BattleTab: Digital Battle Map With Tangible Game Pieces

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***Abstract*—This paper proposes using conductive materials in a non-conductive support to register the movement of tangible game pieces on a touch screen device. This enables players to use their existing game pieces in a digital or hybrid board game. The exploration, experimentation, and implementation of the prototype are described and the resulting game experience is tested autobiographically and with users in completely face-to-face, mixed, and completely remote settings with a focus on the sense of presence enhanced by the prototype. The qualitative user evaluation confirms the system's potential, but reliability and usability issues limit the sense of presence that can be achieved with the current iteration.**

1. Introduction

BattleTab is a digital hybrid multi-player tabletop game that combines physical elements from board games with digital tablets. The ambition is to combine the feeling of playing a traditional board game with physical components and the possibilities for variation and innovation that arise from using digital displays.

This device is a commercial design intended for several users to play tabletop games that utilise battle maps. Every participant has their own tablet (or other touch-sensitive screen) computer that displays the battle map as presented by the Game Master (GM). A battle map often consists of a grid system and tokens used to represent characters in the game from monsters to players. It is proposed that every player has their characters' figurines that they can place on the tablet to represent them in the game. The other players in the game will be represented as tokens on the screen. A digital representation of the figurine and its movement will be shown on the other player's tablets, connecting the players in real-time game-play.

In regards to division of labour, all team members were equally involved in the idea creation, general design of the product and usability tests. However, some parts of the project were allocated to specific team members. Christoph A. Johns was the main responsible for the software of the game, while Lilly A. Helmersen was in charge of the video creation, and Rita Nordström and Carlo Barone took the lead on the written documentation.

2. Background

The enhancement of physical games with digital components is a growing trend in both game industry and research. Until fairly recently, many physical games and their digital counterparts existed in different spaces, completely independent of each other. In the past couple of years, however, the trend of "hybrid games" has introduced a more streamlined experience where physical and digital aspects are combined for an increased innovation in gameplay [1], [2]. As a result, there are now several commercial products that combine digital and physical elements in their game. Examples of digital board game hybrids are "XCOM: The Board Game" and "Mansion of Madness: Second Edition".

Aspects of physicality and presence in co-located and remote gaming have, for example, been examined by Krzywinski et al. [1]. They noted that – while the synchronisation of game state might be the most pressing practical challenge – features of distributed players should be embraced and used as a design material instead of viewing them as constraints. This includes such aspects as information asymmetry and asynchronicity. The authors argue that turn-based games and games using a distinction between public and private information are especially suited for transformation to remote play. In more advanced stages, the authors advocate for viewing the game itself as an actor in play – e.g. using actuated components as representation of the game's intentions – and as a mediator in the communication between the human players – e.g. using game components to translate non-functional communication like body language into the physical space.

One of the most important sources for the project described in this paper is an application developed by Hartelius et al. [3], called *Tisch*. This application allows users to play board-, role-playing- and war-games, keeping in account a large variety of issues and particularities. In many kinds of situation, allowing also to play on distance, nevertheless maintaining a physical aspect in the game. For a role-playing-game or battle game, the physical aspect can, for instance, be provided by miniatures or cards, which are both easily implementable in such a platform. The aim of the BattleTab project is, hence, to study, apply and possibly extend and enhance this kind of implementation.

This project's main idea is also deeply rooted in existing technology for role-playing games. The two most prominent applications for online battle map representation are Roll20.net [4] and Fantasy Grounds [5]. Both of these offer token representation of characters on a battle map, but none of them are directly suited for use with a touch surface.

3. Ideation

The underlying theme of this project is ”Through barriers” – an investigation of how people can connect through, in this case, digital and physical barriers. The question is whether we can achieve a sense of connection and community if we cannot touch each other or share the same physical space.

The authors of this paper initially formed a group because of a joint interest in the area of games for remote presence, within the broader theme of ”connecting through barriers”. And while the design had to incorporate digital aspects, in order to be possible to play the game remotely, it also had to include physical components. Having defined the problem to be solved and the scope of the project, the next step was to decide exactly how this game should be designed.

After some individual research on previous works, the group gathered to have a brainstorming session in order to decide on a game design. The brainstorming session was conducted through Zoom, where every team member could present an idea and discuss it with the team. The prevailing idea from this brainstorming session was a tic-tac-toe-game played by pressing buttons on a pad, where the buttons pressed would light up in the opponent's pad – allowing each player to see the other's move. This was to be achieved by programming a Raspberry Pi and using a special button pad. In addition to being a quite simple idea, some research showed that there had already been several similar projects. Therefore, the conclusion that a different idea was to be thought of.

The rejection of the first design idea warranted a new brainstorming session, carried out in a more rapid and fire-style way. Three of the new ideas formed where deemed interesting enough to develop further: a competitive multi-player remake of the 90's toy ”Bop it Extreme”; a fusion of “Dance Dance Revolution” and “Twister Moves”, where the participants would race to create different shapes on a physical mat; and, finally, a multi-player tabletop game based on digital battle maps with grid layouts and physical figurines. After some reflection, the tabletop idea, named ”BattleTab,” was chosen.

4. Prototyping

This section is meant to outline the general components and interaction patterns which were prototyped, before going into more detail on the conceptual video prototype, the software and the hardware prototype that were implemented.

Design Components. Two main components were used in the design:

- One touch-sensitive screen or tablet per player to display digital information, e.g. an iPad.
- Physical figurines with capacitive material extending underneath the base.

Interaction patterns. First, the miniatures were moved around on the gaming surface and a discussion session was carried out about different ways of natural movement for the miniatures. Afterwards, a brainstorming session was held about what other possible interactions with the miniatures should be included.

The outcome consisted of 3 different movement methods:

- Dragging
- Jumping (lifting from one place to another)
- Hovering (jumping but remaining right over the screen)

In addition to this, other ways to interact with the miniatures were investigated, for instance:

- Tapping
- Rotating
- Grabbing it in different places
- Holding for different durations

Figure 1. Three-quarter view of the first BattleTab sketch. A miniature is placed on an iPad that displays an image of a battle map including tokens representing other players.

4.1. Conceptual Prototype

The final conceptual prototype is a video prototype. It was created using the video prototyping software ”VideoClipper” [6] and combining interaction patterns provided by the role-playing web page Roll20.net [4] and the presentation software Keynote by Apple [7]. In addition, the negative side of batteries was used to mimic human touch on the tablet screen. Flat batteries were attached to the underside of common plastic figurines used in board games, and aluminium foil was used to conduct electricity to the underside of the miniature.

Functionalities. As soon as the movements were decided, Roll20 and Keynote were used to form a baseline for enabling the aforementioned functionalities. The most essential functionalities needed were:

1) Movement of character and their corresponding tokens
2) Movement of the map

In addition to these two main ones, also the knowledge of which direction the token/miniature is facing and the possibility of gaining extra information about the miniatures were considered important and to be implemented.

In the video prototype making, the process was inhibited due to the functionalities of Roll20 and Keynote and this resulted in this mapping of functionality to interaction method:

1) By dragging the miniature on the board, both the miniature and the placeholder token move.
2) By dragging the token/miniature to the edge of the tablet, the map will move to the side, showing more of the map itself
3) If the base of the miniature is held, the map is repositioned, centred on the miniature position.
4) To see more of the map it is possible to zoom, using two fingers to pinch and enlarge; when released, the view automatically snaps back to the original size
5) Turning the miniatures makes the tokens also turn
6) It is possible to tap the head of a miniature for getting more information

4.2. Software prototype

Functionalities. For the baseline of the software prototype, the functionalities defined during the making of conceptual prototype were considered as basis. Due to time and knowledge constraints, not all the functionality were possible to be mapped to the intended interaction method. Regardless, all the functionalities needed for the software to function as intended were eventually implemented.

Implementation. The general infrastructure to run collaborative game sessions, and to process and handle interactions, was mainly set up using JavaScript. After testing native solutions such as Swift and Flutter, a web-based approach was chosen, because of its cross-platform capabilities and low hardware requirements. This decision benefited the later distributed user testing conducted to a great extent.

The setup of separate rooms for simultaneous and independent games as well the main synchronisation of the overall game state (i.e. currently active tokens, token identifier, token display name, token position, token type, and character hit points) were handled using the *Socket.io* client and server libraries that offer a robust and easy-to-use application programming interface (API) for the implementation of web sockets. Because Socket.io treats rooms (i.e. where collaborative game session are held), as sockets and automatically closes sockets without clients, a document-based database in Google's Cloud Firestore was used to offer players a persistent game state. This meant that even an accidental timeout, an automatic disconnect, or a voluntary closing of the currently active game did not lead to an erased game state. Instead, players could refresh or even re-enter earlier created games. This greatly increased overall reliability and usability. In the end, a Node.js and Express based web server hosted on Heroku was connected to a Cloud Firestore database and served static web pages as well as a progressive web app (PWA) to its clients to create, enter, and play games. The interactions were recognised and handled using the Hammer.js library for touch events. Since the figurines effectively imitate touch inputs, multiple single- and multi-touch events were created to handle tapping, panning, and rotation. These event recognisers and handlers were attached to the corresponding HTML elements (i.e. tokens and map) and served to clients with the static web pages.

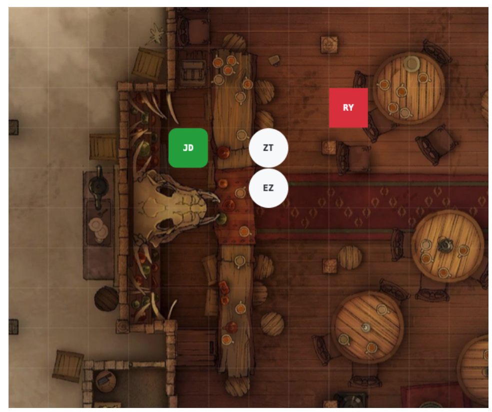

Figure 2. Users can add, move, and rotate tokens represented by HTML elements on an image of a battle map.

4.3. Hardware prototype

The hardware part of the prototype's had multiple stages. For the first iteration, as already stated above in section 4.1, AA batteries and then slim batteries attached to the underside of plastic miniatures with aluminium foil to extend the conductive area were utilised. For the second iteration, after having brainstormed several ideas, the most prominent one was having miniatures that themselves were conductive and would be used directly on the screen. Although this would be the ideal scenario, it is usual that many players already have miniatures, usually made of plastic, and it would be unsustainable both from an environmental and economical standpoint to replace them with conductive minis. A point of merging was eventually reached, with the idea of using conductive bases that a player could place his/her miniature in. Exploration sessions were henceforth carried out, with the scope o both enhancing the knowledge about materials in general and finding a suitable one for the project's sake. During the sessions, different types of conductive material were analysed for the final hardware prototype. In the end conductive carbon paper for the direct contact with the screen and copper strips to extend the conductive area further were used. After several sketches, then, in the end it was reached a final design idea, consisting of a base with two conductive points underneath, where one of the points was static and always touching the screen and the other would come in contact if a player pressed down on the miniature (see figure 3). The reason for setting two touch points is to be able to register when the miniature is rotating. Unfortunately, during the conceptual prototyping phase, it was found out how the presence of two conductive points on the same mini would lead to a series of errors and bugs; one possible solution to this issue could be to make it possible to switch on one of the two touch points when a player wanted to rotate the token. In addition, another solution could have been having the two conductive points always touching the screen, and then, depending on how one would hold the mini, one or two of them would be activated.

In the end, the following key features for the bases were defined:

1) The material in contact with the screen should not make marks
2) The conductive points must have approximately the area of a touch point created by a finger
3) The bases need two conductive points (to make rotation of tokens possible)
4) The bases must accommodate for different sized miniatures

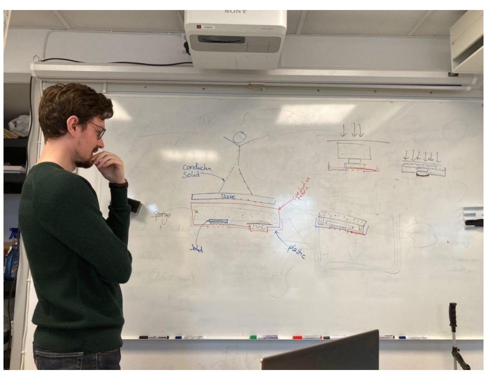

Figure 3. To enable both robust and reliant single-touch-point as well as two-touch-point interaction when needed (e.g. to detect rotation), several material combinations and designs were sketched.

Implementation. For the final hardware showcase, three different designs were printed:

1) A more robust single-touch-point base
2) An experimental two-touch-point base
3) An explanatory wing-and-base design that visualised how, in an ideal scenario, the conductive wing and non-conductive base could be separately printed and assembled by users themselves

All prints used transparent and colourless Nylon, one or two (depending on the design) LR44 batteries, black conductive carbon paper where the batteries would touch the screen, and adhesive conductive strips alongside the top of the base and along the wing. The transparent, colourless Nylon was chosen because of its improved flexibility in comparison to PLA which was prone to breaking along the thin wing.

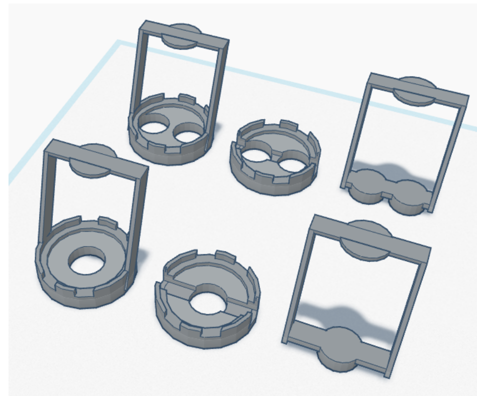

Figure 4. One- and two-touch-point bases were created as well as a visualisation of a design where the non-conductive base and conductive wing are separately printed and later assembled by the user.

After some experiments with different affordances for touching and holding the base, the wing design was slightly angled to give the figurine more space and the design a clearer sense of direction (see Figure 5).

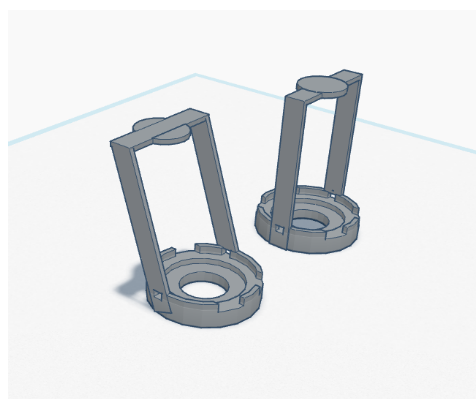

Figure 5. After testing with the originally straight ”archway” design that obstructed the view on the miniature and heavily limited the miniature size, a more angled ”wing” design was chosen.

An added positive effect of the chosen design was that visual properties of the material led to a very easy to understand design that also highlighted the miniature instead of drawing attention to the base itself. The carbon paper was chosen and attached to the underside of the batteries to avoid the hard metal scratching the touch screens. The small batteries were chosen because their sizes closely matched the area of a touch point created by a finger pressing on a touch screen and because of their conductivity. Other metal or generally conductive material could have been used as well. The adhesive conductive strips were used to connect the batteries and thereby the underside of the base to the inherently non-conductive wing. If the wing itself could have been printed out of conductive material, this would not have been necessary.

5. User Testing

5.1. Autobiographical Test

The quickest way to test the prototype was to use the authors themselves as the test subjects. To mimic the experience of playing together but remotely, they sat in different rooms while playing on their own tablet with each having their separate sets of figurines and dices. One of the team members played as game master and had prepared character forms for each player and a story with a quest.

Figure 6. The first test, where three team members tested the experience of playing the game remotely. One is playing on an iPad (centre), another is playing on a phone (right), and the third (in the room to the left), being the game master, is using a computer.

In this first user test, the purposes were to examine the feeling of the physical interaction with the figurines on the tablets. A picture of this can be seen in Figure 2. In a second autobiographical test, the focus was instead on assessing the social experience of playing the game in three different scenarios: playing completely remotely (Figure 6), having all players in the same room and sharing the devices (Figure 8), and finally a mixed setting (Figure 9). In contrast to the first user test, the players were completely separated into different physical spaces when testing the remote experience. All communication was done through the video communication platform Zoom. Each player had their own touch screen, conductive base, figurine, dice, and computer.

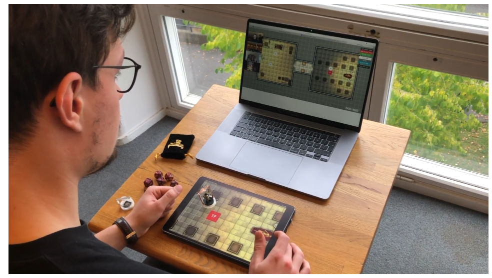

Figure 7. Here, the team is testing the experience of playing completely remotely. Each player is playing in their own separate physical space.

In the user test where all players were in the same space together, the ambition was to experiment with how the physicality of the tablets could be used creatively to enhance the gaming experience.

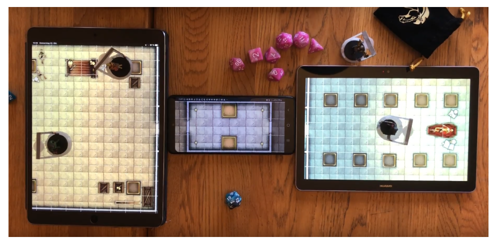

Figure 8. The figure shows how several touch-screen devices can be used to creatively build maps that suit the game-play. In this example, the game master revealed the separate rooms by adding new devices when suitable considering the narrative of the game. In this scenario, the game master and the players must be in the same physical space in order to experience the full effect of the multiple devices.

The third scenario tested was a mixed setting where some players were in the same room while another player joined the game completely remotely. A picture from this session can be found in Figure 5.

5.2. Usability Test and Focus Group Discussion

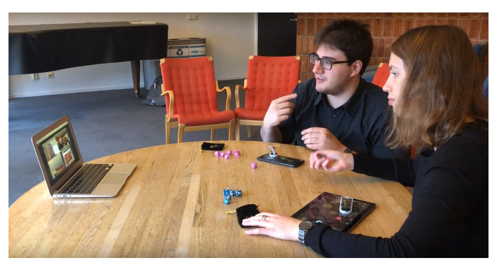

Figure 9. Here, the team is testing a mixed setting with one person playing remotely while the rest is playing in the same physical space. All communication is done through Zoom.

The purpose of this usability test was to study the player's interaction with the game software, conductive bases, and figurines, but also to compare the user experience of a digital hybrid with the traditional, physical version of a Dungeon and Dragons game. To achieve this, a non-intrusive, observational study method was chosen, where the participants, with little preparation or introduction to the system, were first to remotely play a small Dungeons and Dragons-style campaign on the system, and then discuss their experience in a semi-structured focus group.

The participants of the usability study were deliberately selected to include people with previous experience of Dungeons and Dragons (or similar games) and complete novices, to diversify the feedback. Three people were recruited from a circle of friends and family to participate in a usability test, implying that the test group was not randomly selected.

The main segment of the usability test consisted of an observational study of the interaction and behaviour of the participants when playing a shorter version of a Dungeons and Dragons combat. The test subjects used their own touch screens and computers (in order to communicate with the other players via Zoom, read their character sheets, and see an overview of the game map). All players except one was provided with one conductive base where they could place their figurines. The players either used their own sets of physical dice or digital dice. The game was moderated by one of the project group members, acting as Game Master. Each participant was accompanied by a project member, who being in the same physical space could observe the user behaviour and record it through through note taking.

When the campaign was completed, the test included a focus group discussion where each participant could discuss their experience of playing the game. The discussion was facilitated by the test leader asking questions that were related to the interaction experience and the comparison between this digital hybrid system and traditional board games.

Figure 10. A picture of one test subject during the usability test, which was conducted in their own home. On the computer to the left, the subject can interact with the other players and the Game Master, see an overview of the game map, read their character sheet, and make use of digital dice. The conductive base which was provided to the test subject can be seen on the tablet, upon which there is a non-conductive figurine. The tablet is showing the game map and the tokens of the other players.

6. Results

6.1. Autobiographical Test

In the first test, where the focus was on the physical interaction with the figurines and the tablet, it was noticeable to find out that adding a small physical component to the interaction altered the user experience to such a large an extent. If there had been no figurine to move, it would not have felt as the users were playing a board game but instead a regular computer/tablet game. This was a positive and encouraging realisation.

There were, however, many issues relating to the usability of the physical components – the connection to the tablet was often unstable, resulting in mismatches between the position of the figurine and the token and the bases were large and clunky, taking away focus from the figurines' appearance. While the game technically worked on a smaller screen, such as an smartphone, the screens needed to be of a certain size (preferably a large tablet) for the figurines to be an appreciated, experience-enhancing component of the game instead of a nuisance that mostly only blocked the view.

The software had several bugs that interfered with the game-play: sometimes tokens disappeared, duplicated, or moved to the wrong places. There could also be some lag time, sometimes forcing the players to refresh, before everyone's positions were updated on the map.

In the second wave of testing, three different scenarios were tested. In the first scenario, where all players were playing remotely, the experience was somehow streamlined compared to the first autobiographical test, as the software had been improved upon and therefore had less bugs, but otherwise provided little new information.

The biggest realisations came from the second scenario, where all players were in the same room and played together with the same set of touch screens and figurines, which made them enjoyable touch screen's possibilities. Previously, the fixed size and format of the touch screens had been a limiting factor, but then it was realised that this inherent weakness of the design could be turned into a strength. By using several digital devices at once, players can get creative and show different parts of maps or different maps altogether on the different devices. One example of this, which can be seen in Figure 8 in the previous section, was when the game master revealed different rooms of the dungeon as the players progressed in the narrative. This added to the storytelling component and enhanced the user experience.

6.2. Usability Test

The results from the usability test performed on the three test subjects provided new information, both from observing player behaviour during the game but also from the subsequent group discussion. In general, the feedback was positive and the participants enjoyed the experience. However, the usability test brought to light several weaknesses in the design and aspects that could be improved upon.

One key observation that was made was that there exists a strong mental connection between the physical figurine's placement on the tablet and the corresponding token. The players showed unease when the position of the figurine was out of sync with the position of the token to a such degree that some participants were reluctant to move the map or zoom at all. It was also common to remove the figurine from the tablet before zooming or panning and then place the figurine on its new correct position afterwards.

During the game, players struggled to understand the bases and to use them correctly. Most failed to move with precision, causing a mismatch between the figurine on the tablet and its representative digital token. The tapping functionality left much to be desired: often number field representing character health, that is supposed to appear when tapping on the token, would appear unintentionally. Because the tapping function was insufficiently implemented in the bases, there was also difficulty in hiding the health information when it had appeared. This caused visible annoyance and disturbed the game play.

In the following group discussion, all participants verbally confirmed that the bases were inadequate and not intuitive. One participant commented that it took almost the length of the whole game for them to realize and understand how to best interact with the base: holding it too far down caused errors since the user accidentally touched the screens with their fingers, but holding it too high up, on the sides, felt strange and resulted in poor connection between the conductive material underneath the base and the touch screen. In the end, the best way to hold the base was pressing it down directly on the top.

Perhaps the most worrying feedback was that one user felt that the physical elements in BattleTab were not enough to replicate ”the real experience.” They were of the opinion that one figurine simply was not enough – they missed seeing other players' characters and felt that the tokens that represented them were too static and did not adequately express personality or expression.

7. Discussion

7.1. General outcomes

As it appeared from the user testing, the ”physical” component offered an attractive experience, but was lacking in some regards. This may be due to usability issues when using the miniatures. As stated above, the figurines' supports showed some issues which prevented the users to quickly get to use them properly. The setup did, however, help beginners to get to know the game: Since players do not need to gather in the same place, the barriers to entry are lowered.

7.2. Learning outcomes

Three major learning outcomes of this project are to be highlighted, in regards to:

1) Material knowledge
2) Design process
3) Physical interaction and sense of presence

Firstly, one of the main learning outcomes is related to the materials used in the experiment. Multiple different setups and combinations of materials to develop a suitable solution were experimented, that had both the required properties to enable this software-based interaction handling and obstructed as little of the original playing experience as possible. Eventually, the conclusion that a small, flat cylindrical battery covered in conductive fabric and inserted into a 3D-printed support combined with thin copper strips along the miniature's support could achieve both goals in an acceptable manner. It could transmit an electrical signal from a finger pressing on the wing of the base to the touch point at the bottom and allowed users to use and play with their existing miniatures. As an added side effect, the design ”forced” the authors' to learn how to use a 3D printer, which consequently allowed them to obtain physical representations of an idea in a very short time and simultaneously improved the authors' knowledge of different materials' properties. One of the more surprising outcomes of this material exploration was that the design could function even without the need for an external power supply, which pushed the research towards a stronger focus on the sustainability aspects of this project.

Secondly, as for some of the group members this was the first time working with physical components in human-computer interaction, a valuable lesson about the difference between software and hardware development in regards to the required time and effort for initial designs and subsequent updates was received. Even if the overall time needed to create the final hardware component was relatively short, it was still quite longer than the time needed for developing the web- or software-based components of the prototype. This is because of the amount of time required to experiment with different materials in order to achieve the desired effects. This side of the design process clearly requires more time than solely using a computer and coding.

Lastly, one of if not the most important takeaway learnt from the project was that even a slight change in the setup or physical interaction design can lead to huge changes in the perception of the whole phenomenon. As stated above, even though the physical interaction was closely modelled after playing with miniatures on a physical game board in a traditional setup, it was distinctly noticeable how changing the supporting device and ways of interaction created many differences in the emotions that users experienced.

Overall, the project improved the authors' understanding of how physical interaction can be designed in regards to material properties, prototyping techniques, and aspects of physical and remote presence.

7.3. Future Development

There are many aspects that could be improved in order to deliver a better user experience. Since BattleTab is intended for playing games, a type of entertainment, a key question is what makes BattleTab funny. The design improvements should focus on enhancing the fun elements of BattleTab and remove, or at least diminish, any disturbing or distracting components.

A strength of having a digital component is that it allows the inclusion of additional sensory stimuli. It would be, for example, possible to add sound effects or vibration from the tablet. Furthermore, in traditional board games, the players are usually limited to the fixed visual aspects of the board and any figurines or other physical components (e.g. cards, dice), while a digital map would support advanced animation and changes to the look of the map/tokens in between games as well as in real time. Dungeons could, for example, react to figures movement or position and activate traps or open doors. This heavily relates to the expressive player representations and active games (i.e. the game itself can be viewed as an actor) proposed by Krzywinski et al. [1], reviewed for the background section. Augmented reality could also be incorporated to further enhance the sense of presence in a remote or mixed setting. An example of this would be to have the other player's figurines be represented in augmented reality on their corresponding token on screen. These improvements could enhance the experience of the game, making it more fun to play, and, in addition, provide a competitive advantage over traditional board games.

The other obvious improvement area besides the game board are the physical bases. In the usability tests they were identified as distracting from and inhibiting a fully immersive user experience. They were too large, unpractical, and did not function reliably. The bases would be perceived as less of a nuisance if they were, for example, made smaller and more stable in their conductive connection to the tablet. There are also possibilities to add functionality to the bases by adding different touch-points that would register as different interactions by the touch screen. This could, for example be used, to activate different effects on screen depending on how the base was held. It would also be possible to omit the bases completely, but that would require the figurines themselves to be conductive.

Even though *Dungeons and Dragons* was used as the case study for this project, it is possible to adapt the core ideas and technology of BattleTab to play other games. A game with a small, static map, such as chess, would avoid the the figurine/game piece and its digital token getting out of sync. In general, the developed principles could be used for any token- and preferably turn-based board game without shared game pieces where pieces can not occupy the same field on a static flat board.

8. Further Reading

A video presentation of the final design can be found at the following link: https://www.youtube.com/watch?v=n8Kbui3IJoE

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