TouchMate: Understanding the Design of Body Actuating Games using Physical Touch

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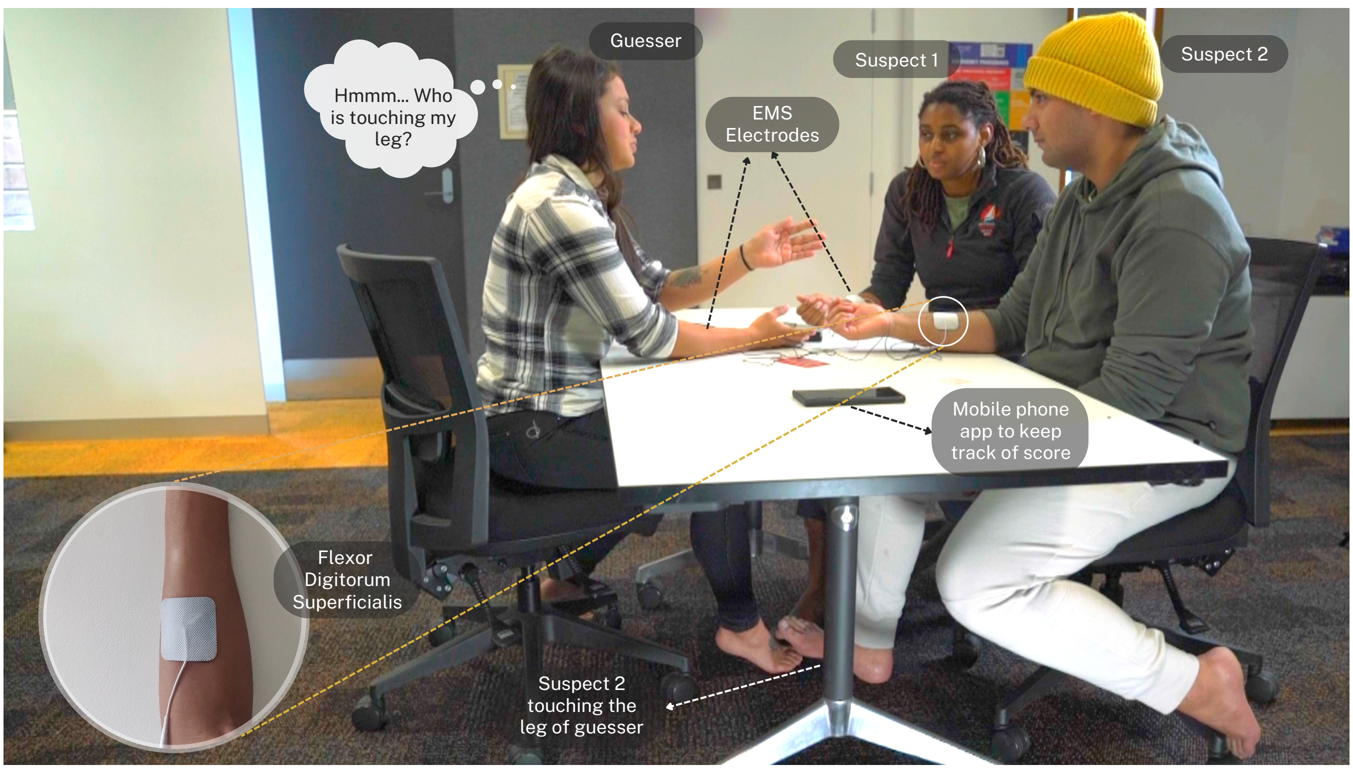

Figure 1: Shows one guesser and two suspects on either side of the table. The guesser had the ground and each suspect had an active electrode from one EMS channel attached to their forearm. Here, suspect 2 is touching the guesser's foot, actuating the guesser's and their own hand. The guesser is pointing correctly towards suspect 2, winning this round.

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ABSTRACT

Body-actuating technologies such as Electrical Muscle Stimulation (EMS) can actuate multiple players simultaneously via physical touch. To investigate this opportunity, we designed a game called "Touchmate". Here, one guesser and two suspects sit across with their legs hidden under a table. The guesser attaches a ground electrode from one EMS channel, and each suspect attaches one active electrode from the same channel on their forearms. When a suspect touches the guesser's leg, their bodies complete the electrical circuit, actuating both their hands involuntarily via the EMS. The guesser's goal is to determine who touched their leg. In this paper, we present the results from our initial study and articulate three player experience themes. Ultimately, we hope our work inspires game designers to create physical touch games using body-actuating technologies.

CCS CONCEPTS

• **Human-centered computing** → *Human computer interaction (HCI)*; Interaction paradigms;

KEYWORDS

electrical muscle stimulation;physical touch games;movement-based games;bodily games;game design;integrated play;EMS games;motor play;social games

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1 INTRODUCTION

HCI's game design researchers often sense the human body to use it as an input for digital games [2, 3, 7–10, 15, 15, 21–30]. These explorations were often fuelled by commercial sensing technologies such as the Playstation Move [33], Kinect [33] and the Nintendo Ring Adventure [20].

Building on this, games such as "Johann Sebastian Joust"[1], "Balance of Power" [21] and "Bundle" [21] have emerged that use sensing technologies. In these games, players must move their bodies and physically touch each other to engage in gameplay. However, the sensing technologies used in these games only use the body as input and do not influence the way players are required to touch each other physically.

Proprioceptive interaction [17], on the other hand, suggests to use the body as input and output using technologies like Electrical Muscle Stimulation (EMS). EMS uses the body as output by passing a small amount of electricity between an active and one ground electrode attached to the body. When electricity passes through these electrodes, the muscle fibers between the two electrodes help complete the electrical circuit. This circuit completion contracts the muscles resulting in involuntary body movements. This mechanism of EMS has been used in bodily games such as to support engagement in Virtual Reality games by providing force feedback [1]. However, EMS can also be used socially by attaching the ground electrode on one user and the ground electrode on another. When these two people physically touch each other their bodies complete the electrical circuit, actuating both their body parts.

Using this social EMS feature for the first time in HCI (to our understanding), we designed a game called "TouchMate". This game has one guesser and two suspects (minimum). The guesser attaches a ground electrode from one EMS channel, and each suspect attaches one active electrode from the same channel on their forearms (flexor digitorum superficialis). Any suspect touching the guesser's bare foot closes the electrical circuit to contract their forearm muscles, moving their middle finger involuntarily. Here, the other suspects can employ deceiving tactics such as moving their fingers to confuse the guesser. The guesser's goal is to determine who touched their leg.

We conducted an initial study and interviewed six participants. We articulate three user experience themes, which we identified by conducting an inductive thematic analysis of the interview data. They are 1) negotiation during shared EMS calibration, 2) role of EMS as a controlling agent, and 3) comfort between players required for physical touch games. Through our work, we make the following contributions:

- We highlight an underexplored social feature of EMS that emerges through physical touch. Our exploration could be helpful for game designers interested in creating social games involving physical touch.
- We are presenting a set of three themes from an initial study. These themes could be helpful for evaluators interested in understanding novel digital play experiences using body-actuating technologies such as EMS.

2 BACKGROUND

Our work is inspired and informed by prior work around bodily games involving physical contact and EMS works in HCI.

2.1 Physical Touch in Digital Bodily Games

Prior work on "bodily interplay" [26] advocates for engaging the human body in social games. As a result, researchers explored the design of games that require players to touch each other brutally [21]. For example, "Balance of Power" [21] involves players trying to push or pull opponents into a particular play area, and "Bundle" [21] involves players cooperating against a single player on whom they exert bodily control in order to confine them to a small space. From these works we learned that digital games can be designed in a way that they result in intertwined bodies that physically touch each other by exerting force.

Johann Sebastian Joust [34] is a game played with PlayStation Move controllers [14]. Players hold the controllers in their hands, which light up as they steadily move around a space in sync with the tempo of the music. The game's goal is to disrupt the pace at which other players move their bodies while not disrupting one's pace; for example, by hitting the other player's hand. Successfully disrupting other players or one's own pace turns off the controller's light, eliminating the player. This work suggests that physical touch can facilitate playful bodily experiences. However, sensing technology cannot detect the touch, limiting physical touch as a choice during gameplay.

[1]http://www.jsjoust.com/

In summary, these games show that physical touch in digital bodily games can result in novel playful experiences. However, these games use the body as input and not as output. Furthermore, the design of these games also suggests an opportunity to use the technology to influence how players physically touch each other. Body-actuating technologies like EMS help explore this opportunity by allowing to use of the body as input and output, which we discuss in the next section.

2.2 Body as Input and Output Using EMS

Proprioceptive interaction inspired the HCI community to use the body as input and output by using EMS. Researchers explored a range of applications using EMS [4, 6, 12, 16, 18, 19, 30, 31]. For example, EMS has been used to provide force feedback in VR [16]. In this case, the users share control of their hand with EMS; for example, when lifting a virtual box, the user contracts their biceps muscle lifting the box while EMS triggers muscle movements to simulate a downward force on the user's hand. Similarly, EMS has been used to allow a machine to use a human hand as an output modality to draw graphs on paper [19], where the user can take control of their hand by resisting the EMS. Social EMS systems such as EMS Painter [4] allow another person to control a painter's hand movements attached to an EMS device to influence how they paint on a canvas. These explorations show that users can share bodily control with EMS in a single-user scenario and allow other users to influence their control over their bodies.

EMS has also been used to create bodily games. For example, Patibanda et al. [30] use EMS to create single-player games. In these games, players share control over one of their hands with EMS to play games like rock-paper-scissors with their EMS-controlled hand using the other hand in their control. Their work demonstrates the potential of EMS for creating digital bodily games using the body as input and output.

In sumamry, HCI researchers explored bodily games involving physical contact and sharing bodily control using EMS. However, the design of games in which players share bodily control to influence the way players physically touch each other using EMS remains underexplored. To understand this, we designed TouchMate and answer our research question: *what is the experience of physically touching other players to initiate shared bodily control?*

3 TOUCHMATE

TouchMate allows players to control other players' bodies through physical touch. This direct skin-to-skin touch between players induces movement in their hands, which either player can terminate by withdrawing from the touch. Thus, there is a three-way sharing of bodily control using the bodies of two players, i.e., the guesser and a suspect.

3.1 Game Setup: Hardware and Software

We learned from prior work [12] and used a commercially available EMS device[2] to maintain the players' safety. An EMS device generally has two electrodes: an active and ground electrode attached to the same body. Contrarily, in our game, we place the ground and the active electrodes on the bodies of two players. This sharing of electrodes from the same EMS channel but on different bodies results in no actuation unless there is no physical touch between them (Fig. 2).

The common ground electrode of the EMS device is placed on the flexor digitorum superficialis of the guesser. Each suspect has one active electrode on the flexor digitorum superficialis on their anterior forearm (Fig. 1). We made sure that the game uses only the right side of all users' bodies since EMS current is not recommended across the heart[3]. Thus, the players use their right hands and their right feet throughout the game.

Three players sit at a table barefoot, so they can reach each other's feet with their own (Fig. 1) but cannot see their feet, to play TouchMate. The suspects can choose to sit close to each other on one side of the table while the guesser sits on the other side. The game's goal is for the guesser to figure out which suspect is touching them. To start the game, players enter their names in a mobile software application, which nominates one player as the "guesser", while the other players become the "suspects". The software keeps track of the score and gives each player a chance to be the guesser for five minutes.

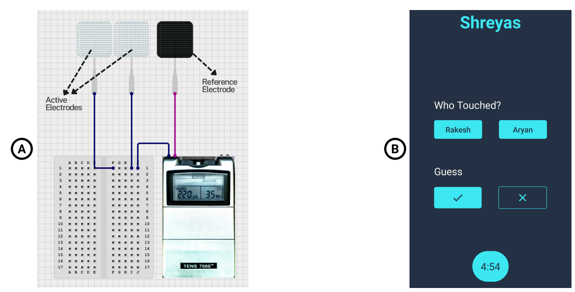

Figure 2: (A) Circuit schematic to convert one channel of the EMS device to multiple channels with a common ground electrode (B) The mobile application keeps track of game score.

3.2 Gameplay

The suspects' goal is to cooperate while touching the guesser and competing against them (Fig. 1). This touch actuates the flexor digitorum superficialis, resulting in the involuntary movement of both players' middle fingers. The guesser's goal is to observe these EMS-induced movements of the suspects' fingers to determine which suspect touched them. The guesser does so by comparing their hand movements to the suspects' hand movements. As such, the other suspect can try to fool the guesser by synchronously moving their hand to mimic the EMS actuated hand movements and any movements they observe.

After one round, the suspects again decide (discretely through signals, so the guesser remains unaware) who will touch the guesser, and the game continues. Each player gets to be the guesser for five minutes, scoring as many points as possible.

[2]https://tens7000.com/

[3]https://tens7000.com/pages/tens-7000-instruction-manuals

4 PRELIMINARY THEMES DESCRIBING PLAYER EXPERIENCE

We performed an initial study with two groups of three participants each, and conducted semi-structured [32] interviews with each participant individually after the game. Questions included inquiry into the design of the game, players' experience with electrical muscle stimulation, strategies they employed during the game, and their views on sharing control of their body with other players. The participants enjoyed playing a game based on EMS, and all of them found the game to be engaging. P5 described the game as *"a combination of fun and strategy"*, and two out of six participants expressed their desire to play the game again.

4.1 Role of EMS when facilitating Shared Bodily Control

This theme discusses differences in the opinion given by participants about the role of EMS in controlling their hands. All participants enjoyed that their fingers moved involuntarily, while they could also take back this involuntary control from the EMS. Four participants felt like they were in control of their hand, while P2 and P3 felt like their hand was almost completely out of their control. P4 strongly felt like they were moving their hand even when EMS triggered it, and said: *"I felt like I was the one moving my hand, but not totally in control because the device was giving me instructions and I could not disobey those"*. P1 and P6 felt they could control their hands despite EMS actuation. P1 said: *"Because the EMS intensity was low for me, I could resist most of the involuntary movements, although it was difficult to control that first jerk when the current just started flowing"*. While P1 resisted the EMS to mislead the guesser, P6 felt this was unnecessary: *"I could have controlled my hand if I wanted to. But I didn't think that was in the spirit of the game, so I did not do it"*. P5, on the other hand, said: *"I did feel like the intensity was a little low, but I do not think I could have stopped my hand from moving even if I wanted to"*.

When asked who they thought was moving their hand, they indicated both the player touching them and the device. P6 said, *"I feel like the player touching me was only an intermediate between me and the device, but the device was controlling my hand. I do not feel like the other player was controlling my hand because he was being controlled!"* P1, however, felt like they had control of their hand for the most part, while P5 said, *"It was the device that had a bigger role, while the person touching me had a minor role. They both together were controlling my hand. If there is no device and someone touches me, they do not control my hand. If there is a device but no touching, my hand isn't being controlled"*. P4 found it interesting that by touching another person, they were controlling not just the other person but their hand as well: *"When I keep my foot on the other person's foot, their hand moves. But I feel the current too, and my hand starts moving. That was really interesting!"*

4.2 Negotiation During Social EMS Calibration

In this theme, participants discussed how they had to negotiate with the EMS technology when calibrating for a shared bodily control game.

The social calibration of EMS, especially setting the intensity for playing TouchMate differed from using an EMS individually. The players shared electrodes from a single EMS channel, so they had to negotiate a shared EMS intensity level. This negotiated level should be capable of passing an electric current that is comfortable enough for all the players involved and can actuate the players' bodies touching each other.

Three out of the six players had not experienced EMS before and expressed hesitation regarding the thought of current passing through their bodies. P4 said: *"I felt like the current was strong initially, but I enjoyed the game a lot and got engrossed in it"*. P3, despite having experienced EMS before, had trouble with the intensity calibration: *"I had tried out EMS before with both electrodes, so I thought I would let the intensity be adjusted according to other players, but one of the players wanted it too high. Initially, my entire wrist was moving, but I got the hang of it and could control it by the end"*. This could mean that while players, both inexperienced and experienced, felt apprehensive initially, they were both able to adjust their bodies towards coping with the shared EMS intensity level. P1, on the other hand, wanted the intensity higher and said: *"The EMS intensity was so low that my hand was hardly moving. But the other players were uncomfortable with higher intensity, so I had to settle for a lower one"*.

Introducing an interesting aspect of the game, P2 said: *"The EMS current was pretty strong, but I realized that it varied based on how I touched the other person. I felt a higher intensity if the touch was firm, so it was in my control, especially when initiating the touch"*.

4.3 Comfort between Players

Since TouchMate introduces EMS-controlled touch between players, participants also talked about how they needed a certain level of comfort with other players. This theme discusses their opinions on the comfort between players.

Participant groups were such that the three people playing together were familiar with the other players from before the study, except P1, who did not directly know P2 or P3. Talking about the level of comfort required with other players, P5 said, *"The fact that there is physical contact between players in this game means that I will not play with strangers. When we travel on a train, sometimes we pull out a deck of cards and play with fellow travellers, but I will not be comfortable playing this game with them. You could say that the touch is impersonal, but I will not be comfortable with that"*. P6 also addressed how they would want a certain level of comfort with other players to play this game: *"I would not play this game with strangers. If I am in a friend group and I do not know everyone, I think it might be fine because my friend will know the person I do not know, so there is some connection. But with strangers, I might be willing to play a board game but not this"*.

5 DISCUSSING THE THEMES

When a single user uses EMS, they set the intensity to their liking [12, 13, 30]. However, in our game, two bodies use electrodes from the same channel to complete the electrical circuit. This means that three players had to share the same EMS intensity, even if it was sometimes uncomfortable for other players (Theme 2). Our goal was to achieve a certain level of actuation in all players while ensuring that none of them was uncomfortable. However, in cases where there was a considerable difference between the intensities required for actuation for different players, we had to proceed to the game with very little actuation for one of the players. To calibrate the EMS intensity, in a separate calibration task before the game started, we asked two players to maintain touch and then increased the intensity so that it actuated the fingers of both players. We then asked the third player to touch the guesser to ensure the intensity was in the comfortable range for them. It appeared that the game experience got the players in a flow state [5] where they were not bothered as much by the EMS intensity, even if it was high for them initially.

Three players considered the EMS device to control their hands partially and completely. One player felt that the EMS device had a significant role in controlling their hand, and the player initiating the touch had a minor role. Another player addressed the player, touching them as an intermediate between them and the EMS device, with the EMS being in control of both players. One player felt in control of their hand, with EMS having a small contribution to the shared control. Overall, players did not consider the other player to have a significant role in controlling their hand through physical touch.

Players had concerns about a certain comfort level required with other players because of the physical touch involved in the game. HCI researchers have explored physical touch to provide audio-visual feedback to users [11]. Our work takes this further by allowing users to control two bodies through EMS by initiating physical touch.

As discussed earlier, TouchMate allowed technology to influence the way in which players touched each other. In addition to this, players unveiled an interesting aspect of being able to decide how much control the system would have based on the nature of the touch. One of the participant talked about how a more firm touch led to the system having more control, while a lighter touch gave the system less control over the players' bodies.

5.1 Observed Gameplay Strategies

The first strategy players had to develop was when they played as suspects and needed to communicate with the other suspect to determine who would touch the guesser. Players used different techniques for this secret communication, including tapping each other's feet to indicate that they would be the next one to touch and using hand signs below the table surface, hidden from the guesser.

Other than this, players devised many strategies to try and tilt the odds in their favour. The two most straightforward strategies that several players employed were: 1) Trying to resist EMS actuation in their hand; and 2) Imitating the other suspect's hand movements to pretend as if their hand was being actuated. However, other strategies evolved during play. One of the players adjusted how they touched the guesser to vary the intensity of the EMS to make it easy to resist actuation. One of the players, while playing as the guesser, also deciphered the eye contact between the two suspects, which they used to decide who would touch the guesser next. Players also decided to cover the EMS electrode with either a long-sleeve shirt or using their other hand since the slight twitching of muscles on the forearm was also a dead giveaway for the guesser.

6 LIMITATIONS AND FUTURE WORK

More than three players can play our game, which we have not yet examined. Another limitation is that all players could not calibrate the EMS individually. However, this is an ongoing challenge faced by the HCI research community, which is being addressed through auto-calibration works like [13]. Moreover, two groups of three participants participated in our study, limiting our understanding of the player experience. Although the findings appear relevant, conducting a complete study with more participants is essential, allowing us to uncover other strategies players might use to play the game.

To simplify the scoring process, we are working on ways to detect bodily contact between players automatically. The themes identified in our work highlight the potential for games involving EMS for simultaneous actuation of multiple bodies. Participants enjoyed being able to play a game where EMS controlled their bodies, where they could trigger it by touching another player. Future work on actuation games and physical touch games using EMS can utilise the new affordance of EMS that we highlighted.

7 CONCLUSION

In conclusion, we presented a social game using EMS, introducing a new affordance of EMS for simultaneous actuation of multiple bodies. We explored a game involving physical touch, which involves direct skin-to-skin contact. We discussed three themes that arose from the initial study of the game, demonstrating that players found the game to be an engaging social experience. Our work offers an initial insight into understanding body actuating games through physical touch, ultimately extending the range of games we play.

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