logs game data, such as the number of times each game was played and features
185 12 challenges to keep players engaged (Appendix A1 - Table 2). We added the challenges considering the
186 games' simplicity and the study's length to facilitate participants' engagement with the system as often as
187 possible. The EMS-controlled hand was referred to as "Player 1" and the non-EMS hand as "Player 2" to not
188 influence how players perceived the EMS hand. Unpredictability in the actuation of the EMS hand due to body
189 orientation, as learned from prior work [26], was addressed with the "Player 1 result" feature. When enabled,
190 players could see what the EMS hand meant to show on the screen (not applicable for Slap-Me-If-You-Can).
191 Each gesture was associated with the same sound played for half a second before the EMS hand to help the
192 player know when the EMS is about to take control, while not giving away what gesture the EMS hand would
193 show. An "EMS countdown" feature was designed to facilitate a playful attitude. When enabled, the EMS
194 actuates in sync with the player performing an up-and-down movement countdown (3-2-1) with their non-EMS
195 hand (as known from rock-paper-scissors): the non-EMS hand mirrors the movement by gently curling three
196 times inwards (actuated for one second each time). This movement is complemented by a "dramatic" sound
197 designed to amplify the experience of the countdown movement.

198 **3.3 Gameplay preparation**

199 Players calibrate the EMS using the software's guidance after attaching the electrodes to their body. The
200 application asks the player to slowly increase the intensity of each channel by turning the dial on the EMS device
201 until they achieve the desired motor-movement. The player might need to reposition an electrode if there is no
202 movement. After repeated testing on the authors' bodies, the pulse rate and width are initially set at 220 ms and
203 45 Hz. Players are free to adjust these parameters and are encouraged to continue fine-tuning these parameters
204 to achieve the desired movement at a comfortable actuation level. To protect the player from muscle fatigue,

205 we added an alarm in the software that notified the players every 30 minutes. This notification pauses the game
206 (even if the player is in the middle of gameplay) and shows a message on the phone asking players to “rest
207 their body before playing more”. We explain each game in the following sections.

208 3.4 Game 1: Elements



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Figure 6. The three EMS channels that show the gestures Elements and Numbers game and their associated meanings.



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Figure 7. A participant is playing a best-of-three rounds game of Elements.

213 In the Elements game (Figure 7), players perform one of three gestures: “fire”, “water”, or “air” (Figure 6). The
214 rules are: “water” beats “fire”, “fire” beats “air”, and “air” beats “water”. The goal is to show an element that beats
215 the other hand. The game starts with players initiating the countdown by moving their non-EMS hand up and
216 down three times. Then both hands show a gesture simultaneously to determine a winner. Figure 7’s left image
217 shows the non-EMS hand with “water” and the EMS hand with “fire”, giving the non-EMS hand one point. In the
218 central image, the non-EMS hand shows “water”, and the EMS hand shows “air” (EMS-hand gets the point). In
219 the right image, the non-EMS hand shows “water” again while the EMS hand shows “water”, awarding one point
220 each, making the round a draw.

221 3.5 Game 2: Numbers

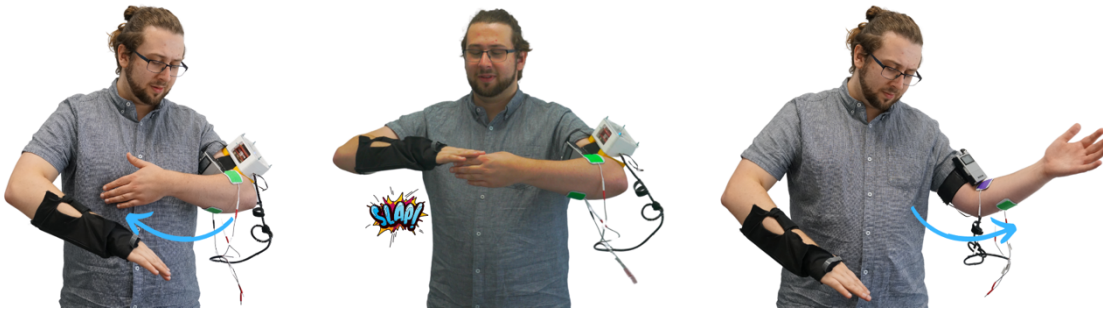
222 The Numbers game (Figure 8) starts with the EMS hand in an open-fist position and the non-EMS hand in a
223 closed fist position. The player mentally chooses whether they are in the “odds” or “evens” team. After the
224 countdown, both hands reveal a number simultaneously, and the sum determines the winner. For example, in
225 Figure 8, a player chooses to be “odds”. The left image (round 1) shows the player’s non-EMS hand revealing
226 a “3” and the EMS hand showing a “0”. The sum is odd ($3+0=3$), giving the player’s non-EMS hand one point.
227 The central image (round 2) shows the player’s hand with a “1” and the EMS hand with a “3”. The sum is “4”,
228 giving the EMS hand one point. The right image (round 3) shows the player’s non-EMS hand with a “3” and the
229 EMS hand with a “5”. The sum is “8”. This result gives the EMS hand one point, making “it” the game-winner.



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Figure 8. A participant is playing a best-of-three rounds game of Numbers.

232 3.6 Game 3: Slap-Me-If-You-Can



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Figure 9. A participant is playing a best-of-three rounds game of Slap-Me-If-You-Can.

235 Slap-Me-If-You-Can (Figure 9) is inspired by Red-hands [45]. The player starts with the non-EMS hand at a 90-
 236 degree angle, with fingers facing upward, and the EMS hand is positioned towards the torso with the palm
 237 facing upward. After the countdown, the player tries to slap the EMS hand quickly. Successful slaps give one
 238 point to the player, while misses give one point to the EMS hand. In Figure 9's left image, the EMS hand dodges
 239 the slap by moving inwards, giving the EMS hand one point. In the central image, the player's hand successfully
 240 slaps the EMS hand, giving the player's hand one point. The right image shows the EMS hand avoiding the slap
 241 by moving outwards, giving the EMS hand one point and making "it" the game-winner for this best-of-three-
 242 round.

243 4 STUDY DESIGN AND DATA ANALYSIS

244 To understand the user experience of interacting with our games, we obtained institutional ethics approval to
 245 conduct a field study [21]. As shown in previous research on novel game experiences [48], this approach allows
 246 us to collect rich data from participants, whilst reducing potential influences of the researchers' personal biases.
 247 This method proved to be particularly beneficial during the COVID-19 pandemic when our study was conducted.
 248 It facilitated remote engagement with our system, allowing participants to play the games from their homes, at
 249 their convenience, and without researchers' immediate presence. It further allowed participants to explore the
 250 system in their own ways, such as creating their own games (Figure 10) or using the games as a relaxation tool
 251 before bed (Figure 11). These instances suggest the potential for this method to capture participants'
 252 preferences in system use, rather than adhering strictly to predetermined expectations by researchers [21]. To
 253 engage players over these seven days, we also provided them with game challenges (Appendix A: Table. 2).

Participant Number	Age	EMS Experience	Gender	Game Genres	Gamer Type
1	21	None	Man	Action and RTS	Console and Board gamer
2	27	None	Man	Action and Strategy	PC and Board gamer
3	22	None	Man	Casual	Mobile gamer
4	23	Medical Purposes	Woman	Action adventure and Survival	Console and Board gamer
5	24	None	Man	Casual	Mobile gamer
6	25	Medical Purposes	Man	Action and MMORPG	Console and Board gamer
7	24	Medical Purposes	Woman	Strategy	Board gamer
8	26	None	Man	Casual	Mobile gamer
9	25	None	Man	NA	Not a gamer
10	28	Medical Purposes	Man	Action adventure, Strategy and Survival	Console, PC and Board gamer
11	27	None	Woman	Action adventure and Sports	Console and Board gamer
12	22	Medical Purposes	Man	Strategy and RPG	PC and Board gamer

Figure 10. Demographics including gender distribution, EMS experience, preferred game genres, and gamer types.

The study had three phases: a pre-study phase, a field study phase, and a post-study interview phase. We recruited 12 participants by advertising through our social media channels and mailing lists. Out of the 12 participants, 75% (n=9) identified as men and 25% (n=3) as women (none non-binary or self-described). The participants' mean age was 24.5 years (SD=2.23). Detailed demographics are in Figure 10.

4.1 Pre-study phase (Safe Onboarding and Informing System's Capability)

We delivered the EMS assemblage to each participant (adhering to COVID-19 restrictions) before setting up a video conference call. The goal of the pre-study phase was to educate participants about the "dos and don'ts" of using an EMS device and relax their body muscles by breathing before calibrating their hands to play all three games at least once. During this phase, participants were also provided with the research team's contact details and informed that they could contact us during working hours to inform or rectify any hardware, software or study-related issue. While one participant could not calibrate for any game, they retained the EMS assemblage during the study period. They attempted to calibrate and play without the research team's support during the field study phase. Consequently, we report on the experiences of 11 participants playing the games and 12 using the system. Also, one participant could not calibrate for Elements and hence only played Slap-Me-If-You-Can and Numbers for the study phase. The average time for the pre-study phase was 58 minutes, with a standard deviation of 18 minutes.

4.2 Field study phase (Feedback, Study and Data Collection)

Participants had the EMS assemblage for seven days and were asked to play each game at least seven times. Participants were also asked to record themselves while playing using the provided GoPro action camera. Based on our log data, we analysed that each participant played "Elements", "Numbers", and "Slap-Me-If-You-Can" for an average of 15, 13, and 8 times, respectively. This means that, on average, each participant engaged with the games for $(15+13+8) * 3$ (average time to play each game), making it a total of 108 minutes over the seven days. This number does not include the calibration time.

4.3 Post-study phase (Further Data Collection and Data analysis)

Following the field study phase, we conducted interviews with participants, lasting for a mean duration of 59.91 minutes (standard deviation = 22.40 minutes), to gain insights into their experiences. These audio and video recorded interviews employed a semi-structured approach [14], providing flexibility in capturing a rich set of

283 subjective responses. The interviews were then transcribed, after which two coders separately conducted an
284 inductive thematic analysis [8] using NVivo software [55]. We chose the inductive thematic analysis method for
285 its ability to distil and articulate patterns within our dataset, allowing the data to drive the identification of our
286 themes. This method helped us explore individual experiences and recurring patterns across our participants.
287 When articulating our themes, our goal was not to make broad generalisations but to explore the various
288 nuanced aspects of our participants' experiences, extending beyond usability and the novelty of the experience.
289 As such, this method met our aim to understand the novel interaction offered by our games.

290 We considered each answer (average word count = 58) as one data unit. Each coder independently read all
291 704 data units two times and assigned every data unit a category code. Coders 1 and 2 created 82 and 75 initial
292 codes for all the data units. The coders then communicated with each other to refine the initial codes down to
293 64 final codes. The inter-rater reliability was 97.43%, and Cohen's kappa coefficient (k) = 0.653. The coding
294 categories were then examined, cross-referenced with the data units, and further analysed for overarching
295 themes, which both researchers again reviewed. Finally, we found seven overarching themes, of which we
296 report on four that align with our research question. These four overarching themes were developed using 41
297 of the 64 final codes, and these 41 codes comprised 360 of the 704 data units.

298 5 QUANTITATIVE RESULTS: ENGAGEMENT PATTERNS FOR ELEMENTS, NUMBERS, AND SLAP-ME-IF- 299 YOU-CAN GAMES

300 A comprehensive analysis of the engagement patterns across the three games, Elements, Numbers, and Slap-
301 Me-If-You-Can, revealed nuanced similarities and differences in the playing behaviour over the seven days.

- 302 • **The total number of games played:** The total number of games played showed that Elements
303 recorded the highest engagement with 179 games played (14.92 games/participant, SD = 5.60),
304 followed by Numbers with 157 games (13.08 games/participant, SD = 4.74), and Slap-Me-If-You-Can
305 with 101 games (8.42 games/participant, SD = 3.15), suggesting that the Elements game was the most
306 appealing overall.
- 307 • **Daily engagement patterns and variability:** For Elements, engagement peaked on Day 1 with an
308 average of 4.08 games per participant (SD = 3.71) and generally declined over the week, reaching its
309 lowest point on Day 4 with 0.92 games per participant (SD = 1.16). Numbers exhibited the highest
310 engagement on Day 1 at 3.5 games per participant (SD = 2.67). It fluctuated throughout the week and
311 the lowest engagement on Day 3 at 0.83 games per participant (SD = 1.03). With Slap-Me-If-You-Can,
312 engagement was the highest on Day 1 with 2 games per participant (SD = 1.67). It fluctuated
313 throughout the week, reaching its lowest engagement on Day 7 with 0.67 games per participant (SD
314 = 0.98). These patterns suggest that the Elements game's novelty may have worn off over time, while
315 Numbers and Slap-Me-If-You-Can maintained a more lasting appeal for some participants.
- 316 • **EMS experience and game engagement:** We observed several patterns when considering prior EMS
317 experience and game engagement. With Elements, participants with medical experience had an
318 average engagement of 2.67 games/participant (SD = 2.31), and those with research experience had
319 an average of 14 games/participant (no SD available as only one participant had research experience).
320 Participants with no EMS experience had an average engagement of 2.5 games/participant (SD =
321 1.58), with the single participant using EMS for research purposes having the highest engagement.
322 With Numbers, participants with no experience had the highest average engagement (average 3.5

323 games/participant; SD = 1.73), followed by the participant with research experience (2.83
324 games/participant; no SD available) and those with medical experience (average 2.67
325 games/participant; SD = 1.25). Similarly, with Slap-Me-If-You-Can, participants with no experience had
326 the highest average engagement (average 1.83 games/participant; SD = 0.83), followed by the
327 participant with research experience (1.5 games/participant; no SD available) and those with medical
328 experience (average 1.33 games/participant; SD = 0.82).

329 In summary, Elements was found to have higher engagement levels for participants with prior EMS
330 experience for medical and research purposes. In comparison, Numbers and Slap-Me-If-You-Can had higher
331 engagement levels for participants with no previous EMS experience. Day 1 had the highest engagement levels
332 for all three games, but Elements consistently declined throughout the week. In contrast, Numbers Slap-Me-If-
333 You-Can games experienced more fluctuations.

334 6 QUALITATIVE RESULTS: FOUR PLAYER EXPERIENCE THEMES

335 At the beginning of the study, some participants expressed their apprehension about using EMS. However, they
336 enjoyed playing the Auto-Paizo games over the study period. For example, P4 said, *"It was scary at first, but it
337 felt nice over time, in a weird way"*. In this section, we articulate and discuss four overarching themes that
338 describe the participants' experiences: 1) loaning bodily control to a computer, 2) playfully engaging with the
339 integrated computer, 3) playing with the ambiguity of the computer-controlled body parts, and 4) bodily
340 awareness when loaning bodily control to a computer to play.

341 6.1 Theme 1: Loaning bodily control to a computer

342 In this theme, our participants discussed how they allowed EMS to control their hand movements and how the
343 speed of the EMS hand's movement affected their experience of playing with a computer-controlled version of
344 themselves. Eleven of the 41 codes are associated with this theme, representing 84 data units. The theme has
345 two sub-themes: learning to adapt to the body to turn it into a playful material (representing six codes and 45
346 data units), and influence of the EMS hand's movement speed on gameplay (five codes and 39 data units).

347 6.1.1 Learning to adapt to the body to turn it into a playful material

348 Eleven of our twelve participants discussed their experiences when they were learning how to give away bodily
349 control to the computer to turn it into a playful material. Participant P7 described the relationship they tried to
350 have with the EMS and said, *"It is my body, but I am trying to use it to listen to [the] computer."* When questioned
351 about how this "listening" worked, P7 said, *"I relax my muscles for the computer [to] work well so I can play with
352 it."* Here, the participant relaxed their muscles to allow the EMS to work best. When participants did not relax,
353 the EMS could not always actuate their muscles fully, so the gestures could be incomplete. For example, P3
354 said, *"Sometimes, I just forgot to relax my EMS hand, leading to incomplete gestures"*. As such, participants
355 said that they were actively involved when allowing the computer to use their body. For example, P8 said, *"I
356 tried to increase the intensity of the EMS and let it control my body."* P3 added, *"I initially forgot the advice you
357 [referring to the researcher] gave about breathing. Later, this breathing helped me let go of my EMS hand."*

358 Participants suggested that turning the body into a playful material is a personal experience. P10, who tried
359 to calibrate the system but could not achieve the desired hand movements, said, *"It was fascinating to see that
360 your [referring to the researcher] hand was moving, but I was surprised and sad that my fingers were not moving."*

361 *I increased the intensity to maximum comfort, but it was still not working.*” Participants who relaxed their muscles
362 could mostly experience complete actuation. However, the others experience incomplete actuation. P9
363 suggested that such ambiguous body movements were also a source of their enjoyment and said, *“It’s fun to*
364 *anticipate what the EMS hand tried to show when the actuations are fully executed by the EMS.”* This participant
365 also said, *“When I am anticipating what is going to happen, I sometimes forget that I have to play with my hand*
366 *too because it is fascinating to watch the hand move involuntarily.”* These participant responses suggest they
367 tried varied ways to turn their body into a playful material. While some sought to change the system’s parameters
368 (EMS intensity), others tried to relax their bodies by breathing (or both).

369 *6.1.2 Influence of the EMS hand’s movement speed on gameplay*

370 Participants discussed the influence of the EMS-hand’s movement speed on their ability to loan bodily control.
371 Five participants said that they had trouble playing Slap-Me-If-You-Can. P6 said, *“I was easily slapping “it” most*
372 *of the time.”* While our participants believed their muscles were actuated promptly, they felt the arm movements
373 were slower for this game. P7 reflected on this matter and said, *“I think bigger movements were required to play*
374 *Slap-Me-If-You-Can, and my body could not respond to the EMS actuations quickly enough.”* P1, who
375 experimented with the EMS intensity while playing this game, said, *“It gets too uncomfortable too quickly when*
376 *I increase the intensity.”* We also enquired if participants felt the EMS moved their hands slowly, even during
377 calibration. P6 said, *“No, during calibration, I didn’t feel there was a lag in-between toggling the channels on the*
378 *application and the response of my EMS hand.”* P9 reflected on this subject and said, *“During calibration, I was*
379 *only focusing on one hand, and therefore did not have my other hand moving to compare the speed. However,*
380 *I could notice the speed difference while playing as I needed to control my non-EMS hand to play the game.”*

381 Four participants reported they enjoyed playing Slap-Me-If-You-Can. P2 said, *“My hand was moving quickly*
382 *enough.”* P12 believed they added their own force to the EMS hand’s movement and said, *“Maybe because I*
383 *like physical games, I felt like I supported the computer’s movements with my own [laughs].”*

384 Participants also compared their experience of movement speed across all three games. P2 said, *“When*
385 *playing the Elements and Numbers game, you only move your body very slightly, just your fingers. However,*
386 *you are moving your upper body forward to slap the EMS hand when playing Slap-Me-If-You-Can. Therefore,*
387 *while thinking I was letting the EMS control my hand, I might have taken back control without your knowledge.*
388 *This could have caused the delay because you are restricting the computer from acting.”* They also compared
389 the actuation time, and P3 said, *“The short actuation time was enough to control small finger movements in*
390 *Numbers and Elements and was not enough for the bigger movements required for Slap-Me-If-You-Can.*
391 *However, I could not control this parameter.”*

392 These insights indicate that participants’ engagement in such games can dynamically influence their
393 gameplay experience. Participants can potentially enhance their experience by intentionally loaning more
394 control of their body to the computer. Conversely, they could diminish their gameplay experience by obstructing
395 the computer’s control. This might occur, for example, if participants focus too heavily on the computer’s
396 movements rather than on the body parts they themselves are controlling.

397 **6.2 Theme 2: Playfully engaging with the integrated computer**

398 This theme discusses how participants used the games’ varieties to playfully engage with the integrated
399 computer. Nine of the 41 codes were associated with this theme, representing 90 data units. This theme has

400 two sub-themes: varied attitudes towards the computer-controlled hand when playing the games (five codes
401 and 53 data units) and various ways to engage with the body during gameplay (four codes and 37 data units).

402 6.2.1 Varied attitudes towards the computer-controlled hand when playing the games

403 Nine participants discussed their attitude towards the computer-controlled hand. P6 said, *"I treated the EMS*
404 *hand as a different person, but it was still mine"*. Participants discussed the competition and game outcome and
405 noted, *"It was weird to experience losing to myself if the EMS hand won"* (P6). Some participants spoke to the
406 EMS-controlled body part, with P1 saying, *"I personalised the experience by speaking to it, and after every*
407 *result, I was trying to speak to myself and 'it' to feel the presence of another player."* P8 expressed a sense of
408 social play, saying, *"If I am playing against someone, there will be a psychological banter, but here I am playing*
409 *against a robot. So, I felt the fun you achieve is not so much because you are still playing to compete against*
410 *yourself."* On the other hand, some participants (n=5) did not focus on the competition but on interacting with
411 the EMS hand. P3 intended *"to play and interact with the EMS hand."* They did not care about the result because
412 *"I knew I was not playing with somebody else."* Similarly, P4 said, *"My goal was to have fun while exploring my*
413 *body"* as the traditional understanding of competition did not apply.

414 These results show that some participants saw the EMS hand as a personal entity and personalised the
415 experience by speaking to the EMS-controlled body part to foster a sense of social play. Moreover, while some
416 wanted to compete and experienced weirdness when losing to the EMS hand, others did not care, indicating
417 their intention to engage with their body.

418 6.2.2 Various ways to engage with the body during gameplay

419 Seven participants reflected on the various ways in which they engaged their body to play the games. P3 said,
420 *"I played all the games every day for about 30 minutes but changed the order of these games."* Four participants
421 said they had a favourite game initially. P4 said, *"Initially, I liked the Numbers game better because I had to*
422 *calculate and decide the winner."* Upon enquiring the reason behind this change of preference, they said, *"I felt*
423 *the result was more direct with the Elements game, meaning I did not have to do any math mentally, and I just*
424 *understood the result by feeling and looking at my hands compared to the Numbers game."* Six participants
425 also described how they did not like that they had to keep changing the electrodes to continue playing. P3 said,
426 *"I liked to play the games, but I did not like the associated labour job of changing electrodes."* Moreover, five
427 participants reflected on the gestures themselves. P5 said, *"I was more comfortable with the EMS hand*
428 *actuating the "Fire" gesture in the Elements game than the "Air" gesture, as I am not used to just closing my*
429 *middle finger."*

430 Five of the seven participants also discussed how much control over their body they had to give up playing
431 the three games. P5 said, *"I had to give away only a small amount of bodily control when playing Numbers and*
432 *Elements, which I was happy about, but a greater amount when playing Slap-Me-If-You-Can."* P12 added to
433 this commentary, saying, *"Playing Slap-Me-If-You-Can made it more challenging to give away bodily control,*
434 *and it took a while for me to understand how much I had to relax my muscles so that I could properly play the*
435 *game."* Participants also used the EMS system beyond the designed games. Three participants decided to
436 design a game of their own, *"After I finished playing these games, I was playing a prediction game with my*
437 *boyfriend in which he was wearing the glove with the phone and playing Numbers. His movement, of course,*

438 was controlled by the EMS hand, but I was also showing a number with my non-EMS hand. The game was to
439 predict the number the EMS might show.” (P7) (Figure 11).



440
441

Figure 11. A participant who designed their own social EMS game.

442 6.3 Theme 3: Playing with the ambiguity of the computer-controlled body parts

443 In this theme, participants discussed their experiences dealing with the sometimes-ambiguous movements of
444 the EMS hand and how this led to fun associated with prediction. Nine of the 41 codes are related to this theme,
445 representing 81 data units. This theme has two sub-themes: dealing with the incomplete movements of the
446 computer-controlled hand (4 codes and 35 data units) and predicting the computer-controlled hand’s gameplay
447 (5 codes and 46 data units).

448 6.3.1 Dealing with the incomplete movements of the computer-controlled hand

449 Eight participants described how the EMS hand occasionally did not finish its movements, with P12 saying that
450 “sometimes the finger movement was vague”. P12 continued saying, “The computer cannot know what it nor I
451 showed while playing the games. I had to be true to play the game.” P5 added, “There is the temptation not to
452 be ethical when playing against yourself,” but tried to resist this. Some participants admitted using this flaw to
453 their advantage in competitive situations. P9 said, “When I really wanted to win, I could.”

454 Five participants discussed determining the outcome when the EMS hand did not fully close its fingers. P7
455 said that when playing Numbers, “I knew the EMS hand was showing a three because I could feel what EMS
456 channel got actuated for that number on the skin, but the visual was a two as the third finger didn’t move
457 completely.” P4 described their response to this situation: “In these scenarios, I gave the point to the computer.”
458 However, some participants were unsure whether the computer moved their fingers completely. P3 said,
459 “Sometimes I was unsure if the computer moved my body or was it just me, moving for the computer.” Four
460 participants tried to resolve this ambiguity by closing their eyes while playing to improve their perception of what
461 the incomplete hand movements showed. P12 said, “While playing Elements and when my eyes were open, it
462 was a bit more ambiguous because I was just watching my hand and trying to see what it was doing.” Switching
463 the hardware between arms was another approach used to reduce ambiguity. P5 said, “I don’t know why my
464 left hand was not working; therefore, I calibrated my right hand to play the games.”

465 6.3.2 Predicting the computer-controlled hand's gameplay

466 Three participants described played with the computer's ambiguity by trying to predict "its" movements. P2 said,
467 *"I wanted to get better at dealing with the ambiguity initially. But when I didn't notice any pattern of when the*
468 *EMS was doing incomplete movements, I tried to predict when it could happen and tried to predict what it was*
469 *trying to say."* P4 said, *"Sometimes, the EMS hand's fingers would not close fully while playing Numbers, and I*
470 *would just nudge the computer to do the action fully."* P5, who used this tactic of prediction in all the games,
471 said, *"I realised that these uncertain/incomplete movements were also fun and tried to do it. However, prediction*
472 *in the psychological games was more fun than the physiological game."*

473 P1 described how they played such a prediction game and said, *"I would try to predict the EMS hand's*
474 *movement by trying to feel the point of actuation on my muscles."* Upon questioning the reason behind this
475 action, they added, *"When the actuation happened, sometimes, I subconsciously knew what it meant"*.
476 Participants described the effect of the sound feedback coming from the mobile phone, which influenced their
477 experience with this prediction. P1 said, *"I have a hearing problem, and therefore, I did not listen to the sound*
478 *created right before actuation."* P3, who did not have any prior EMS experience, said, *"I am more focused on*
479 *predicting just by focusing on one sense, I could not pay attention to two kinds of feedback at the same time."*
480 P7 liked the generic said, *"I enjoyed receiving the sound feedback as it helped me give away more control to*
481 *the computer when it was about to get actuated. I also liked that each gesture has the same sound as it felt like*
482 *the computer was trying to confuse me and give away the gesture it was about to perform at the same time"*.
483 Participants also utilised the ambiguity arising from the EMS to either support it (work as a team) or use it to
484 their advantage. P12 added to this narrative, *"Sometimes I knew what the EMS wanted to know as I was feeling*
485 *the actuation on my skin. So, if the actuation didn't fully happen, I would comply and complete the action the*
486 *computer was trying to achieve."*

487 These results suggest that participants used the ambiguity of the EMS to make gameplay more playful, with
488 some trying to predict incomplete movements to gain an advantage and others working as a team with the EMS
489 hand to support it. One key lesson learned is that users may find ways to deal with incomplete computer-
490 controlled bodily actions, making the experience more engaging and enjoyable. Another lesson is that a
491 multisensory approach could improve the accuracy of predictions and help users deal with ambiguity.

492 6.4 Theme 4: Bodily awareness when loaning bodily control to a computer to play

493 In this theme, participants discussed their experiences about how loaning bodily control to a computer to play
494 the games allowed them to reflect and become more aware of their body. 13 of 41 codes were associated with
495 this theme, representing 135 data units. The theme has two sub-themes: reflecting on one's body due to the
496 computer-controlled hand's performance (7 codes and 77 data units), and leveraging sensory cues and rhythmic
497 movements to reflect on the body (6 codes and 58 data units).



498

499

Figure 12. A participant playing the Numbers game before bedtime by relaxing the EMS hand (left) on their thigh.

500

6.4.1 Reflecting on one's body due to the computer-controlled hand's performance

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Six participants reflected on how playing reminded them of their past bodily activities while playing the games.

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P7 said, "Oh! I think I skied too much last week, and my muscle must be tired". Upon asking how they felt

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remembering this memory, they said, "It was strange that this game made me recollect that memory. We did

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have a good time during the Ski trip." P9, for whom the actuation did not work for the games for a couple of

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days in a row, said, "I was a little concerned as I was not sure why it was not working. I started to think about

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what I did or did not do over the last two days and realised I was overworked at the gym." Two participants

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specifically played these games after their work time, in the evening. P4 explained their choice and said they

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like to play these games before bedtime and "it does make you take 15 minutes out of your day to think about

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your body, and that's an interesting concept." Upon questioning how they think about their body, P4 said, "I

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thought of these games as almost like, mindfulness or meditation activities, where I had only to use one part of

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my body actively and let the computer play with the other part, I didn't have to think about this other part and

512

just let it loose."

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6.4.2 Leveraging sensory cues and rhythmic movements to reflect on the body

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Seven participants described their experience of reflecting on their body with the help of sensory cues and

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actuated rhythmic movements. P8 specifically discussed how they used their body differently while preparing

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to play and said, "When I felt the EMS hand performing the countdown movement for the first time, my

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immediate reaction was to take back control." Upon questioning what this reflection meant to them, P8 added,

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"I knew it would take a while to learn to allow the EMS to control my body, but I was unsure of how to do this as

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I never had to let go of my bodily control consciously." P7 said, "I used the sound of the rhythmic movement

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and chose to focus on it." Upon asking how focusing on the sound helped, P7 said, "It helped me keep track of

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my movement count. Since I was counting the countdown, I focused less on the EMS hand, which enabled me

522

to not think of it. It was a tricky learning curve." P12 commented on what they liked about this countdown feature

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and said, "I liked the feeling of response by the EMS hand. It helped me prepare and know when the EMS will

524

take control of my body." P6 added to this topic and said, "It feels like the EMS has a bit of character and made

525 *the gameplay dramatic.*” Overall, participants described that the sound “*added pop to the games*” (P12 and P5),
526 giving the game an “arcade” (P6 and P9) feel.

527 7 DISCUSSING THE PLAYER EXPERIENCE THEMES

528 The four themes discussed above describe participants’ experience of engaging with their body as a play
529 material, which can be helpful as descriptive tools for game design researchers. These themes uncovered that
530 our participants appreciated engaging with the variety of bodily movements of the computer-controlled hand for
531 play and the ambiguity of using their body as a play material. Prior work has highlighted that varied bodily
532 movements [32] and ambiguity [20, 51] are key concepts when designing bodily games [32, 38]. We extend
533 these concepts by articulating prescriptive design considerations for our Body as Play Material approach.

534 7.1 The body as a varying play material

535 Prior work stressed that variety is an important ingredient for engaging gameplay [47, 54]. Our results confirmed
536 this prior theory and extended it to the Body as Play Material approach. In particular, our participants highlighted
537 that variety in computationally controlled bodily movements could contribute to an engaging gameplay
538 experience. We now discuss four aspects of our games that promoted this variety and turn them into design
539 considerations for designers aiming to utilise this knowledge in their games.

540 7.1.1 Consistent hardware set up across multiple simple games for deeper bodily reflection

541 Our game hardware required participants to retain the size and position of the EMS electrodes to play Elements
542 and Numbers but not for Slap-Me-If-You-Can, allowing them to enjoy playing Numbers and Elements more than
543 Slap-Me-If-You-Can (Theme 1 and 3). Reflecting on this observation, we note that participants could play two
544 games (Numbers and Elements – as they had a consistent electrode set up) consecutively while having to
545 pause to recalibrate for playing Slap-Me-If-You-Can. This continuity in gameplay might have given them extra
546 time to get accustomed to the EMS actuations, allowing them to achieve a flow state [13]. Moreover, continued
547 playtime without changing hardware possibly helped players to focus inward and reflect on their own body,
548 especially considering the simplicity of the games. This inward focus might have also helped *how* the computer
549 would control their body.

550 In prior work, Mueller et al. [35] highlighted that bodily play experiences should help a human look inward
551 into their living body, not just use the body as an object. Our design confirms this theory and extends it to the
552 Body as a Play Material approach by suggesting that designers consider retaining any hardware for controlling
553 the body across multiple simple games for deeper bodily reflection.

554 7.1.2 Leveraging the limitations of the body-technology integration to create meta-gameplay

555 Game designers often create playful experiences using novel technologies, pushing their boundaries [16]. One
556 of the significant limitations of EMS, or so researchers thought [12, 26], is that there is a slight delay (less than
557 half a second) for the electricity passing through the body to transform into actuations. We thought this might
558 also be a limitation. However, our results in Theme 2 suggest that participants used it to their advantage. This
559 temporal gap between the time of actuation and the result getting visually displayed through the actuation on
560 their hand allowed them to play by trying to anticipate the EMS hand’s gesture. Therefore, a player could

561 anticipate by feeling the electricity and waiting for the visual confirmation, allowing them to create a meta-
562 guessing game.

563 Prior work suggested that the limitations of technology can be used to amplify the player's experience of
564 focusing on their bodily actions while playing movement-based games [43]. We confirm this theory with our
565 work and extend it to the Body as a Play Material approach by suggesting that designers leverage the limitations
566 of the body-technology integration to create meta-gameplay.

567 *7.1.3 Compensating for the tediousness of calibration through a minimalist rule set*

568 As described in section 4, the average pre-study took about one hour per participant, out of which a large portion
569 was dedicated to the calibration process (approximately 30 minutes on average), indicating the tediousness of
570 the process. Our results suggest that participants took much less time during the field study phase (15 minutes
571 on average) but indicated that recalibration to change games could still be improved. While researchers are
572 exploring using artificial intelligence to optimise this process [19, 27], our results suggested that designers could
573 compensate for the tediousness of calibration through a minimalist rule set.

574 Prior work showed that minimalist games can have a small rule set while still being sufficiently deep [40].
575 Our work extends this to the Body as a Play Material approach by suggesting that designers could compensate
576 for the tediousness of calibration through a minimal rule set.

577 *7.1.4 Varying computer-controlled movements to support reflection on bodily limitations*

578 We used one of the forearms to create fine- and gross-motor movements as this is the most used body part
579 when using EMS in HCI [17]. We designed games in which the EMS and non-EMS hands perform both kinds
580 of gestures to play. Participants reported enjoyment with the variety of movements but expressed discomfort
581 with some unnatural gestures, especially when these gestures were performed by the EMS-controlled hand.
582 For instance, participants felt more at ease with the "Fire" gesture than the "Air" gesture in the Elements game,
583 due to the unnatural motion of solely closing their middle finger. Despite the discomfort, participants found
584 reflecting on and understanding their body movement limitations useful.

585 Prior work has detailed the importance of combining fine- and gross-motor movements when creating bodily
586 games [34] and suggested that supporting varied bodily actions can facilitate diverse bodily reflections [3]. Our
587 work confirms this theory and extends it to the Body as a Play Material approach by suggesting that designers
588 consider varied computer-controlled movements to support reflection on bodily limitations [3].

589 **7.2 The body as an ambiguous play material**

590 Research highlights the importance of ambiguity for play as it can foster a sense of "curiosity, exploration and
591 empowers the player" [51]. Through our study, we learned that participants elicited various ways to engage and
592 deal with the ambiguity of a computer-controlled body part. This section discusses three aspects of ambiguity
593 that our participants experienced.

594 *7.2.1 Incorporate sound to notify players when the computer is about to take bodily control without specifying the nature 595 of this control*

596 Designing meaningful play requires players to receive immediate and clear feedback [47]. In our games, since
597 the "other player" was part of their own body, we designed sound feedback so that players knew when the
598 computer was about to take bodily control. Moreover, we played the same sound for every kind of gesture made

599 by the EMS hand to help retain “its” ambiguity. Our results from Themes 3 suggest that participants enjoyed
600 the sound as it helped them to know when to give up control while retaining the suspense of what gesture the
601 EMS hand might show.

602 Previous research showed that feedback should be given to inform the participant when the computer will
603 take control of their body [4]. Our results support and extend this theory to the Body as a Play Material approach.
604 We suggest that designers incorporate sound to notify players when the computer is about to take bodily control
605 without specifying the nature of this control.

606 *7.2.2 Allow players to manipulate the rules in response to the computer control’s limitations to facilitate referential ambiguity*

607 Huizinga [23] argues that game rules operate within the context of play but also suggests that players should
608 be able to alter these rules. Our study suggested that participants had difficulty accurately calibrating the
609 electrodes on their body to perform some gestures required for playing the games. Particularly, it was those
610 gestures that they felt uncomfortable performing. To address this, some participants changed the “air” gesture
611 to closing the ring finger instead of the middle-finger (Figure 1). They changed the rules by adjusting the
612 semantic reference of the designed gestures to something their body could perform using the EMS. This ability
613 to manipulate rules empowered the participants to feel more in control of the gameplay.

614 Sutton-Smith [51] refers to this ability to modify the rules to match the participant’s abilities as “referential
615 ambiguity”. We embrace this concept of referential ambiguity and extend it to the Body as a Play Material
616 approach. Specifically, we suggest that designers consider allowing players to manipulate the rules in response
617 to the computer control’s limitations to facilitate referential ambiguity.

618 *7.2.3 Balance the computer’s ability to perform fine- and gross-motor movements to amplify “its” ambiguity*

619 The balance of gestures is crucial in digital game design for fair and engaging gameplay [25, 47]. Participants
620 suggested that they tried to feel the electricity in their muscles for anticipating the computer-controlled actions
621 before the EMS hand displayed the result. Specifically, participants could more easily anticipate the one gross
622 movement gesture of the EMS hand in Elements and Numbers compared to the two fine gestures. This ability
623 to anticipate the gross gesture easily could be due to the imbalance between the number of fine and gross
624 movement gestures in these games.

625 Previous research has found that balancing bodily games can be achieved by increasing the player’s or the
626 technology’s ability in the environment [2]. Our study confirms this theory and extends it to the Body as a Play
627 Material approach by suggesting that designers could consider balancing the computer’s ability to perform fine-
628 and gross-motor movements to amplify “its” ambiguity.

629 **8 LIMITATIONS AND FUTURE WORK**

630 While this work offers unique insights, it is also subject to certain limitations that future research might address.
631 One limitation is the sample size (n=12) used in the field study, which may mean that the results are
632 generalisable to a larger population. Moreover, our study’s exploratory and descriptive nature may be prone to
633 novelty effects [44]. However, our study was conducted over seven days, and we showed that our participants
634 engaged with the system for a significant time, which allowed us to gather insights beyond the system’s novelty.
635 Future studies with a larger sample size and a longer-term engagement or a comparative study with
636 conventional game controls could help reduce novelty effects and provide more insights into the potential of the

637 proposed approach. Researchers could also use quantitative game experience tools such as the player
638 experience inventory to gather further insights about autonomy and ease of control [1].

639 One significant area identified for future research is the comfort and control associated with the EMS. The
640 use of EMS can be discomfoting for some players, and the loaning of bodily control to the technology may
641 negatively influence the gaming experience [26, 31]. Furthermore, the calibration process for EMS might not be
642 universally effective, resulting in unexpected modifications of body movements [26]. Nonetheless, we learned
643 that designing multiple games can address this constraint to a certain extent. Future research could explore
644 using more sophisticated EMS systems that can automate the calibration process (e.g., [27]) or other
645 technologies such as pneumatics or exoskeletons that do not depend on the player's muscular structure,
646 possibly dampening the effects of discomfort when loaning control.

647 We also acknowledge that our study focused primarily on single-player, competitive games. Future research
648 can consider employing our proposed approach to cooperative games, for example, by creating teams of EMS-
649 controlled hands across multiple players' bodies. Some of our participants indicated such possibilities, noting
650 their enjoyment in putting the mobile sleeve onto another person, retaining the EMS device on their arm, and
651 then playing the games.

652 In conclusion, by addressing the limitations and building upon the opportunities for future work outlined in
653 this paper, we hope to inspire game researchers and designers to continue exploring the potential of using the
654 body as a play material. This, in turn, could lead to the development of innovative gaming experiences that
655 foster bodily play and engage a wider range of users in unique and inclusive ways.

656 9 CONCLUSION

657 In conclusion, our work proposes the Body as a Play Material approach, where players use the body as input
658 and output by loaning bodily control to technology. This approach aims to bridge the gap by unifying the physical
659 body and the virtual world. We designed three novel games to showcase this approach and studied them
660 through a field study, resulting in four player experience themes. By reflecting on these themes, we provided
661 design considerations for promoting variety and using the body as an ambiguous play material when designing
662 future games. Ultimately, our approach brings a new perspective to creating games that aim to unify the physical
663 body and the virtual world.

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669 REFERENCES

- 670 [1] Abeele, V.V., Spiel, K., Nacke, L., Johnson, D. and Gerling, K. 2020. Development and validation of the player experience inventory: A
671 scale to measure player experiences at the level of functional and psychosocial consequences. *International Journal of Human-Computer*
672 *Studies*. 135, (Mar. 2020), 102370. DOI:<https://doi.org/10.1016/j.ijhcs.2019.102370>.
- 673 [2] Auda, J., Pascher, M. and Schneegass, S. 2019. Around the (Virtual) World: Infinite Walking in Virtual Reality Using Electrical Muscle
674 Stimulation. *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (New York, NY, USA, 2019), 1–8.
- 675 [3] Benford, S., Greenhalgh, C., Giannachi, G., Walker, B., Marshall, J. and Rodden, T. 2012. Uncomfortable Interactions. *Proceedings of*
676 *the SIGCHI Conference on Human Factors in Computing Systems* (New York, NY, USA, 2012), 2005–2014.

- 677 [4] Benford, S., Ramchurn, R., Marshall, J., Wilson, M.L., Pike, M., Martindale, S., Hazzard, A., Greenhalgh, C., Kallionpää, M., Tennent, P.
678 and Walker, B. 2020. Contesting control: journeys through surrender, self-awareness and looseness of control in embodied interaction.
679 *Human-Computer Interaction*. 0, 0 (Oct. 2020), 1–29. DOI:<https://doi.org/10.1080/07370024.2020.1754214>.
- 680 [5] Bianchi-Berthouze, N. 2013. Understanding the Role of Body Movement in Player Engagement. *Human-Computer Interaction*. 28, 1
681 (Jan. 2013), 40–75. DOI:<https://doi.org/10.1080/07370024.2012.688468>.
- 682 [6] Björk, S. and Holopainen, J. 2003. Describing Games - An Interaction-Centric Structural Framework. *Level Up – CD-ROM Proceedings*
683 *of Digital Games Research Conference 2003*. Referred to www.playresearch.com/publications/2003/structuralframework.pdf (ref.
684 *October the 25th* (2003), 4–6.
- 685 [7] Bounden: <https://www.ign.com/games/bounden/articles>. Accessed: 2023-02-19.
- 686 [8] Braun, V. and Clarke, V. 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology*. 3, 2 (Jan. 2006), 77–101.
687 DOI:<https://doi.org/10.1191/1478088706qp063oa>.
- 688 [9] Caillois, R. 2001. *Man, Play, and Games*. University of Illinois Press.
- 689 [10] Chatain, J., Sisserman, D.M., Reichardt, L., Fayolle, V., Kapur, M., Sumner, R.W., Zünd, F. and Bermano, A.H. 2020. DigiGlo: Exploring
690 the Palm as an Input and Display Mechanism through Digital Gloves. *Proceedings of the Annual Symposium on Computer-Human*
691 *Interaction in Play* (New York, NY, USA, Nov. 2020), 374–385.
- 692 [11] Cortazar, J. 2020. *Hopscotch*. Random House.
- 693 [12] Coyle, D., Moore, J., Kristensson, P.O., Fletcher, P. and Blackwell, A. 2012. I did that! Measuring users' experience of agency in their
694 own actions. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (New York, NY, USA, May 2012), 2025–
695 2034.
- 696 [13] Csikszentmihalyi, M. and Csikszentmihalyi, M. 1990. *Flow: The psychology of optimal experience*. Harper & Row New York.
- 697 [14] Dearnley, C. 2005. A reflection on the use of semi-structured interviews. *Nurse researcher*. 13, 1 (2005).
- 698 [15] Depping, A.E., Mandryk, R.L., Johanson, C., Bowey, J.T. and Thomson, S.C. 2016. Trust Me: Social Games are Better than Social
699 Icebreakers at Building Trust. *Proceedings of the 2016 Annual Symposium on Computer-Human Interaction in Play* (New York, NY, USA,
700 Oct. 2016), 116–129.
- 701 [16] Dyck, J., Pinelle, D., Brown, B. and Gutwin, C. 2003. Learning from Games: HCI Design Innovations in Entertainment Software. (2003).
- 702 [17] Faltaus, S., Koelle, M. and Schneegass, S. 2022. From Perception to Action: A Review and Taxonomy on Electrical Muscle Stimulation
703 in HCI. *Proceedings of the 21st International Conference on Mobile and Ubiquitous Multimedia* (New York, NY, USA, Dec. 2022), 159–
704 171.
- 705 [18] Farbiz, F., Yu, Z.H., Manders, C. and Ahmad, W. 2007. An Electrical Muscle Stimulation Haptic Feedback for Mixed Reality Tennis Game.
706 *ACM SIGGRAPH 2007 Posters* (New York, NY, USA, 2007), 140-es.
- 707 [19] Gange, G. and Knibbe, J. 2021. Optimising Automatic Calibration of Electric Muscle Stimulation. *Proceedings of the AAAI Conference on*
708 *Artificial Intelligence*. 35, 5 (May 2021), 3759–3767.
- 709 [20] Gaver, W.W., Beaver, J. and Benford, S. 2003. Ambiguity as a resource for design. *Proceedings of the SIGCHI Conference on Human*
710 *Factors in Computing Systems* (New York, NY, USA, Apr. 2003), 233–240.
- 711 [21] Grzyb, T. and Dolinski, D. 2021. *The Field Study in Social Psychology: How to Conduct Research Outside of a Laboratory Setting?*.
712 Routledge.
- 713 [22] How to play Statues - Hella Entertainment: 2008. <https://www.hellaentertainment.com/blog/games/statues/>. Accessed: 2023-02-19.
- 714 [23] Huizinga, J. 2016. *Homo Ludens: A Study of the Play-Element in Culture*. Angelico Press.
- 715 [24] Isbister, K. and Mueller, F. "Floyd" 2015. Guidelines for the Design of Movement-Based Games and Their Relevance to HCI. *Human-*
716 *Computer Interaction*. 30, 3–4 (May 2015), 366–399. DOI:<https://doi.org/10.1080/07370024.2014.996647>.
- 717 [25] Jaffe, A.B. 2013. *Understanding Game Balance with Quantitative Methods*.
- 718 [26] Knibbe, J., Alsmith, A. and Hornbæk, K. 2018. Experiencing Electrical Muscle Stimulation. *Proc. ACM Interact. Mob. Wearable Ubiquitous*
719 *Technol.* 2, 3 (Sep. 2018). DOI:<https://doi.org/10.1145/3264928>.
- 720 [27] Knibbe, J., Freire, R., Koelle, M. and Strohmeier, P. 2021. Skill-Sleeves: Designing Electrode Garments for Wearability. *Proceedings of*
721 *the Fifteenth International Conference on Tangible, Embedded, and Embodied Interaction* (New York, NY, USA, Feb. 2021), 1–16.
- 722 [28] Li, Z., Patibanda, R., Brandmueller, F., Wang, W., Berean, K., Greuter, S. and Mueller, F. "Floyd" 2018. The Guts Game: Towards
723 Designing Ingestible Games. *Proceedings of the 2018 Annual Symposium on Computer-Human Interaction in Play* (New York, NY, USA,
724 Oct. 2018), 271–283.
- 725 [29] Lohse, K.R., Hilderman, C.G.E., Cheung, K.L., Tatla, S. and Van der Loos, H.F.M. 2014. Virtual reality therapy for adults post-stroke: a
726 systematic review and meta-analysis exploring virtual environments and commercial games in therapy. *PLoS One*. 9, 3 (2014), e93318.
727 DOI:<https://doi.org/10.1371/journal.pone.0093318>.
- 728 [30] Lopes, P. and Baudisch, P. 2017. Immense Power in a Tiny Package: Wearables Based on Electrical Muscle Stimulation. *IEEE Pervasive*
729 *Computing*. 16, 3 (2017), 12–16. DOI:<https://doi.org/10.1109/MPRV.2017.2940953>.
- 730 [31] Lopes, P., Ion, A., Mueller, W., Hoffmann, D., Jonell, P. and Baudisch, P. 2015. Proprioceptive Interaction. *Proceedings of the 33rd*
731 *Annual ACM Conference on Human Factors in Computing Systems* (New York, NY, USA, Apr. 2015), 939–948.
- 732 [32] Márquez Segura, E., Waern, A., Moen, J. and Johansson, C. 2013. The design space of body games: technological, physical, and social

- 733 design. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (New York, NY, USA, Apr. 2013), 3365–3374.
- 734 [33] McElroy, G. 2012. Folk Lore: How Johann Sebastian Joust is defining a new gaming genre. *The Verge*. (2012).
- 735 [34] Mueller, F., Agamanolis, S. and Picard, R. 2003. Exertion interfaces: sports over a distance for social bonding and fun. *Proceedings of*
736 *the SIGCHI Conference on Human Factors in Computing Systems* (New York, NY, USA, Apr. 2003), 561–568.
- 737 [35] Mueller, F. "Floyd," Byrne, R., Andres, J. and Patibanda, R. 2018. Experiencing the Body as Play. *Proceedings of the 2018 CHI*
738 *Conference on Human Factors in Computing Systems* (New York, NY, USA, 2018), 1–13.
- 739 [36] Mueller, F. 'Floyd,' Gibbs, M.R., Vetere, F. and Edge, D. 2017. Designing for Bodily Interplay in Social Exertion Games. *ACM Transactions*
740 *on Computer-Human Interaction*. 24, 3 (May 2017), 24:1-24:41. DOI:<https://doi.org/10/gj6p7q>.
- 741 [37] Mueller, F. "Floyd," Kari, T., Li, Z., Wang, Y., Mehta, Y.D., Andres, J., Marquez, J. and Patibanda, R. 2020. Towards Designing Bodily
742 Integrated Play. *Proceedings of the Fourteenth International Conference on Tangible, Embedded, and Embodied Interaction* (New York,
743 NY, USA, 2020), 207–218.
- 744 [38] Mueller, F. and Isbister, K. 2014. Movement-based game guidelines. *Proceedings of the SIGCHI Conference on Human Factors in*
745 *Computing Systems* (New York, NY, USA, Apr. 2014), 2191–2200.
- 746 [39] Nacke, L.E., Kalyan, M., Lough, C. and Mandryk, R.L. 2011. Biofeedback Game Design: Using Direct and Indirect Physiological Control
747 to Enhance Game Interaction. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (New York, NY, USA,
748 2011), 103–112.
- 749 [40] Nealen, A., Saltsman, A. and Boxerman, E. 2011. Towards minimalist game design. *Proceedings of the 6th International Conference on*
750 *Foundations of Digital Games* (New York, NY, USA, Jun. 2011), 38–45.
- 751 [41] Panaite, A.F., Rîșteiu, M.N., Olar, M.L., Leba, M. and Ionica, A. 2019. Hand rehabilitation - a gaming experience. 572, 1 (Jul. 2019),
752 012092. DOI:<https://doi.org/10.1088/1757-899X/572/1/012092>.
- 753 [42] Pasch, M., Bianchi-Berthouze, N., van Dijk, B. and Nijholt, A. 2009. Immersion in Movement-Based Interaction. *Intelligent Technologies*
754 *for Interactive Entertainment* (Berlin, Heidelberg, 2009), 169–180.
- 755 [43] Patibanda, R., Mueller, F. "Floyd," Leskovsek, M. and Duckworth, J. 2017. Life Tree: Understanding the Design of Breathing Exercise
756 Games. *Proceedings of the Annual Symposium on Computer-Human Interaction in Play* (New York, NY, USA, 2017), 19–31.
- 757 [44] Poppenk, J., Köhler, S. and Moscovitch, M. 2010. Revisiting the novelty effect: When familiarity, not novelty, enhances memory. *Journal*
758 *of Experimental Psychology: Learning, Memory, and Cognition*. 36, (2010), 1321–1330. DOI:<https://doi.org/10.1037/a0019900>.
- 759 [45] Red Hands: <https://www.twoplayergames.org/game/red-hands>. Accessed: 2023-02-19.
- 760 [46] Reeves, S., Benford, S., O'Malley, C. and Fraser, M. 2005. Designing the spectator experience. *Proceedings of the SIGCHI Conference*
761 *on Human Factors in Computing Systems* (New York, NY, USA, Apr. 2005), 741–750.
- 762 [47] Salen, K. and Zimmerman, E. 2004. *Rules of Play: Game Design Fundamentals*. MIT Press.
- 763 [48] Semertzidis, N., Scary, M., Andres, J., Dwivedi, B., Kulwe, Y.C., Zambetta, F. and Mueller, F.F. 2020. Neo-Noumena: Augmenting
764 Emotion Communication. *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems* (New York, NY, USA, Apr.
765 2020), 1–13.
- 766 [49] Serrano, R. and Zapater, I. 1998. The Three-Legged Race: Cooperating to Compete. *Games and Economic Behavior*. 22, 2 (Feb. 1998),
767 343–363. DOI:<https://doi.org/10.1006/game.1997.0588>.
- 768 [50] Shake, drop, and test! Simulation and test for electronics reliability - Electronics & Semiconductors: 2022.
769 <https://blogs.sw.siemens.com/electronics-semiconductors/2022/08/03/vibration-test-and-simulation-in-electronics-design/>. Accessed:
770 2023-05-04.
- 771 [51] Sutton-Smith, B. 2001. *The Ambiguity of Play*. *Harvard University Press.
- 772 [52] de Vignemont, F. 2020. Bodily Awareness. *The Stanford Encyclopedia of Philosophy*. E.N. Zalta, ed. Metaphysics Research Lab, Stanford
773 University.
- 774 [53] Walker, D. and Walker, G. 2004. *The Official Rock Paper Scissors Strategy Guide*. Simon and Schuster.
- 775 [54] Waters, J. and Maynard, T. 2014. *Exploring Outdoor Play in the Early Years*.
- 776 [55] Wiltshier, F. 2011. Researching With NVivo. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research*. 12, 1 (Jan. 2011).
777 DOI:<https://doi.org/10.17169/fqs-12.1.1628>.
- 778 [56] Wobbrock, J.O. and Kientz, J.A. 2016. Research contributions in human-computer interaction. *Interactions*. 23, 3 (Apr. 2016), 38–44.
779 DOI:<https://doi.org/10.1145/2907069>.
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781 APPENDICES

782 A.1 Game Challenges

783 *Table 2. Compulsory and optional challenges were added to the software application as part of the Auto-Paizo games*
 784 *study.*

Mandatory Challenges	Optional Challenges
Calibrate for Numbers game	Play these games in a public place
Calibrate for Elements game	Play standing outside your house where people can see you playing
Calibrate for Slap-Me-If-You-Can	Take it to the restaurant and see if other people are interested to play the games
Play while you're on a zoom call and other people are watching you play	Design a game by integrating these games with another game/ create a new game
Play by asking your partner/ friend/ family to wear the arm guard with the phone and then let them play with your computer hand	Use these EMS games to settle a bet
Play using both your hands (Switching calibration)	
Integrate these games into a daily life activity (e.g., Playing board games or as a decision-making tool)	

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