THE EFFECTS OF DIGITIZATION AND AUTOMATION ON
BOARD GAMES FOR DIGITAL TABLETOPS

by

Joseph A. Pape

A thesis submitted to the Department of Computing
In conformity with the requirements for
the degree of Master of Science

Queen’s University
Kingston, Ontario, Canada
(January, 2012)

Copyright © Joseph A. Pape, 2012
Abstract

Digital tabletop computers are an ideal platform for games with the social advantages of traditional tabletop games, such as board games and card games, combined with the more streamlined and automated gameplay of video games. Implementing a board game digitally allows for aspects of the game, such as routine in-game activities, rule enforcement and game progression, to be automated. However, the effect of this automation on the players’ social experience and enjoyment is poorly understood. To explore this question, a mixed-method study was carried out in which 24 groups of participants played either the abstract strategy board game Checkers or the cooperative board game Pandemic using three different interfaces: the original physical game; a digital tabletop interface which provided minimal automation in an attempt to replicate play of the original game; and a digital tabletop interface which automated many in-game activities, enforced the rules and managed the progression of the game. The study revealed that while automation does have the potential to reduce the overhead to play the game, it can lead to player frustration in several ways. Automating routine in-game activities and game progression can lead to severe awareness deficits. Automation of rule enforcement and management of the game state can streamline gameplay, but can lead to scenarios where players would prefer more control over the game. The negative space around the active game area is important to consider for storage of digital artifacts and physical objects above the table. Finally the digitization and automation of the games did not reduce social interaction, making digital tabletops a promising platform for social games.
Co-Authorship

J. Pape, J. R. Wallace, Y. Chang, P. J. McClelland, T. C. N. Graham, S. D. Scott, M. Hancock,
"A Study of Automation in Digital Tabletop Board Games,"

Not yet submitted

- The background, presented in Chapter 1, and sections 2.4 through 2.6, draws from the
  background presented in the listed paper.

- The listed paper presented areas of the user study, which we will discuss further,
  pertaining to the Pandemic board game. Section 3.2, Chapter 5, sections 7.1 through 7.4,
  sections 8.1 through 8.4, and Chapter 9 all draw from the listed paper.

J. R. Wallace, J. Pape, Y. Chang, P. J. McClelland, T. C. N. Graham, S. D. Scott, M. Hancock,

- This short paper presents a summary of some of the key findings from the previously
  listed paper.

J. Pape, T. C. N. Graham, "Coordination Policies for Tabletop Gaming," in Proceedings of

- This short paper presents the early versions of the Checkers and Pandemic software
  presented in this thesis. The paper proposed a different research direction, in which the
  turn-based gameplay of board games is relaxed, in favor of real-time gameplay for the
  digital tabletop platform.
Acknowledgements

This research is funded by the NSERC SurfNet Strategic Network. I would like to thank my supervisor, Nick Graham, and my co-researchers at the University of Waterloo; Jim Wallace, Phil McClelland, Betty Chang, Mark Hancock and Stacey Scott. I would also like to thank Chris Cooper for his help in coding gameplay videos, and Dr. Neil Randall and the University of Waterloo Games Institute for their assistance in preparing the experimental software. I would also like to thank Matt Leacock and Z-Man Games for permission to use Mr. Leacock’s excellent Pandemic board game as the subject of this research, and Todor Doychev of www.doychev-design.com for permission to use his Pandemic board graphic. Finally, I would like to thank everyone who proofread for me: my Dad, Paul Pape; my colleagues Cheryl Savery and Tad Stach; and my board gaming buddies Ryan d’Eon, Calvin Chan and Adam Baig.
# Table of Contents

Abstract ........................................................................................................................................... ii  
Co-Authorship ................................................................................................................................. iii  
Acknowledgements ............................................................................................................................ iv  
Chapter 1 Introduction ....................................................................................................................... 1  
Chapter 2 Board Games on Digital Tabletops ................................................................................... 7  
   2.1 Board Games ............................................................................................................................ 7  
      2.1.1 Sociality ............................................................................................................................. 8  
   2.2 Digital Tabletops ....................................................................................................................... 10  
      2.2.1 Digital Tabletop Technologies .......................................................................................... 11  
         2.2.1.1 Optical Technologies ................................................................................................. 12  
         2.2.1.2 Electrical Technologies ............................................................................................. 14  
         2.2.1.3 IR Frame ...................................................................................................................... 15  
         2.2.1.4 Anoto .......................................................................................................................... 15  
   2.3 Digital Tabletop Interaction Techniques .................................................................................... 18  
      2.3.1 Press, Release and Drag ..................................................................................................... 18  
      2.3.2 Menus ............................................................................................................................... 18  
         2.3.2.1 Pie Menus ...................................................................................................................... 19  
         2.3.2.2 Stacked Half-Pie Menus ............................................................................................. 20  
      2.3.3 Gestures ............................................................................................................................. 21  
      2.3.4 Speech Input ....................................................................................................................... 21  
      2.3.5 Physical Objects ................................................................................................................ 21  
      2.3.6 Multiple Devices ............................................................................................................... 22  
   2.4 Digital Tabletops and Board Game Design ............................................................................. 23  
   2.5 Survey of Tabletop Games ....................................................................................................... 24  
      2.5.1 Commercial Games .......................................................................................................... 25  
      2.5.2 Weathergods .................................................................................................................... 25  
      2.5.3 False Prophets .................................................................................................................. 26  
      2.5.4 Dungeons and Dragons for Microsoft Surface ............................................................... 27  
      2.5.5 Real-Time Chess .............................................................................................................. 27  
      2.5.6 SIDES ............................................................................................................................... 28
Chapter 6 Results from Checkers Trials

6.1 Effort and Enjoyment

6.2 Acting as an Impartial Referee

6.3 Performing Complex or Routine In-Game Activities

6.4 Providing Improved Visualizations through Digital Media

6.5 Technology

6.6 Sociality

6.7 Conclusion

Chapter 7 Results from Pandemic Trials

7.1 Performing Complex or Routine In-Game Activities

7.1.1 Game Length and Number of Pen Interactions

7.1.2 Effort and Enjoyment

7.1.3 Players’ Contributions to the Game

7.1.4 Automated Infection Events and Player Awareness

7.1.5 Trust in the Digital Implementation

7.2 Acting as an Impartial Referee

7.2.1 Reducing the Overhead of Rule Enforcement

7.2.2 Incorrect Implementation of Rules

7.3 Automating Game Progression

7.3.1 Narration of Game Turn

7.3.2 Undo Functionality

7.3.3 Turn Order and Game Setup

7.4 Providing Improved Visualizations through Digital Media

7.4.1 Conveying Game Information Through Visualizations

7.4.2 Display Size and Use of Space

7.5 Representing Physical Objects Digitally

7.5.1 Emulating the Physical Board Game

7.5.2 Providing the Benefits of Digitization

7.6 Sociality

7.6.1 Maintaining Sociality of the Physical Game

7.6.2 Equity of Participation

7.7 Conclusion
## List of Figures

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1.1:</td>
<td>Gameplay of Blue Moon the card game [41]</td>
<td>1</td>
</tr>
<tr>
<td>Figure 1.2:</td>
<td>Digital Tabletop (Microsoft Surface) [58]</td>
<td>2</td>
</tr>
<tr>
<td>Figure 1.3:</td>
<td>Digital tabletop version of Checkers</td>
<td>5</td>
</tr>
<tr>
<td>Figure 2.1:</td>
<td>Frustrated Total Internal Reflection (FTIR)</td>
<td>13</td>
</tr>
<tr>
<td>Figure 2.2:</td>
<td>Diffuse Illumination (DI)</td>
<td>14</td>
</tr>
<tr>
<td>Figure 2.3:</td>
<td>Anoto Pen</td>
<td>16</td>
</tr>
<tr>
<td>Figure 2.4:</td>
<td>Schematic Diagram of an Anoto Digital Tabletop</td>
<td>17</td>
</tr>
<tr>
<td>Figure 2.5:</td>
<td>Pie Menu [29]</td>
<td>19</td>
</tr>
<tr>
<td>Figure 2.6:</td>
<td>Stacked Half Pie Menu [28]</td>
<td>20</td>
</tr>
<tr>
<td>Figure 2.7:</td>
<td>Physical objects being detected on a Microsoft Surface [56]</td>
<td>22</td>
</tr>
<tr>
<td>Figure 2.8:</td>
<td>Weathergods Gameplay [3]</td>
<td>26</td>
</tr>
<tr>
<td>Figure 2.9:</td>
<td>The Sims Multimodal Gesture [65]</td>
<td>29</td>
</tr>
<tr>
<td>Figure 3.1:</td>
<td>The original Checkers board game</td>
<td>35</td>
</tr>
<tr>
<td>Figure 3.2:</td>
<td>A screenshot of the digital tabletop interface for Checkers.</td>
<td>37</td>
</tr>
<tr>
<td>Figure 3.3:</td>
<td>The original Pandemic board game.</td>
<td>38</td>
</tr>
<tr>
<td>Figure 3.4:</td>
<td>An Infection Event.</td>
<td>40</td>
</tr>
<tr>
<td>Figure 3.5:</td>
<td>A screenshot of the digital tabletop interface for Pandemic.</td>
<td>41</td>
</tr>
<tr>
<td>Figure 3.6:</td>
<td>Action Pointer</td>
<td>44</td>
</tr>
</tbody>
</table>
Figure 3.7: Action pointer in use. The green action pointer (A) is being used to perform a long move from the green player’s location (B) to a location on the other side of the map (the in-game indication of the player’s path has been highlighted for clarity). Note that this move would have to be performed in a single drag using the press/drag/release gesture for moving. The action pointer widget can instead be moved in a number of drags, and even passed to another player to help complete the action.

Figure 3.8: Hand Widget.

Figure 3.9: Visual indication of a rule infraction. The orange player is attempting to move their piece, though it is the white player’s turn. The ‘X’ indicates that this is an illegal move (Some features of the image have been recolored for clarity).

Figure 3.10: Examples of in-game animations (1-2) Step 1 and 2 of Epidemic animation in Beijing. (3) Infection animation in Kolkata. (4) Initial state in Kolkata. (5-6) Step 1 and 2 of Outbreak animation in Kolkata.

Figure 4.1: Reference architecture for digital tabletop versions of board games.

Figure 5.1: Summary of the three game versions of Checkers and Pandemic included in the study.

Figure 5.2: A screenshot of the Low-Automation interface for Checkers. Note that there are no indications as to whose turn it is or if a jump is required. Also note that free floating pieces are offset from the centers of squares on the board, and that captured pieces are stored outside of the active playing area.

Figure 5.3: A screenshot of the Low-automation Pandemic interface. This version closely resembles the physical board game, but is played using pens on a digital tabletop surface. Differences between the Physical interface and this interface include: A) On-board storage areas for unused disease cubes. B) Automation of deck interactions, including drawing cards from the top/bottom of the deck and shuffling.

Figure 5.4: Interface elements for handling card interactions specific to Pandemic. These include A) drawing a card from the top of the deck B) drawing a card from the bottom of the deck and C) shuffling the discard pile and placing the shuffled pile back on top of the deck.

Figure 5.5: Participants playing the high-automation interface of Pandemic.

Figure 7.1: When playing with the physical interface, participants frequently used the space surrounding the game board to store unused game pieces. This was not possible in the digital versions.
Chapter 1

Introduction

Playing multiplayer games is a collaborative activity with the shared objective of having fun [45]. Traditional tabletop games (see Figure 1.11), such as board games and card games, are a social activity. Players gather around a table and create a shared, engaging and entertaining experience in a social setting. Players can look each other in the eyes and see how the other players are interacting through their physical interactions with the game. In contrast, when playing multiplayer video games on a TV or across a network, players communicate their actions through their digital representations on a screen, and therefore have less person-to-person contact.

Figure 1.1: Gameplay of Blue Moon the card game [42]

1 Copyright permission received from Minotaur Games & Gifts
CHAPTER 1: INTRODUCTION

Board games and multiplayer video games offer other gameplay benefits over single player games. There is a significant body of research which indicates that it is preferable to play against a human opponent vs. a computer artificial intelligence (AI). Players have greater psychological arousal and enjoyment when playing games against a human than an AI opponent [38]. In a study of the social aspects of the Nintendo DS, players reported that they preferred playing against humans to playing against an AI [60]. In a study of gaming practices on the Nintendo Wii, players claimed that social interaction was their favourite aspect of playing co-located console games [67].

Figure 1.2: Digital Tabletop (Microsoft Surface) [58]

Digital tabletops (see Figure 1.2) permit a game setting with the social advantages of board games, combined with the streamlined and automated gameplay and the dynamic visuals

2 Copyright permission received from J. David Smith
CHAPTER 1: INTRODUCTION

and interactions of video games. A digital tabletop is a computer with a large screen built into the surface of a table. In many cases, input is provided to digital tabletops through touch, or through the use of digital pens. Digital surfaces have achieved mainstream attention with the popularity of smartphones such as the iPhone, and tablet computers such as the iPad. However, these devices are primarily meant for individual use.

Recent implementations of traditional tabletop games for large digital surfaces, such as SmallWorld for the iPad and The Settlers of Catan for the Microsoft Surface, show that digital surfaces are promising platforms for digital versions of board games. Digital board game implementations tend to automate many of the activities involved in board games, such as placement of game objects and rule enforcement; however, it is unclear what effect the automation of these activities has on the enjoyment and sociality of the players (i.e. the tendency for the players to engage in social interaction). Can a board game which is implemented on a digital surface, with many of its gameplay aspects automated, maintain the same appeal as the original game?

Several groups have looked at the trade-off between group awareness and automation of group activities [23, 44, 67, 22] and the design of digital interfaces for activities which are traditionally done with pen and paper [52]. This research has been oriented towards how to maximize the task performance of a group in a business setting. While it is important for game designers to consider these trade-offs, efficiency of a task is less of a priority in the context of gaming than are fun and enjoyment. Therefore, it is unclear how well this work transfers to game design. Does improved performance from the automation of routine activities, such as shuffling cards and setting up the game board, improve the game experience or detract from it? How does the automated enforcement of rules affect the sociality of the original game? In general, we are
interested in whether or not digitization and automation of traditional tabletop games can enhance the game experience.

This is an interesting area of research to explore because digital table tops are a promising platform for replicating social experience of playing a board game. The face-to-face settings of both board games and digital tabletops are often cited as contributing to their social nature, when compared to networked or collocated video games. However, the effects on sociality and gameplay, which may arise from the inherent differences between playing a board game and playing on a digital tabletop, have not been explored. Digital tabletop gaming is a relatively new area for research and industry. While games are being developed on a large scale for more popular smaller devices such as the iPad and iPhone, developers have not had the same chance to perfect interfaces for games on digital tabletops. We hope to provide some insight into the design of interfaces for digital tabletop versions of board games.

To explore this area, we ran an exploratory mixed-methods user study in which players played three different interfaces of either the abstract strategy game Checkers (see Figure 1.3) or the cooperative game Pandemic. The first interface was the original physical game. The second interface, which we call the ‘high-automation interface’, automated many activities within the game, enforced the rules, and provided the players with enhanced visualizations such as counters and animations. The third interface, which we call the ‘low-automation interface’, provided minimal automation in an attempt to replicate play of the original board game, through the use of free-floating digital artifacts to represent the original physical game objects. In the low-automation interface players must enforce the rules and manage the progression of the game themselves.
The study was conceived by myself as the subject for this Thesis. The experimental software was designed and implemented by myself. The study, including questionnaires and video code sets, was designed in conjunction with our co-researchers at the University of Waterloo. The study was carried out at both locations, with half of the participants being run at each location. A statistical analysis of the questionnaire and video data was carried out primarily by myself, with help from one of our co-researchers in Waterloo. Implications of the results were extracted in conjunction with our co-researchers in Waterloo.

The study revealed that introducing automation within a gaming context can have positive and negative effects on the game experience, and should be used with discretion. Automation of routine game activities, rule enforcement and game progression reduced the
overhead for participants to play the game. However, these automations resulted in other frustrations such as severe deficits in situational awareness and a desire for less constrained manipulation of the objects within the game. Despite these frustrations, players noted automated features which were sorely missed from the low-automation interface. These included snapping to location to streamline organization of game objects, and the ability to move more than one object at a time (a trivially easy interaction when using physical game pieces). We also found that the digitization and automation of Pandemic and Checkers did not have a negative impact on the sociality of the original games, making digital tabletops a promising platform for social gaming. The study also revealed that the negative space around the active game area is important to consider for the storage of game objects. Finally, we found that players tended to prefer the high-automation interface to the low-automation interface in Checkers as opposed to vice versa in Pandemic. We attribute this difference in preference to some of the key differences between the two games, such as complexity and number of players. We discuss these results in detail, and suggest guidelines for the design of digital tabletop interfaces for board games.

To set the context for this research, we first look at board games for digital tabletop games, including brief histories of both board games and digital tabletops: we discuss the potential benefits of digitization of board games, and we survey digital tabletop hardware technologies, digital tabletop interaction techniques and games implemented for digital tabletops.
Chapter 2

Board Games on Digital Tabletops

Playing traditional tabletop games, such as board games and card games, is a popular social activity in which a group of friends get together in a collocated face-to-face setting to share an enjoyable experience. Digital tabletop computers (computers with a large horizontal screen built into a table) are an ideal platform for digital implementations of board games, due to the similar setup of players seated around a table. However, the design of digital interfaces for such games is a relatively new domain. This chapter reviews board games implemented for digital tabletop computers.

The discussion begins with a brief explanation and history of board games, including a review of the social aspects of board games. This is followed by a discussion of the history of digital tabletops, including the different technologies and interaction techniques currently available. The chapter concludes with a survey of games implemented for digital tabletops, particularly focusing on examples with board game-like gameplay. We extract from this survey a list of potential benefits of digitizing board games.

2.1 Board Games

Games played on a horizontal surface have existed for thousands of years. The earliest known board game, the ancient Egyptian game Senet, dates to 3100 B.C [50]. The abstract strategy game Go dates as far back as 2300 B.C. [2], and maintains its popularity today. The original version of the popular board game Monopoly sells several million copies a year [16].
CHAPTER 2: BOARD GAMES ON DIGITAL TABLETOPS

while games in the more recently popular Settlers of Catan series have sold over 15 million copies [12].

Electronically augmented board games have existed since the late 1970’s. An example is the game Stop Thief, in which players attempt to catch a hidden thief, while an electronic phone gives players clues as to where the thief is. The first example of digital tabletop games appeared in the early 1980’s with cocktail arcade games. These games consisted of a horizontal arcade cabinet which displays the game on the surface of a table [62]. Players sit on either end of the table and control the game using standard controls, such as joysticks and buttons, positioned directly in front of the players.

2.1.1 Sociality

Board games are a social activity. More specifically, board games are characterized by the companionship of interacting with others. Players get together, and gather around a table to play together. Video games played on a desktop computer or television can be social, but lack the direct face-to-face human contact of board games and, therefore, much of the social benefit of board games. One of our main motivations was to look at how games implemented for a digital tabletop can maintain the sociality of traditional tabletop games, when compared to standard video games. However, little research has been done to compare the social elements of board games and video games. The following is a list of factors that contribute to the sociality of board games when compared to video games.

- **Close Proximity.** Gathering in a social setting, in which people get together to collaboratively share an enjoyable experience, is a key element of social interaction. Though it has been shown that online games can be social [71], social interaction is limited to text chat, audio chat, and (rarely in the context of gaming) video chat, or it is
mediated by the actions of the players’ digital avatars. Getting together in a collocated group to play games immediately opens up the possibility for rich social interaction [47].

- **Face-to-Face Interaction.** Of course, not all multiplayer video game settings are distributed. Co-located multiplayer game settings include networked games played on a local area network (or LAN parties), and console gaming, in which multiple players play on a single television screen. However, both of these settings lack the face-to-face interaction of board games. In a board game, the social space and the game space are aligned [47], allowing for easy switching of focus between the game and the other players. Additionally, it is more comfortable to look straight ahead, meaning that it is easier to view the entire screen in video games [33], but that social interaction is enhanced in board games, since players are seated directly in front of each other.

- **Turn-based Gameplay.** Many video games, including first person shooters and fighting games, involve frenetic real-time gameplay. The fast paced nature of these games leaves little time for social interaction. In contrast, most board games and card games involve some form of turn-taking, allowing the players more opportunity to interact socially. Turn-taking can also lead to a significant amount of downtime, while other players are taking their turns. This downtime facilitates social interaction. It is important to have time which is not spent actively participating in the game to socialize with the other players [32].

- **Static Game State.** The computing power behind video games allows for complex and dynamic situations, which are constantly being updated by the computer. It is therefore necessary for players to pay constant attention to the game in order to remain aware of what is taking place in the game world. In contrast, the game state of a board game is
static, changing only in response to players’ actions. A player can observe the state of the
game and be sure that the state will not change without intervention from one of the
players, allowing for more opportunity to interact with the other players [36].

- **Unmediated by Technology.** In video games, players do not directly interact with each
other. Instead, their interaction is mediated by the virtual domain, meaning that players
are mainly aware of the other players through the virtual representations of the other
players on the screen. Players communicate actions to each other using game pads or
keyboards [36]. In board games, players are fully aware of the other players. Players
communicate their actions by physically manipulating the game objects.

In summary, a number of features contribute to the inherent sociality of board games.
These features make communication between players easier, either by providing the necessary
downtime to communicate, or by making the physical arrangement of players conducive to
communicating with each other.

### 2.2 Digital Tabletops

Digital tabletops are an ideal platform for combining the social advantages of board
games and the streamlined gameplay of video games played on a television or desktop computer.
A digital tabletop is a computer for which the input and output occurs on a large horizontal
surface. A table acts as a screen, either through the use of a large monitor or a projection surface.
Users sit around the table and interact using some kind of physical input, such as pen-based
interaction, manipulation of physical objects, or touch (also known as “multitouch” when the
surface supports multiple simultaneous touches). Due to this collocated and face-to-face
interaction, digital tabletops are a promising platform for social gaming.
CHAPTER 2: BOARD GAMES ON DIGITAL TABLETOPS

One of the earliest examples of a multitouch surface was a tablet developed by Bell Labs, which used capacitance to detect touches [6]. Multitouch systems have become more widely available with the recent surge in popularity of smartphones, such as the iPhone [18], and tablet computers, such as the iPad or the Galaxy Tab. Touch games, such as Chillingo’s Cut the Rope and Rovio’s Angry Birds, have shown that multitouch systems can be a successful platform for video games.

2.2.1 Digital Tabletop Technologies

In order for the underlying technology of a digital tabletop to properly support the collaborative experience of playing a board game, there are a number of features which the technology should include:

- Supporting multiple concurrent users is crucial, since many games would be barely playable if only one user could interact with the game at once.
- Multitouch can lead to rich interactions beyond simply pressing, dragging and releasing. For example, users can interact using two-finger or whole-hand gestures.
- User identification can ensure that a player may not interact with another player’s private game area or personal game objects.
- Technology which allows the players to be comfortably seated at the table is important, since games may be played for an extended period of time.
- The detection and identification of physical objects placed on the table opens the possibility for games that include the tactile interaction of traditional board games.
CHAPTER 2: BOARD GAMES ON DIGITAL TABLETOPS

The following section discusses some of the available digital surface technologies, and how they support these criteria for digital tabletop implementations of board games.

2.2.1.1 Optical Technologies

Frustrated total internal reflection (FTIR) [26] and diffuse illumination (DI) [48] are two widely used optical technologies for digital tabletops. In both of these technologies, touches are detected when a camera views bright spots of infrared light where the touches are occurring. FTIR (see Figure 2.1) depends on the light phenomenon known as total internal reflection. When light passing through a medium of higher refractive index (slower light velocity) reaches a medium of lower refractive index (e.g., light passing through water or glass reaching an interface with air), the light is either reflected back into the original medium or refracted (change of direction) in the new medium. If the incident angle (angle between the light and the interface surface between the two media) is below a certain critical value all of the light is reflected, a situation known as total internal reflection. In the case of light passing at a shallow angle through a glass plate sandwiched between air interfaces (or a similar arrangement), all of the light will reflect back at any glass-air interface thereby passing through the length of the plate.

In the case of FTIR, the plate consists of a high density transparent medium such as acrylic. Infrared light sources, which are positioned around the edges, shine light into the acrylic plate. When a touch occurs, the finger creates a seal with the acrylic. Rather than totally internally reflecting at an acrylic-air interface, the light illuminates the finger, scattering down towards the camera. This scattered light is detected as a bright spot on the x-y position of the image, corresponding to the x-y position on the surface of the tabletop. FTIR is used in the SMART table; a commercially available table made by SMART technologies.
In DI (see Figure 2.2), light is shined up through a diffuser layer, which also acts as a projection screen. If the transmitted light reaches a fingertip, some of the light scatters back and reaches the camera below the table as occurs with FITR.

Diffuse illumination offers the advantage of object detection. Fiducial markers can be printed on the bottom of objects, and differentiated by image processing software. Both of these technologies are commonly used in the academic and hobby communities due to their low cost. Both technologies are also capable of multitouch, as the number of bright spots which can be detected by the camera is virtually unlimited. However, many of these tables are sensitive to ambient light [70]. There is also hardware underneath the table, including the camera and, in the
case of DI, infrared illuminators, making it awkward for users to sit at the table. DI is used in the Microsoft Surface; a commercially available table made by Microsoft.

![Diagram of Diffuse Illumination (DI)](image)

**Figure 2.2: Diffuse Illumination (DI)**

2.2.1.2 Electrical Technologies

Some technologies use electronic systems to detect touches. For example the Diamond Touch table [14] emits small electrical currents from the surface. These currents carry a signal that can be used to interpret the x-y coordinates of the surface. The current travels through the user to a receiver that they are sitting on. This allows for easy detection of which user is making which touch. However, this technology is not capable of multitouch, as even two touches create ambiguity in the signal.
CHAPTER 2: BOARD GAMES ON DIGITAL TABLETOPS

Other surfaces use complex electrical systems embedded within the screen to detect touches, such as recently popular tablets which use a capacitive technology. However, due to the high cost of these technologies, it is currently impractical to use this as a digital tabletop technology.

2.2.1.3 IR Frame

Infrared (or IR) frames can be found in tables such as those manufactured by PQ Labs [54] An IR frame is a rectangular frame which can be positioned around the border of any screen. Embedded around all four sides of the frame are IR light emitting diodes (or LEDs) and infrared sensors. When no touches are being made, all sensors receive infrared light from an LED on the other side of the frame. When a touch is made, some of the sensors no longer receive light. From this information, software can detect where touches are being made [49]. This technology has the advantage of having all of its hardware above the table, and being relatively compact. This means that players can comfortably sit with their legs underneath the table. The current iteration of the frame is limited to detecting 32 simultaneous touches. This limit would likely be enough for most gaming situations, but may cause problems in games with many players. Presumably this limit could be increased as the technology is improved.

2.2.1.4 Anoto

Anoto [1] is a pen-based technology, meaning that users interact with the display using a pen rather than touch. The pen is equipped with a tip, which can detect when it is being pressed. A camera is located near the tip. A specialized paper, printed with a fine non-repeating dot pattern, is used as a surface. When a press is made, the camera detects the dot pattern, and can decode the x-y coordinates of the touch.
This technology was originally developed to store writing and drawing in notebooks made with the specialized paper. Everything a user writes is stored in the pen and uploaded to a computer later (see Figure 2.3). However, a recently developed Bluetooth streaming version of the pen can be used in conjunction with a top-down projector and a large sheet of the specialized paper to create a digital tabletop (see Figure 2.4). The pens are equipped with a plastic tip, to avoid writing on the table. When the pen is pressed to the table, the information that would usually be stored and saved in the pen is streamed directly to a computer. The pen interactions are
interpreted by the computer and feedback is given to the user immediately, allowing for pen-based interactions.

Figure 2.4: Schematic Diagram of an Anoto Digital Tabletop

While Anoto is an intermediate technology, due to the impracticality of having a top-down projected table in the home, this technology has a number of appealing features for the implementation of a board game on a digital tabletop. The pen offers a very fine level of control, and allows software to differentiate players based on the pen they are using. Possibly the most appealing feature is the fact that there is no hardware below the table, allowing players to comfortably sit.

In this section we have presented a number of available digital tabletop technologies, and we have considered how well each technology would support digital tabletop board games. In the next section we present techniques that have been designed for interacting with digital tabletops.
CHAPTER 2: BOARD GAMES ON DIGITAL TABLETOPS

2.3 Digital Tabletop Interaction Techniques

When playing a board game, the variety of game actions that the player may take are carried out by moving and placing physical objects. The action of moving an object across the table can be emulated on a digital tabletop using a drag and drop interaction. However, not all of the actions that a player may take in some board games are easily expressible in this way.

Multitouch tabletops allow for the design of novel interaction techniques and interfaces. The large shared display and direct manipulation of virtual objects with a user’s hands create a tactile and social experience, which is unsupported by desktop computers. However, certain interaction techniques, such as selection through drop-down menus, do not carry over well to tabletop interaction. This section presents some of the interaction techniques designed specifically for multitouch tables. This will provide context to the game designs we present in Chapter 3.

2.3.1 Press, Release and Drag

Pressing, dragging and releasing are the simplest types of interaction with a digital tabletop. These interactions are the basic touch events that tabletop application-programming-interfaces (APIs) provide. Most of the interactions that can be achieved with a mouse (such as the selection and movement of objects) are made possible with these simple touch events. In a digital implementation of a board game, this interaction can enable actions such as moving a player piece.

2.3.2 Menus

Many applications use menus to allow the user to choose an action from a large number of options. A digital tabletop version of a board game needs to address this issue, since players are often faced with various choices on their turn. When the user is interacting with a mouse, drop-down menus work well. On the large display of a tabletop, however, the user would be
required to perform a number of long reaches to make a single selection with a drop down menu. The menu would also obscure much of the display, which is especially problematic if the application is intended to support multiple users on a single display. Here we present two alternative menus which are more appropriate for tabletop interaction.

2.3.2.1 Pie Menus

Pie menus (or radial menus) [7] display the user options arranged in a circle around some point (see Figure 2.5). Typically, this type of menu is initiated around any point with some kind of gesture, such as a press and release. A pie menu specific to a virtual object can also be initiated in that object’s location. This is similar to how drop-down menus are instantiated on a right mouse click in many desktop applications.

![Pie Menu](image)

Figure 2.5: Pie Menu [29]

The main drawback of pie menus is that at each level, the number of selections is limited. As the number of choices increases, the circle around which the choices are positioned becomes crowded.

---

3 Copyright permission received from Don Hopkins
2.3.2.2 Stacked Half-Pie Menus

Stacked half-pie menus [28] are a recently developed attempt to provide the advantages of pie menus while avoiding the strict limitation on the number of options per level. As illustrated in Figure 2.6, a stacked half-pie menu is initiated at the edge of the display. The selections at the first level appear in a half circle around a point at the edge of the display, and can be cycled using an interaction similar to dialing on a rotary phone. As options disappear on one side of the menu, new options appear on the other side, allowing for unlimited options at each level, with only a subset of those options visible at once. As selections are made, new levels appear as half circles surrounding previous levels. To prevent the menus from becoming too large, lower levels minimize as the number of levels increases.

![Figure 2.6: Stacked Half Pie Menu](image)

Figure 2.6: Stacked Half Pie Menu [28]

---

4 Image provided by Tobias Hesselmann; Copyright permission received from Tobias Hesselmann
2.3.3 Gestures

As an alternative to selecting actions through the use of menus, many tabletop applications support the use of recognizable gestures to select different actions. An example of this is ‘pinch out,’ which is often used as a zoom or resize gesture. This gesture involves the user making two points of contact on the display with their fingers, and moving the touches further from each other. On digital tabletops, this gesture is commonly used for a similar zooming gesture as well as resizing virtual objects.

Many applications use a small set of simple gestures effectively. However, systems exist that use a wide range of complex gestures. Teaching systems have been developed (e.g. ShadowGuides [21]) to aid users in learning gestures.

2.3.4 Speech Input

Another alternative to gestures and menus is to use speech recognition software to give commands verbally. This interaction technique, combined with simple touch gestures, can allow for expressive interactions, as touch is used to indicate the target of an action while voice commands are used to convey the desired action. This interaction technique was used in digital tabletop versions of The Sims and Warcraft III [64].

2.3.5 Physical Objects

As discussed in section 2.2.1.1, diffuse illumination tables support the use of physical objects as interaction tools [31] (see Figure 2.75). A marker is printed onto the bottom of the object being placed on the table. A camera, which is positioned below the table, detects the position of the object through image processing software. This software can differentiate between

5 Copyright permission received from Gunter Geiger

21
CHAPTER 2: BOARD GAMES ON DIGITAL TABLETOPS

markers printed on various objects. This technology enables numerous novel interaction techniques, and allows for games with the tactile interaction of board games.

Figure 2.7: Physical objects being detected on a Microsoft Surface [56]

2.3.6 Multiple Devices

Some systems use multiple displays for multiple purposes. A prominent example is the STARS platform [37], in which the following hardware is used:

- The large display of the tabletop is used to display information about the game state to all players. Object recognition is also used to detect player pieces.
- Each player is given a PDA to display private information. These PDAs can also be used to send secret messages to other players.
- A large wall display is used to display public information for all players to see at any time.
CHAPTER 2: BOARD GAMES ON DIGITAL TABLETOPS

In this section, we reviewed a number of the interaction techniques that are possible on digital tabletops. These included press/drag/release, menus which are optimized for use on a digital tabletop, gestures, physical object recognition, speech input and multiple devices. In the next section we present some of the design issues that arise when bringing a board game to a digital tabletop.

2.4 Digital Tabletops and Board Game Design

Digital tabletops allow for the design of interfaces that bridge the physical and digital spaces. However, new challenges arise when designing for this platform. The practice of using windows, icons, menus and pointers (also known as WIMP) as common user interface elements, has had decades to develop. However, these practices do not apply when interacting with a tabletop.

While digital tabletops have the apparent comfortable social setting of players sitting around a card table, their physical layout does cause some problems. As mentioned earlier with some tabletop hardware, users can not always comfortably sit with their legs extended under the table. Users often must reach across the table to access objects, possibly disturbing other users and making inadvertent touches. The “fat finger problem” [57] arises because fingers do not support as high input resolution as a mouse or stylus.

The orientation of interface elements is important in digital tabletop applications. This is not an issue for desktop applications, since applications need only be designed to support a single orientation. However, digital tabletop applications should support multiple users seated around the table, viewing the application from multiple angles. The orientation of objects on a table is critical for how people comprehend information, establish private and public work spaces, and communicate with each other [34]. Board game designers are aware of this, as the physical layout
CHAPTER 2: BOARD GAMES ON DIGITAL TABLETOPS

of a board game must not be heavily dependent on orientation. The design of digital tabletop games is no different. The game should be easily understandable from multiple viewing angles, or it will not be enjoyable to all of the players.

The physical interactions of board games and of digital tabletops share some inherent similarities. Interaction with board games is dictated by social protocol and physical space. Players often take turns based on each other’s physical arrangement around the table, choosing a clockwise or counter-clockwise turn order. Players also use the physical space around the table to manage game objects. The design of tabletop applications, which support players’ use of physical space and players’ physical arrangement around the table, is still poorly understood.

2.5 Survey of Tabletop Games

Digital adaptations of board games have been commercially available for decades for non-tabletop gaming platforms. For example, the first computer versions of Monopoly were available in 1985 [30]. Other video games for desktop computers and game consoles, such as the classic game Archon [5] and the more recent game Greed Corp [27], emulate the gameplay of board games, while creating experiences only possible with the underlying computing power of video games. It is only recently that commercial game developers and the research community have started to develop games for the digital tabletop platform, with many of these games having board game like gameplay.

This section discusses a selection of existing digital tabletop games, with a focus on those which have gameplay similar to board games. All of the games employ some of the interaction techniques discussed in section 2.3. In the section following this survey, we extract a list of potential benefits of board game digitization from the games covered in this survey.

24
CHAPTER 2: BOARD GAMES ON DIGITAL TABLETOPS

2.5.1 Commercial Games

A number of commercially available versions of board games have been implemented for digital surface platforms. These include games for the Microsoft Surface, such as The Settlers of Catan and Checkers. The iPad has also shown that digital board games can achieve mainstream success on a touch display, with releases such as Days of Wonder’s Small World and Big Daddy’s Creations’ Neuroshima Hex.

Besides showing that there is a demand for digital versions of board games on digital surfaces, these games illustrate some of the potential benefits of digitizing board games, such as enforcing the rules and automatically setting up the game. These games provide valuable insights into commercial game developers’ best practices.

2.5.2 Weathergods

Weathergods [3] is a tabletop game with board game like gameplay (see Figure 2.86). The goal of the project was to design a game with the dynamic multimedia of digital games, combined with the hands-on activity and social interaction of board games.

The game uses physical objects as playing pieces. The designers of the game tested how players react to iconic playing pieces vs. symbolic playing pieces. Symbolic playing pieces are abstract shapes, whereas iconic playing pieces try to depict what the pieces represent. The majority of players preferred iconic pieces. The most frequent explanation for this preference was that the iconic pieces fit the theme of the game better. The researchers also report that the iconic designs were better for understanding the different pieces.

---

6 Image provided by Saskia Bakker; Copyright permission received from Saskia Bakker
2.5.3 False Prophets

The False Prophets game [39] was designed using elements of board games to facilitate player interaction, combined with the underlying computing power of video games to allow for more complex and streamlined gameplay.

For the project, a hybrid board/video game was designed. The game is a team based puzzle game. Players do not initially know which team they belong to. The goal of the game is to discover which players belong to which team. False Prophets creates an interesting bridge between the physical space around the table and the virtual game space, since players’ proximity to each other factors into the gameplay. The game also enforces the rules, and provides the players with clues as to which players are on which teams.
CHAPTER 2: BOARD GAMES ON DIGITAL TABLETOPS

2.5.4 Dungeons and Dragons for Microsoft Surface

Dungeons and Dragons for the Microsoft Surface [10] is a role-playing game based on the Dungeons and Dragons rule set. Players interact with the game on a digital tabletop display, while a game master coordinates the gameplay and keeps the plot moving forward on a monitor adjacent to the table.

Players interact with the game using both tangible game pieces and multitouch gestures. The game includes a novel interaction technique, which combines physical objects, menus and multitouch interactions. A physical piece is included in the game, which when placed on the screen instantiates a menu. From this menu, players can select actions by touching the screen around the menu object. This menu provides information about available play options. This is a very useful feature for a game with a complex rule set like Dungeons and Dragons, particularly for novice players.

2.5.5 Real-Time Chess

Real-Time Chess [9] is a game developed for the DiamondTouch tabletop [14]. In the game, each player controls chess pieces that move following the standard chess movement rules. In Real-Time Chess, however, rigid turn-taking is relaxed in favor of real-time gameplay. A player can move a piece at any time, but once moved, it cannot be moved again for some period of time.

Though the game shares some of the gameplay features of chess, this design would not be possible as a traditional tabletop game, since the computer is needed to constantly keep track of which pieces were moved and when. Real-Time Chess shows what can be accomplished when gameplay concepts from classic board games are used in conjunction with the computing power of tabletop computers to design an original game.
2.5.6 SIDES

Shared Interfaces to Develop Effective Social Skills (or SIDES) [53] is a 4-player cooperative game developed for the DiamondTouch table [14]. The game was designed to aid adolescents with Asperger’s Syndrome to use effective group work skills. An observational study showed that the adolescents, whose condition ordinarily makes it difficult for them to remain engaged with group activity, managed to remain engaged and put in a concerted effort to work collaboratively. The researchers concluded that the group setting of the tabletop platform, combined with the consistent and automated enforcement of the rules by the computer helps the adolescents to learn social skills.

2.5.7 PinguTouch

PinguTouch [40] is a game implemented for a multitouch table. The gameplay is similar to the popular video game Lemmings. In PinguTouch, players work together to lead penguin characters, called pingus, through an obstacle course. Players accomplish this task by using gestures, such as creating a bridge for the pingus by laying their hand down on the table.

The game includes novel design concepts. One of the goals of the project was to create a collaborative game. To promote equity of participation between the players, a circular table was considered. However, due to the awkwardness of constructing and interacting with a circular digital table, a hexagonal table was constructed. The game was made more manageable by limiting the number of actions that players can take. In particular, a player may only take one action per hand (for example, a player could create two bridges at one time, but would then have no free hands to perform another action). In this way, PinguTouch effectively promotes the collocation and group coordination that tabletops naturally support.
CHAPTER 2: BOARD GAMES ON DIGITAL TABLETOPS

2.5.8 The Sims and Warcraft III

The popular computer games ‘The Sims’ and ‘Warcraft III’ were adapted to a digital tabletop [64] (see Figure 2.9). The project explored multimodal gameplay, including both multitouch gestures and voice commands, as discussed in section 2.3.4. Players can select a unit by tapping the unit. Players can then tell the selected unit to move by pointing and saying “Move Here” into a headset microphone, or by pointing with two fingers at once. This project highlights the novel interaction techniques that are possible on a digital tabletop.

![Image of The Sims Multimodal Gesture]

**Figure 2.9: The Sims Multimodal Gesture [65]**

In this section, we have reviewed a number of games for digital surfaces, focusing on games with board-game-like gameplay. In the next section we present a number of potential

---

7 Copyright permission received from Edward Tse
CHAPTER 2: BOARD GAMES ON DIGITAL TABLETOPS

benefits of digitizing board games, which were extracted from the review of games presented in this section.

2.6 Potential Benefits of Board Game Digitization

As we have seen, tabletop displays provide significant promise as a gaming platform; they combine a large, shared horizontal display and interaction through direct contact with the table’s surface, a format already familiar to those who have played traditional board games. We have also seen examples of games where the underlying computing power of digital tabletops provides the opportunity for new interactions and visualizations, including speech input (section 2.5.8), animated characters (section 2.5.7) and real-time gameplay (section 2.5.5). These games reveal several of the potential benefits of digitizing board games. We summarize these benefits here:

- **Performing complex or routine in-game activities.** When playing board games, players must carry out mechanical tasks to move the game forward. These activities include setting up the game, shuffling cards, placing game objects to carry out in game events, and managing resources such as money. In addition to handling tasks like these, digital games can be saved and returned to later, a distinct advantage over some of the longer, complex board games involving many physical components. For example, Real-Time Chess (section 2.5.5) automatically sets up the game pieces on the non-standard chess board, so that players can immediately start playing.

- **Acting as an impartial referee.** Keeping track of all of the rules of a game is a significant task, even for experienced players. Game rules range in complexity from very simple, such as in Go and Checkers, to very complex simulations with dozens of rules and special situations to keep track of. Discovering later in a game that an earlier move was done
incorrectly can be a discouraging experience when playing a board game. Digitization enables the impartial and reliable enforcement of an objective set of rules. For example, Dungeons and Dragons for the Microsoft Surface (section 2.5.4) keeps track of the many rules from the original game, and only allows legal play.

- **Automating game progression.** Keeping track of the current phase of the game (i.e., what the players are currently doing in the game) can be a significant task for players. For example, if a player’s turn involves a number of complex steps, remembering which step the player is currently carrying out, or how many times a certain action has been performed, can be difficult. Some of the more complex board games include tracks printed on the board to remind players what the current phase of the game is, but neglecting to update these tracks can cause the same problem for players. Digital versions of board games can show players which phase the game is currently in, and restrict player interaction to activities permitted in the current phase. For example SIDES (section 2.5.6) ensures that players do not play out of turn order.

- **Providing improved visualizations through digital media.** Traditional board games provide physical interfaces, which consist solely of physical objects. Digital interfaces are more flexible; these interfaces can update information in real-time, such as scores or in-game prompts, and can personalize information for each player thereby enhancing the gaming experience. Digital media can also provide a more sensory and engaging experience through the use of sound and animation. For example, PinguTouch adds flavour to the game by animating the cartoon penguins.

- **Assisting novice players as they learn to play.** Learning to play is a significant barrier of entry for new players of a board game. The learning process can be discouraging if the
other players are more experienced, or if the new player did not fully understand the rules after having them described. In-game assistance, such as displaying possible moves or providing an interactive tutorial, can help novice players learn complex games. For example, when a piece is selected in Real-Time Chess (section 2.5.5), all of the possible moves for that piece are highlighted.

- **Filling in for absent humans.** Many board games are best played, or are only possible to play, with a minimum number of players. In a digital version of a board game, “artificial intelligence” (or AI) players can substitute for human players. In addition to filling out the required number of players in a game, this feature could be used on a temporary basis to allow play to continue if someone has to leave. It can also allow individuals to play a multi-player game, which could be very useful for learning a complex game on one’s own. For example, The Settlers of Catan for the iPad includes single player gameplay against AI players.

- **Digital distribution.** Finally, digitizing board games opens up the possibility of purchasing and maintaining board game collections in digital form, as is common today for movies, music and video games. Possible benefits include reduced physical space required to store games, and allowing people to play a demo version of a game before the decision is made to buy the full version. For example, versions of board games for the iPad are sold exclusively through the Apple online app store.

These potential benefits of digitization provide a starting point for our exploration of board games on a digital tabletop, and suggest areas where digitization may positively impact the gaming experience.
CHAPTER 2: BOARD GAMES ON DIGITAL TABLETOPS

2.7 Conclusion

In this chapter, we have provided background for the implementation of board games for the digital tabletop platform. This included brief histories of board games and digital tabletops, and a look at the factors contributing to the sociality of board games. We also presented surveys of digital tabletop technologies, interaction techniques, and digital tabletop games with a focus on those with board-game-like gameplay. We concluded with a list of potential benefits of digitizing board games. In the following chapters, we present the design and implementation of a user study, in which participants were asked to play digital tabletop versions of the board games Checkers and Pandemic. This study was designed to evaluate whether or not the game experience is enhanced with digitized versions of the board games played on tabletop technology.
Chapter 3

Designing Tabletop Versions of the Checkers and Pandemic Board Games

Digital tabletops are an ideal platform for digital implementations of board games. In both settings, players sit around a table and share in a collaborative experience on a large horizontal surface. However, digital tabletop gaming is a relatively new domain. It is still poorly understood how to design interfaces for such games. While some interactions, such as moving a piece across the board, are well supported by the basic interactions of a digital tabletop (press, release and drag), it is not obvious how to design other interactions, such as holding a secret hand of cards.

In this chapter, we describe the design of interfaces for two board games, which we implemented on a digital tabletop computer. Along the way, we describe how some of the design decisions were reached. The implemented games were the abstract strategy game Checkers (see Figure 3.1), and the popular cooperative board game Pandemic (see Figure 3.3). We chose these games because they vary in a number of ways; Pandemic is cooperative, while Checkers is competitive; Checkers is abstract, while Pandemic is based around the concrete theme of curing infectious diseases; Checkers is for two players, while Pandemic is a multiplayer game. We studied the effectiveness of these designs through a user study, which is described in detail in Chapter 5.

3.1 Checkers

This section describes the original Checkers board game and the interface which we designed for the digital tabletop implementation.
3.1.1 The Board Game

Checkers is a two player abstract strategy game. The game is played on an 8x8 grid board. The squares on the board are colored black and white in a checkerboard pattern, such that no two orthogonally adjacent squares are the same color. The game is played solely on the white squares. Each player initially sets up by placing a piece of their own color in every white square in the three rows closest to their side of the board. On each turn, the current player either moves a piece diagonally forward one space, or, if possible, captures one of the other player’s pieces. Captures are made by moving one’s own piece to an empty square on the opposite side of an opposing piece which is diagonally in front of it. If a capture is possible, then the capture must be made. If after a capture another capture can be made by the same piece, the player must make the subsequent capture. This continues until no more captures are possible, or the piece is promoted.
to a ‘king’. A piece is promoted to a king as soon as it enters a space in the row closest to the opposing player, if it has not already been promoted. A king is marked by stacking a second already-captured piece on top of promoted piece. A king is not restricted to move and capture in the forward two diagonal directions, but may move and capture in all four diagonal directions.

A player wins if the opposing player can make no moves on their turn (this includes capturing all of the opponent’s pieces) or if the opposing player forfeits [17]. Figure 3.1 shows the original Checkers board game. We will refer to this version of the game as the “physical game” from here on.

### 3.1.2 Digital Tabletop Interface

The digital tabletop interface for Checkers (see Figure 3.2) provides many of the potential benefits of board game digitization described in section 2.6. By including these benefits we hoped to streamline the task of playing Checkers while maintaining the face-to-face and tactile interaction of the original game.

The game rules are enforced, thus players are not permitted to make illegal moves, including failing to make a capture when one is possible. The progression of the game is also automated. The game dictates when one player’s turn ends and the next player’s turn begins. A piece is automatically promoted to a king when the piece reaches the last row. A king is represented by a piece with a crown symbol.

We found, while testing an early version of Checkers, that merely enforcing the rules and managing the progression of the game without providing feedback as to why gameplay is being restricted leads to player confusion. Thus, we included text to indicate whose turn it is, and whether a player must make a capture.
Figure 3.2: A screenshot of the digital tabletop interface for Checkers. Note that the pieces are all perfectly aligned with squares due to the snap-to-location functionality. Interface elements include: A) turn indicator, B) ‘must jump’ indicator, C) kinged piece.

Players use a simple press, drag and release gesture to move the desired piece. This was designed to replicate the action of moving pieces in the physical game. After a piece is moved, the game snaps the piece to its current space, ensuring that pieces are not displayed offset from the center.

3.2 Pandemic

The second game we developed was the popular cooperative board game Pandemic. We felt that the digital tabletop platform was a good fit for cooperative games, since digital tabletops have been shown to support other forms of groupware, as we have seen in Chapter 2. In this
CHAPTER 3: DESIGNING TABLETOP VERSIONS OF THE CHECKERS AND PANDEMIC BOARD GAMES

section, we describe the original Pandemic board game (see Figure 3.3), and the interface we designed for the digital tabletop implementation (see Figure 3.5).

Figure 3.3: The original Pandemic board game. Game elements include: A) infection cubes, B) player pawns, C) infection draw pile and infection discard pile, D) player draw pile and player discard pile, E) infection rate counter, F) outbreaks counter, G) cure markers

3.2.1 The Board Game

Pandemic is a cooperative board game, meaning players work together towards a common goal. At the end of the game, either all players win, or all players lose. We now present a brief overview of the gameplay of Pandemic to provide the context for the design decisions that we made when designing the digital tabletop interface, which we will present in section 3.2.2.
CHAPTER 3: DESIGNING TABLETOP VERSIONS OF THE CHECKERS AND PANDEMIC BOARD GAMES

The game tasks two to four players with eradicating four diseases which threaten to wipe out civilization. The game is played on a map of the world, consisting of 48 connected locations representing major cities. Players move their player pieces (see Figure 3.3 B) around the map to contain the four diseases. The diseases are represented by disease cubes (see Figure 3.3 A). The players win by successfully trading cards (see Figure 3.3 H) to find cures for each of the four diseases. The players lose if the diseases spread too quickly, or if the players do not successfully cure all four diseases within a certain number of turns. Players must balance concentrating on the immediate threat of spreading diseases, and working towards the ultimate goal of researching cures for each of the four diseases.

A player is permitted to take four actions on their turn. There are a variety of actions that a player can take including:

- Removing disease cubes from their current location.
- Trading cards with other players.
- Moving their player piece to an adjacent location.
- Discarding a card to move to the location depicted on the card.

As Pandemic is a cooperative game, negative events that work against the players occur, in order to keep the game interesting. At the end of each player’s turn, there is a game event called an ‘infection event’ (see Figure 3.4), which dictates how new disease cubes are placed on the board. This forces the players to deal with the constant threat of new disease cubes. Players carry out a set of deterministic actions to carry out an infection event, including drawing cards, and placing disease cubes. While carrying out these actions, players do not make any game decisions, rather they simply follow instructions on the cards. This type of card driven system that
CHAPTER 3: DESIGNING TABLETOP VERSIONS OF THE CHECKERS AND PANDEMIC BOARD GAMES
dictates how the game fights back is common in cooperative board games. We will refer to these events which occur at the end of a player’s turn as infection events.

![Images of a game setup with disease cubes and cards]

**Figure 3.4:** An Infection Event. 1) Madrid initially has one disease cube. 2) The Madrid card is drawn from the infection deck. 3) A disease cube is added to Madrid. 4) Madrid ends with 2 disease cubes.

3.2.2 Digital Tabletop Interface

We were able to keep the Checkers interface simple, due to the simplicity of the interactions which users perform while playing the board game. However, Pandemic is a much more complex game, with a variety of player interactions. The design goals for the digital tabletop interface of Pandemic were similar to those implemented for checkers. The Pandemic interface was designed to provide many of the potential benefits of digitizing board games presented in section 2.6, and to be easy for players to understand the various interactions with the interface. Figure 3.5 depicts the digital tabletop interface we implemented for Pandemic.
Figure 3.5: A screenshot of the digital tabletop interface for Pandemic. Several forms of automation were incorporated into this interface, including: A) Action pointers to carry out special card actions. B) Counts of remaining pieces (research stations and disease cubes of each color) displayed in one corner of the board. C) Player and infection card decks and discard piles were maintained by the interface. D) The infection rate counter and outbreak counter (E) were incremented by the interface as needed.
CHAPTER 3: DESIGNING TABLETOP VERSIONS OF THE CHECKERS AND PANDEMIC BOARD GAMES

3.2.2.1 Gestures

During a game turn, the current player is allowed to take a certain number of “actions”. Some of the actions which a player can take, are represented as gestures consisting of press, release and drag. An example of this is the simple move action, in which the player moves their player piece to an adjacent location (connected by a line segment to the current location). This counts as one of their four actions. The number of actions required to make a move to a more distant location is the minimum number of line segments connecting the two locations. To make a single or multiple move actions, the player presses on their player piece, drags to the location to which they would like to move, and releases. When the player drags to a location, the shortest path between that location and their player piece is highlighted. In this way, the players can complete multiple move actions with a single dragging gesture. This gesture was designed to replicate the interaction of picking up their player piece and moving it to the desired location.

3.2.2.2 Circular Menu

A player has a number of options on their turn, including removing disease cubes, trading cards with other players and discarding cards to move around the board. It is not clear how to design interactions for all of these using the simple press, drag and release interactions that digital tabletops support. For this reason, we implemented a circular menu (see Figure 3.5) which appears when the active player presses and releases on their own player piece. From this menu, the player can select the action that they wish to perform. If the action requires a further decision, such as which location to move to during a direct flight, then an action pointer (see section 3.2.2.3) is created. Other actions, which are not easily expressed as gestures, can be selected from the circular menu, including placing a research station (a building which helps players move around the board) and trading cards with other players.
CHAPTER 3: DESIGNING TABLETOP VERSIONS OF THE CHECKERS AND PANDEMIC BOARD GAMES

As we have seen in section 2.3.2.1, circular menus are a good fit for the digital tabletop platform. The circular menu in Pandemic allows players to select actions without multiple long reaches across the table. The only reach required to select an action is the reach to the player piece. This selection of the desired action at the location of the player piece, through the use of a circular menu, was designed to emulate the direct manipulation of physical game objects present in board games. Note that we refer to our menu as a circular menu, because it does not present options in a filled in circle, and is therefore not a pie menu (see Figure 2.5)

![Circular Menu Image]

Figure 3.5: Circular Menu (Some features of the image have been recolored for clarity). Actions are depicted as images around the player piece. The number of actions a player has remaining on their turn (four in this example) is depicted to the left of the player piece.

3.2.2.3 Action Pointers

Some of the actions in Pandemic require that a decision be made after the desired action has been selected. For example, simply expressing that a player wants to move their piece does not convey enough information to the game. The player must also communicate the target of the move action (i.e. the location to which they would like to move). In some cases the target may be a long distance from the starting location. For example, if the player is in San Francisco and
CHAPTER 3: DESIGNING TABLETOP VERSIONS OF THE CHECKERS AND PANDEMIC BOARD GAMES

wants to move to Tokyo, this requires only one action, as the locations are adjacent. However, these cities are drawn on opposite sides of the board. If a player attempts to move between them with the press/drag/release for moving, then a single very long drag would be required. During this drag, the player would likely have to lean across the other players. It is also possible that this action would be difficult to complete at all, as the touch interface may mistakenly detect a release during the drag, interrupting the attempted move. These and other issues were resolved with “action pointers” (see Figure 3.6).

![Action Pointer](image)

**Figure 3.6: Action Pointer**

Action pointers are widgets, used by the players, to indicate the targets of the various actions. These widgets prevent the need for very long drags across the board. Many of the actions performed in Pandemic target a location or game piece. To avoid being prompted to select the target of the action through a modal selection, such as a dialog, using Action Pointers involves a gesture toward the target’s location on the board. This was especially critical when selecting a location, since selecting between the 48 locations on the board from a list would be cumbersome.
CHAPTER 3: DESIGNING TABLETOP VERSIONS OF THE CHECKERS AND PANDEMIC BOARD GAMES

However, as we have discussed, it was not ideal to implement these actions with the simple press/drag/release gestures we had been using up until this point, since this would lead to long awkward drags across the entire board (see Figure 3.7).

![Figure 3.7: Action pointer in use. The green action pointer (A) is being used to perform a long move from the green player’s location (B) to a location on the other side of the map (the in-game indication of the player’s path has been highlighted for clarity). Note that this move would have to be performed in a single drag using the press/drag/release gesture for moving. The action pointer widget can instead be moved in a number of drags, and even passed to another player to help complete the action.](image)

Action pointers are novel interface elements, which were designed for our digital tabletop implementation of Pandemic. They were designed to allow players to initiate and complete actions without requiring a single long drag. As illustrated by Figure 3.7, when a player chooses an action from the circular menu, a widget appears next to their player piece. The widget is associated with the player (visualized using the color of the widget’s border) and the action which
CHAPTER 3: DESIGNING TABLETOP VERSIONS OF THE CHECKERS AND PANDEMIC BOARD GAMES

they selected (visualized with the icon of the action). The action pointer is dragged to point at the target of the action. The check mark button completes the action, and the ‘X’ button cancels the action destroying the action pointer. The way this interface avoids long drags done all at once is that the action pointer stays active until the action is completed or cancelled. As a result, the action can be done with several click-drag-release gestures some of which could be performed by other players around the tabletop that are better situated.

3.2.2.4 Hand Widget

In Pandemic, players have a hand of cards, each card depicting a location on the map. The rules of the game state that the players should keep the cards hidden, but may discuss their cards in full detail. However, players commonly display their cards publicly, since Pandemic is a cooperative game. A widget, similar to an action pointer and denoted the “hand widget”, implements this hand of cards (see Figure 3.8). In place of the ‘complete action’ button, there is a button which opens or closes the widget to display or hide the player’s cards. When a hand widget is closed, it collapses to the size of an action pointer, and does not display card names.

Figure 3.8: Hand Widget
CHAPTER 3: DESIGNING TABLETOP VERSIONS OF THE CHECKERS AND PANDEMIC BOARD GAMES

The hand widget is also used for players to take the ‘cure’ action. Taking cure actions is the only way that players win the game. The cure action involves choosing five of the cards in the player’s hand to discard. We felt that this requirement made the hand widget an appropriate interface element to carry out the cure action, preferable to trying to implement the action as an interaction with the main game board.

The decision was made to implement the hand widget as a moveable game artifact, similar to an action pointer. This was decided due to the fact that, when playing a board game, a player’s hand of cards is a mobile and physical artifact which the player has control over. The players may choose to place the cards face up in front of them, or constantly hold them as a secret hand. Cards are not tied to a physical space in the play area in the way that the board or game pieces are. Giving players some control over the position and secrecy of their hand of cards was done in an attempt to emulate the interaction with a physical hand of cards. We felt this was important, in order to capture the player interactions of the original game. The hand widget does not explicitly support secrecy, but players may choose to only open their hand widget discreetly or to obscure it with an arm or hand.

3.2.2.5 Automation of Routine Activities

Like many board games, Pandemic involves some routine activities, such as shuffling cards, placing cubes in the appropriate locations, and setting up the game. In section 2.6, we proposed handling these routine activities as one of the potential benefits of board game digitization. The digital tabletop interface for Pandemic automates many such routine activities. For example, at the end of each player’s turn, infection events (see Figure 3.4) are automated. In the original game, a player draws cards from the top of a deck, each of which depicts a location on the map, and places a disease cube at that location. Because this event is not associated with
any one player, and its outcome is not determined by any player decisions, it is carried out automatically by the computer.

3.2.2.6 Rule Enforcement

As indicated in section 2.6, one of the potential benefits of board-game digitization is to take over the possibly cumbersome tasks of learning and enforcing the rules of a game. Rule enforcement is automated in our implementation of Pandemic. Players are prevented from making illegal moves. These include moving along a path which is longer than the number of remaining actions that a player has on their turn, or taking a direct flight action to a location for which they do not have the card. Many of these rule infractions display a red ‘X’ on the target of the action in order to alert the player that they are attempting an illegal move (see Figure 3.9).

Figure 3.9: Visual indication of a rule infraction. The orange player is attempting to move their piece, though it is the white player’s turn. The ‘X’ indicates that this is an illegal move (Some features of the image have been recolored for clarity).

3.2.2.7 Automation of Game Progression

Board games can have various phases that the players carry out each game round. For example, in Pandemic a player takes four actions on their turn, and then carries out the card drawing and placement of disease cubes to represent the growing threat of diseases on the board. More complex games can have many phases and complex actions during a single round of play.
CHAPTER 3: DESIGNING TABLETOP VERSIONS OF THE CHECKERS AND PANDEMIC BOARD GAMES

Keeping track of the current phase of the game can be a significant task for players. In section 2.6, we presented automation of game progression as a potential benefit of game digitization.

In the digital tabletop interface for Pandemic, the game automatically handles game progression based on the rules rather than having the players manage the progression of the game. The game keeps track of the number of actions a player has left on their turn, and displays this information to the player when they open the circular action menu (see Figure 3.5). At the end of each player’s turn, an infection event occurs in which the disease spreads. This would ordinarily be carried out by the players, but is instead handled by the game. The game also displays when the players have won, or when they have lost.

It should also be noted that the phase of the game is rigidly enforced. Once a player has taken an action or completed their turn, there is no opportunity to undo that action. This was not a deliberate design decision, and as we will see in our discussion of the user study, this lack of an ‘undo’ feature can cause problems for players.

3.2.2.8 Animations

In the digital interface for Pandemic, in-game events, such as drawing cards and placing disease cubes at the end of a player’s turn, are carried out automatically by the game, as described in section 3.2.2.5. In an informal pilot test, we found that awareness deficits arose from the fact that these events were carried out instantaneously. Players would reach the end of their turn, and would be unaware of what had changed when the end of turn event was carried out. We added animations to convey when these events were happening (see Figure 3.10). These include explosions to display when a cube was being added to a location, as well as animations for the other various events which can take place in a location such as outbreaks and epidemics.
CHAPTER 3: DESIGNING TABLETOP VERSIONS OF THE CHECKERS AND PANDEMIC BOARD GAMES

3.2.2.9 Counters and Visualizations

When playing a board game, various game pieces are often stored in piles beside the main play area. In some games, these pieces are intended to be unlimited, and are replaced with placeholders if they run out throughout the course of the game. In many games however, these pieces are deliberately limited, and have an impact on gameplay if the pieces run out. This latter situation applies to Pandemic, as the players lose when they must place a disease cube, but have run out of that color of disease cube. In the original game, players are able to count the remaining objects, including the size of the decks and the number of remaining disease cubes of each color. To convey all of the required information to the players about the current game state, the digital interface displays numbers of remaining objects in the game (Figure 3.5 B). These include counters for the size of a deck of cards, and the number of remaining disease cubes of each color.

In the board game, players are permitted to look through the discard pile, giving them important information about the game state. This same information is represented in the digital interface by a red arrow pointing to the card’s location on the map.
3.3 Conclusion

In this chapter we described the two-player abstract strategy game Checkers and the cooperative board game Pandemic, as well as digital tabletop interfaces we designed for each. In the next chapter, we describe a reference architecture for the implementation of board games for a digital tabletop platform. In Chapter 5 we describe a user study, which makes use of the digital tabletop interfaces of Checkers and Pandemic described in this chapter.
Chapter 4

Architecting Tabletop Versions of a Board Game

In the previous chapter, we described the board games Checkers and Pandemic, as well as digital tabletop interfaces for each. The implementation and interface design were ongoing and parallel processes, which included a number of design iterations as well as a change in tabletop hardware.

In this chapter we describe a reference architecture that addresses a number of the challenges involved in implementing a digital tabletop version of a board game.

4.1 Challenges

Implementing a digital tabletop version of a board game involves a number of challenges not present on other platforms.

- The fact that digital tabletops are multi-user, multitouch devices introduces the problem that at any given time, multiple users may be making multiple concurrent touches.
- The tabletop platform has the issue of portability across different digital tabletops, as touch input libraries are not as standardized as mouse and keyboard input.
- Implementing the interfaces that we described in Chapter 3 presented issues when programming the interactions. The interfaces went through a number of design iterations. Coming up with a code structure which allowed us to iterate on some of the interactions was a challenge.
- There was a significant challenge involved in implementing the rules of the games. Checkers has a simple rule set, while Pandemic is a more complex game,
involving game mechanics such as point-to-point movement, card drawing and action selection.

The game architecture that we present in this chapter addresses these challenges.

4.2 Architecture

In this section we describe a reference architecture for digital tabletop implementations of board games. This reference architecture captures idealized implementation drawn from experience implementing these games. The Pandemic interface described in Chapter 3 follows this architecture closely. An architecture diagram, expressed in Fiia notation [69], can be seen in Figure 4.1.

Figure 4.1: Reference architecture for digital tabletop versions of board games
CHAPTER 4: ARCHITECTING TABLETOP VERSIONS OF BOARD GAMES

The ‘Game’ structure contains the main game loop. It also contains code for tasks such as drawing the game entities and loading the game assets. The ‘Game Data’ storage structure includes information about the game. This information includes the locations of player pieces and information about the layout of the game board. In the case of Pandemic, game data also includes information about the game cards, disease cubes, and other information about the state of the game.

The ‘Input Handler’ was implemented to address the issues of portability across tabletop hardware, and multiple concurrent users and touches. The input handler is as a separate structure, which runs as a different thread than the main game loop. Players provide input to the game through the use of Anoto digital pens, which is delivered to the main game as game board coordinates by the input handler. The game interprets these coordinates by referring to the game data. For example, if a player attempts to move their piece in Pandemic to a different location, the game must first check if there are any player pieces at the coordinates of the first pen press, then check if there is a location on the map at the coordinates where the pen was released.

Implementing player input as a separate layer made the software easily portable across platforms. For example, at an early stage of the implementation, Pandemic and Checkers were running on a diffuse illumination table running EquisFTIR [70]. The transition to the Anoto platform was easy, since the user input was implemented as a separate structure, rather than being interpreted at various points in the code.

After the game has received game board coordinates from the input handler, these coordinates are passed to the ‘Selection Handler’. The selection handler then accesses the game data to decide what operation the user is attempting to perform. The selection handler first searches the interface elements, referring to their size and position, to determine if the user is
attempting to perform an interface operation, such as moving an action pointer. If so, the coordinates of the touch are passed to the interface element. The interface element handles the touch from there. If no interface elements are being accessed, then the selection handler searches game entities, including player pieces and map locations. If a game entity is being pressed, then the selection handler passes this information to the ‘Action Interpreter’ to determine the game action that the user is attempting to take. The action interpreter can also be accessed by interface elements which are used to take actions, such as action pointers (see section 3.2.2.3).

The action interpreter receives information about which game entities are being acted on by the players, and determines the game action that is to be taken. Isolating this structure simplified the task of implementing the interaction design. For example if a player presses on their player piece, drags to a location and releases, the action interpreter considers a move action to have been specified. The action interpreter checks in a ‘release on location’ method whether the press before the drag was on a player. If so, the action interpreter knows the player is trying to move their piece to the location. Note an important difference between the input handler and the action interpreter; in the example of moving a player piece, the input handler receives raw data from the Anoto pens, and translates this to ‘press on player piece, release on location’; the action interpreter receives ‘press on player piece, release on location’ and translates this to ‘move action’. Once the action interpreter has decided the action that is being attempted, it passes this information to the ‘Rules Structure’.

The rules for the games were isolated into a separate structure. This allowed for a simple iterative procedure for enforcing the rule set. This could also make it easy to implement future variants of the game by using a different rule-set module. The rules structure was implemented as code. However, future implementations could include an API for defining rules.
When the action interpreter decides that a user is attempting to take a certain action, a call is made to the game rules with the information about the desired action. For example when a player is trying to move to a location, the game passes to the rules structure both references to the player and to the desired location. The rules structure then computes whether this is a legal move. If it is not, the rules structure instantiates a visual cue that the attempted move is illegal. If the move is legal, then the rules structure proceeds to carry out the action by changing the game state in the game data structure.

The rules structure also contains code for managing the progression of the game. For example, in Pandemic a player has four actions on their turn. When a player has finished their fourth action, the rules structure carries out the various in-game events that happen at the end of a players turn, before moving on to the next players turn. The rules are not consulted when users attempt to perform user interface operations. For example if a player attempts to move their hand widget (see section 3.2.2.4), the rules structure is not called, since this operation is always permitted.

Due to the turn based gameplay of Pandemic and Checkers, there was little need for handling potential conflicts between players’ concurrent actions. Though the software did need to handle multiple concurrent touches, the turn-based progression of the game ensured that only one player acted at a time. If a player attempted to take action while another player was already doing so, this was easily dealt with by the software, since this would not be a legal play. Dealing with concurrent actions could be an issue with possible future real-time variants of the games, or in games where players do act concurrently. Dealing with concurrent game actions could be handled within the rules structure. Players are able to take concurrent interface operations, such as moving their hands of cards. This is handled within the interface elements themselves. If the interface
element is already being controlled by a player, a different player may not control the same interface element.

By isolating the tasks of managing concurrent users and input, as well as enforcing game rules, into separate structures, we feel that the architecture that we have presented addresses some of the issues with implementing a board game for a digital tabletop platform. Developers attempting to implement games of similar or greater complexity will likely be faced with the same types of challenges. This architecture provides a starting point for addressing such issues.

4.3 Conclusion

In this chapter, we have presented a reference architecture for board games implemented for digital tabletops. The reference architecture most closely describes the architecture of the digital tabletop implementation of Pandemic described in section 3.2.2, but could be applied to the implementation of Checkers described in 3.1.2. We anticipate that this reference architecture would serve to help simplify the development of digital-tabletop versions of other board games, either as presented or as a starting point for more elaborate architectures.
Chapter 5

Exploring the Effects of Automation in Digital Tabletop Games

In section 2.5, we presented a survey of games for digital tabletops, and other large surface computers such as the iPad. We focused on games with board game like gameplay, and included a number of commercially available games. These games show that digital tabletops are an apparently ideal platform for digital implementations of board games. The majority of these games automate many aspects of the game, such as rule enforcement and game progression. Such automations of gameplay are among the potential benefits of board game digitization which we proposed in section 2.6. However, it is unclear whether automation of gameplay in board games is always the correct design choice. There are few examples of available versions of board games that do not take the approach of automating aspects of the game. There has also been little research on the effects of automation on gameplay of board games.

In order to investigate the impact of automation on gameplay, we conducted a mixed-methods user study where we observed groups playing the cooperative board game Pandemic and the abstract strategy game Checkers. Each group played only one of the two games. The groups played three versions of the game: the original physical board game and two alternative digital tabletop interfaces. The first digital interface automated many aspects of the gameplay, and the second digital interface provided minimal automation. We describe these interfaces in more detail in section 5.1.

We used a number of methods to capture data from the study sessions. These data included background questionnaires, post-condition questionnaires, free-form comments, video
CHAPTER 5: EXPLORING THE EFFECTS OF AUTOMATION IN DIGITAL TABLETOP GAMES

recordings of the sessions, and game data logged by the software. We describe the collected data in more detail in sections 5.4 and 5.5.

As we will see in Chapter 6 and Chapter 7, where we present and discuss the results from this study, we found that automation can have a positive impact on the gameplay of board games, reducing the amount of overhead required to play the game. Additionally, adding automation to the game does not reduce the sociality of the original board games, making digital tabletops a promising platform for social games. However, if not handled properly, the results also indicate that game automation can lead to awareness deficits and player frustration.

In this chapter, we describe the experimental setup and design of the user study to provide context for the results, which we present and discuss in future chapters.

5.1 Experimental Software: High and Low-Automation Interfaces

To study the impact of automation on gameplay, we developed two digital tabletop interfaces for each of Checkers and Pandemic; a high-automation interface and a low-automation interface. Figure 5.1 describes the degrees of automation in the physical game and the two digital interfaces.

In Chapter 3, we described our designs for digital tabletop interfaces for both Checkers and Pandemic. These interfaces are the high-automation interfaces for those games. These interfaces represent what we feel could be expected from a mainstream release of a digital version of a board game, as both interfaces attempt to include many of the potential benefits of board game digitization presented in section 2.6. The high-automation interface for Checkers (Figure 3.2) is described in section 3.1.2. The high-automation interface for Pandemic (Figure 3.5) is described in section 3.2.2.
CHAPTER 5: EXPLORING THE EFFECTS OF AUTOMATION IN DIGITAL TABLETOP GAMES

The low-automation interfaces for Checkers and Pandemic were designed to closely resemble the original physical games. Rule enforcement and game progression are not automated. Game pieces are free-floating. Players must manually drag pieces, markers and cards across the board, similar to how the physical game is played. As such, players can perform any action, including illegal actions or actions out of turn, at any time.

<table>
<thead>
<tr>
<th>Physical Game</th>
<th>Low-Automation Interface</th>
<th>High-Automation Interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Traditional board game</td>
<td>• Closely resembles the traditional board game</td>
<td>• Significant automation</td>
</tr>
<tr>
<td>• No automation of any kind</td>
<td>• Minimal automation of in-game activities (shuffling of cards, game setup)</td>
<td>• In-game activities largely automated</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Game progress automated</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Rules are enforced</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Animations for in-game events</td>
</tr>
</tbody>
</table>

Degree of Automation

Figure 5.1: Summary of the three game versions of Checkers and Pandemic included in the study.

The low-automation interface for Checkers (Figure 5.2) provides almost no features besides displaying the board and allowing players to drag pieces. The only other action that the players may take in the game is promoting a piece to a king. To take this action, players drag one of their own captured pieces and drop it on top of another of their pieces. The pieces are then merged into a single piece which is marked with a crown symbol. This interaction was designed to imitate stacking pieces on top of each other to denote a king.
CHAPTER 5: EXPLORING THE EFFECTS OF AUTOMATION IN DIGITAL TABLETOP GAMES

Figure 5.2: A screenshot of the Low-Automation interface for Checkers. Note that there are no indications as to whose turn it is or if a jump is required. Also note that free floating pieces are offset from the centers of squares on the board, and that captured pieces are stored outside of the active playing area.

The low-automation interface for Pandemic (Figure 5.3) provides some minimal automation of routine activities, including interacting with decks of cards, and setting up the game. Because the digital tabletop uses digital pen input, simulating realistic interaction with cards would be cumbersome. Instead, pen-appropriate card interactions were developed. To draw a card from a deck, a player uses their pen to drag cards from the deck into their hand. Unlike the hand widget from the high-automation interface, which automatically lists the cards in a players hand in an organized way, the hand widget in the low-automation interface is simply a portable container to store the digital objects which represent player cards. The hand widget can be opened
Figure 5.3: A screenshot of the Low-automation Pandemic interface. This version closely resembles the physical board game, but is played using pens on a digital tabletop surface. Differences between the Physical interface and this interface include: A) On-board storage areas for unused disease cubes. B) Automation of deck interactions, including drawing cards from the top/bottom of the deck and shuffling.
and closed similarly to the high-automation interface. To discard a card from their hand, players drag the card from their hand into the discard pile.

Interface elements were included to facilitate other card interactions specific to Pandemic. As part of an ‘epidemic event’ in Pandemic, players are required to draw a card from the bottom of the infection deck. To facilitate this, a secondary area was added to this deck. When players press this secondary area, the bottom card is drawn rather than the top card. Also as part of the same epidemic event, players are required to shuffle all of the cards in the infection discard pile, and stack those cards back on top of the infection deck. A button was added to the area of the infection discard pile, which when pressed, shuffles any infection card object within the infection discard area and stacks the shuffled cards back on top of the infection deck (Figure 5.4).

The low-automation interface also sets up the game for players by placing the starting game pieces around the board, shuffling the decks of cards, and placing initial cards into players’ hands, as per the rules of the game. This automated setup was provided in order to allow quicker
5.2 Setting and Apparatus

The study was a collaboration between groups at the University of Waterloo in Waterloo, Ontario and Queen’s University in Kingston, Ontario. The study was run at a research laboratory at Queen’s and a mixed-use laboratory in a museum in Waterloo. The experimental software was fully designed and implemented by myself, though both games exist as commercially available board games. The study was designed and carried out in conjunction with our co-researchers at Waterloo. The collaborative design of the study included selecting the methods which we would use to collect data, and deciding on the events which were of interest to us for an open video coding process [59] (see section 5.5). The questionnaires were designed by our co-researchers in Waterloo. Each site collected data from exactly half of the participants.

In both locations, participants were seated at a digital tabletop computer (see Figure 5.5). The computer was shut off for games played with the physical board. Anoto pen technology [25] was used for user input, and a dual top-mounted projector setup, with a combined resolution of 1024x1536, was used to display the games. At Queen’s, an oval table measuring 105x200cm was used, with a projected area of 77x116cm. At Waterloo, a rectangular table measuring 80x120cm with a projected area of 57x82cm was used. The same game software, programmed in C#, was used at both locations. Similar computer hardware was used at each site.
5.3 Participants

Twelve groups of three players were recruited for the Pandemic trials, and twelve groups of two players were recruited for the Checkers trials, for a total of 60 participants. Participants who played Pandemic ranged in age from 19 to 49 with a median age of 26. Of the Pandemic players, 28 participants were male and 8 were female. Participants who played Checkers ranged in age from 19 to 31 with a median age of 22. Of the Checkers players, 14 participants were male and 10 were female. Participants consisted primarily of math, engineering and science students. Recruiting material asked for participants familiar with the game that they would play; however,
a number of players reported in their background questionnaire that they were casual players of the game, having only played it once or twice, and thus needed a reminder of the rules. Recruiting material was posted around university campuses, and at board game and hobby stores. Recruiting emails were sent to university mailing lists and to members of an online board gaming community. Therefore, our participant pool consisted of either students and of experienced board game players.

Groups who played Pandemic were primarily recruited as self-formed groups of three (i.e. groups were composed of players who already knew each other). This was done in an attempt to reproduce and observe the social setting of board games. However, of the twelve Pandemic groups, three groups consisted of a group of two who signed up together, and an individual who we added to the group. Ten groups who played Checkers were individuals who we paired together. Two groups who played Checkers signed up as pairs. The approval letter to run this user study, which we received from the General Research Ethics Board at Queen’s, can be seen in Appendix E.

5.4 Procedure

The study consisted of two sessions. During the first session, which lasted approximately two hours, players started by filling out a background questionnaire of data such as their age, gender and occupation, as well as their gaming habits (see Appendix A). Players then played the original physical board game. After playing the original board games, players played either the low-automation interface or the high-automation interface. Each game was videotaped.

After each game, players filled out a questionnaire consisting of 7-point Likert scale questions [63] about enjoyment and perceived awareness during the games (see Appendix B and Appendix C). The questionnaires given after each of the digital versions also included two free-
CHAPTER 5: EXPLORING THE EFFECTS OF AUTOMATION IN DIGITAL TABLETOP GAMES

form written questions. These questions asked participants to comment on which aspects of the interfaces they felt helped gameplay, and which aspects they felt hindered gameplay. At the end of this first session, players were compensated $10 for their time, and a second session was scheduled.

The second session, which was scheduled on a different day with the same group, lasted approximately one hour. Players played either the high-automation interface or the low-automation interface, whichever one they had not played yet. The first digital interface they played was balanced for order, but they always played the physical game first. After this final game, they filled out the same post-conditions questionnaire, including the free-form written answer questions. At the end of this session, an informal interview with the participants was videotaped (note that these interviews were not used in our analysis, and we therefore did not draw any of the results which we will present in Chapter 6 and Chapter 7 from these interviews). Participants were each compensated $10 for their time, for a total of $20 per participant.

5.5 Data Collection and Analysis

For this study, we collected data from three sources; the 7-point Likert scale and written answer questionnaire data, the video recording of each of the games, and interaction data collected through logging within the game software.

Audio and video data were collected during each game, using a stand-alone video camera. An open coding process [59] was used to identify interesting occurrences throughout the course of each game. Codes included players having a discussion unrelated to the game and players being confused about automated rule enforcement. An initial set of codes was decided upon. The videos and the code sets were given to two people (one at Queen’s and one at Waterloo) brought into the project specifically to code the video. We did not code the video
CHAPTER 5: EXPLORING THE EFFECTS OF AUTOMATION IN DIGITAL TABLETOP GAMES

ourselves, as it may have invalidated our results. Following the open coding procedure, the code set was iterated on over a series of meetings between the researchers and the video coders. During these meetings, we reviewed and modified the code set based on events that the coders had observed in the video data. The final code set can be seen in Appendix D.

The audio and video data analyzed (or “coded”) differed between the checkers and Pandemic games. Games of Checkers were coded in their entirety. For Pandemic, critical incident analysis [19] was performed to select non-overlapping intervals of each video which were interesting to us. The first five minutes and the last five minutes of each game, as well as the seven minutes surrounding a randomly selected epidemic event (a significant in-game event in Pandemic) were coded. Video code data was weighted for the length of games for Checkers, but not for Pandemic as we always coded the same length of video. For example, two occurrences of a particular event of interest during a 2-hour game of checkers would have the same contribution to the overall average as 1 such event in a 1-hour game. Repeated-measures analysis of variance (RM-ANOVA) statistical tests were conducted to examine differences between video code data. Post-hoc pairwise comparisons were performed with Bonferroni adjustment, for an alpha-value of $\alpha = 0.05$.

The results of the 7-point Likert scale questionnaires were compared across interfaces using the Friedman statistical test. Post-hoc Wilcoxon Signed-Rank tests with Bonferroni adjustment were performed for an alpha-value of $\alpha = 0.05$. Similar comments within the free-form written answer questions were counted for comparison between interfaces. In order to ensure that there was not a test of group on questionnaire responses, we first measured the intraclass correlation [13] of response across all participants, for both Checkers and Pandemic. These were
CHAPTER 5: EXPLORING THE EFFECTS OF AUTOMATION IN DIGITAL TABLETOP GAMES

found to be 2.1 for Pandemic and 2.3 for Checkers. We considered these values negligible, and proceeded with the Friedman test analyses.

Data logged by the games themselves were used to augment other findings. We compared the amount of work required to play the digital versions of Pandemic by comparing the total number of pen presses per minute across interfaces. An RM-ANOVA was used to compare these values. Data logged by the games also provided us with information about which player took which action, as the pens had unique IDs. We used this information to assess equity of participation by computing a Gini coefficient [55] for each game (a measure of equity). Again, RM-ANOVA analysis was used to assess possible differences in Gini coefficients between game implementations.

5.6 Conclusion

In this chapter, we have detailed the design of a mixed-methods user study to assess possible differences in the user experience between three versions of either the abstract strategy board game checkers or the cooperative board game Pandemic. The first version was the original board game. The other two versions were digital tabletop implementations with different degrees of game automation. In the next chapters we will present and discuss the results from this user study, which we gathered from questionnaire responses, logged game data and coding of audio and video data.
Chapter 6

Results from Checkers Trials

The results collected during the Checkers trials of the user study revealed a number of effects of automation and digitization on gameplay. Players tended to prefer the high-automation interface of Checkers, and wished that some of the automated features had been present in the low-automation interface. Automation of routine activities, automation of rule enforcement, and indicators of the current phase of the game helped gameplay. Finally, automation and digitization did not have a negative impact on the sociality of the original game. In this chapter, we present the results which were collected during the checkers trials of the user study.

It should be noted that all results from the free-form comments sections of the questionnaires are spontaneous. Therefore when we report the number of similar comments, it is possible that more participants felt the same way, but did not report it. As indicated in section 5.3, the statistics in this section were based on data from N = 24 players for each interface (12 groups of 2 players per group). See section 5.5 for a discussion of the statistical tests which we used to analyze the results.

6.1 Effort and Enjoyment

There was a significant difference in agreement with the statement “I felt that it took a lot of effort to play the game” ($\chi^2=10.548$, $p=0.005$). Players felt it took significantly more effort to play the low-automation interface (M=3.85, SD=2.04) than the high-automation interface (M=3.38, SD=1.64, $p=0.013$) or the physical game (M=3.17, SD=1.71, $p=0.016$). No significant difference for this statement was found between the high-automation interface and the physical game ($p=0.295$). However, the greater effort in the low-automation interface was not
CHAPTER 6: RESULTS FROM CHECKERS TRIALS

accompanied by a significant effect on players’ enjoyment of the game, as no significant difference was found in agreement with the statement “I had fun playing this game” ($\chi^2=2.800$, $p=0.247$). Based on the written-comments part of the questionnaires, it appears that players generally preferred the high-automation interface version of checkers. Of the 24 participants, three noted that the high-automation interface was easy to play and seven noted that the game was faster. Three participants noted that the low-automation interface was easy to play.

6.2 Acting as an Impartial Referee

There were few events that revealed a significant effect of automation on behaviors related to rule enforcement. No significant difference was found between the numbers of occurrences of players consulting the rulebook ($F(1.154,12.689)=3.925$, $p=0.065$); players making a rule correction ($F(1.248,13.724)=1.257$, $p=0.294$); infractions of house rules the players had established ($F(2,22)=0.478$, $p=0.626$); or infractions of official game rules ($F(2,22)=2.135$, $p=0.142$). However, a significant difference was found across interfaces in the number of occurrences of players establishing a rule ($F(2,22)=6.992$, $p=0.004$). This occurred significantly more in the physical interface ($M=1.008$, $SD=1.031$) than the high-automation interface ($M=0.000$, $SD=0.000$; $Z=0.298$, $p=0.018$). No significant difference was found between the low-automation interface ($M=0.756$, $SD=0.979$) and the high-automation interface ($Z=0.283$, $p=0.065$), or the physical game ($Z=0.260$, $p=1.000$). We also observed a significant difference in the number of occurrences of the players being confused by automated rule enforcement ($F(1, 11)=6.450$, $p=0.027$). This occurred significantly more frequently in the high-automation interface ($M=1.591$, $SD=2.170$) than in the low-automation interface ($M=0.000$, $SD=0.000$; $Z=0.626$, $p=0.082$), or the physical game ($M=0.000$, $SD=0.000$; $Z=0.626$, $p=0.082$). No significant difference was found between the physical game and the low-automation interface.
CHAPTER 6: RESULTS FROM CHECKERS TRIALS

(Z=0.000, p=NS). Of the 24 participants, 14 stated in the free-form comments that rule enforcement helped game play, and six liked that turn order was enforced.

6.3 Performing Complex or Routine In-Game Activities

In the free-form comments, players expressed a preference towards the automation of routine in-game activities. Of the 24 participants, six liked the automatic capture of pieces; five liked that pieces snapped to location. Participants also noticed that some of these features were missing from the low-automation interface; four players did not like the lack of snapping to location; three did not like that they had to remove captured pieces themselves. These results highlight the need for the automation of routine activities.

6.4 Providing Improved Visualizations through Digital Media

Of the 24 participants, nine noted that the game-state cues in the high-automation interface helped gameplay. Participants also noticed when game-state indicators were missing; five participants noted that the lack of an indication of the number of pieces that each player has captured hindered gameplay in the high-automation interface; four participants did not like the lack of indicators in the low-automation interface, further highlighting the need for visualizations of every aspect of gameplay.

Despite this general preference towards visual indications of the game state, our analysis of players’ questionnaire responses revealed that the interface did not have a significant effect on players’ awareness of what was happening in the game. No significant difference was found in player agreement to the following statements; “I was aware of the other player's actions” ($\chi^2=4.133$, p=0.127); “when the other player took action, I was always aware of his/her motivations for doing so” ($\chi^2=1.660$, p=0.436); “when taking my turns I was always aware of my
CHAPTER 6: RESULTS FROM CHECKERS TRIALS

play options” ($\chi^2=5.143$, p=0.076); and “I always understood what was happening in the game” ($\chi^2=0.246$, p=0.884).

6.5 Technology

The majority of feedback for the low-automation interface was based around the technology; six participants noted that the technology was appealing; three liked the brightness, and three liked the size of the display. However, three players liked that the low-automation interface resembled the board game. One of the major complaints that we received for both interfaces was the use of pens for input; seven participants in the high-automation interface and five in the low-automation interface claimed that they had trouble with the pens. Three participants did not like the lack of tactile feedback in the digital versions.

6.6 Sociality

Our video code analysis revealed that there was little effect on the sociality between players across interfaces. No significant differences were found across interfaces in the number of occurrences of players discussing the game (F(2,22)=0.552, p=0.234); players having a discussion unrelated to the game (F(2,22)=0.400, p=0.675); players looking at the other player on their own turn (F(2, 22)=2.944, p=0.074); players gesturing at the board (F(2, 22)=2.000, p=0.159); and players looking at the active player when it is not their own turn (F(1.242, 13.666)=0.024, p=0.919).

6.7 Conclusion

In this chapter we presented results, which we collected during the Checkers trials of the user study described in Chapter 5. We found that providing indicators of the current game state, automating routine activities, and enforcing rules helped gameplay and that the high-automation
interface reduced the amount of effort for players. We also found that the digitization or automation of Checkers did not have a negative effect on sociality. In the next chapter we present results collected during the Pandemic trials of the user study.
Chapter 7

Results from Pandemic Trials

In this chapter, we present the results of the user study of the different interface versions of the game Pandemic. The first four sections present results related to the potential benefits of digitization of board games (section 2.6). Briefly, these include: performing complex or routine in-game activities, acting as an impartial referee, automating game progression and providing improved visualizations. We then present results related to the digital representation of physical objects, and finally results related to social interaction between players. In general, we found that digitization and automation of a board game can benefit gameplay. However, if not handled properly, automating a board game can lead to player frustration and a lack of game-state awareness. We also found that it is important to leave an inactive border around the active play area to store digital and physical artifacts. Finally, we found that automating a board game does not have a negative impact on the sociality of the original game, making digital tabletops a promising platform for social gaming.

As in Chapter 6, note that all results from the free-form comments sections of the questionnaires are spontaneous. When we report the number of similar comments, it is possible that more participants felt the same way, but did not report it. As indicated in section 5.3, the statistics in this section were based on data from N = 36 players for each interface (12 groups of 3 players per group). See section 5.5 for a discussion of the statistical tests that we used to analyze the results.
CHAPTER 7: RESULTS FROM PANDEMIC TRIALS

7.1 Performing Complex or Routine In-Game Activities

In section 2.6, we proposed that automation of complex or routine in-game activities are a potential benefit of board game digitization. We designed the high-automation interface of Pandemic to automate many of these activities, such as drawing cards into a player’s hand, and carrying out the events that occur at the end of a player’s turn. While we did find that many of these automations helped gameplay, we also found that taking control away from the players led to awareness deficits. In this section, we report on the results related to the automation of complex or routine activities.

7.1.1 Game Length and Number of Pen Interactions

Our analysis of the computer logs revealed that the high-automation interface tended to reduce the overhead required to play a game versus the low-automation interface. The RM-ANOVA comparing game completion time found a significant difference between interfaces (F(2,22)=4.952, p=0.017). Follow-up pairwise comparisons showed that there was no significant difference in game length between the physical game interface (M=37min27sec, SD=8min13sec) and either the low-automation interface (M=44min19sec, SD=12min20sec, p=0.323), or high-automation interface (M=29min50sec, SD=11min4sec, p=0.256). There was no significant difference in game length between the high-automation interface and the low-automation interface (p=0.079).

The RM-ANOVA comparing pen interaction across the low and high-automation interfaces indicates that players made significantly more pen interactions with the low-automation interface (M=258.33 pen actions, SD=59.40 pen actions) than with the high-automation interface (M=78.47 pen actions, SD=24.38 pen actions), (F(1,11)=96.275, p<0.0005). The game-time and
frequency-of-pen-interaction results indicate that the high-automation version requires less overhead than the low-automation version to play.

7.1.2 Effort and Enjoyment

Participants reported that automation negatively impacted gameplay in a number of ways. The Friedman test comparing agreement with the statement “I had fun playing this game” across the three interfaces found a significant difference in participant responses ($\chi^2=6.162$, $p=0.046$). Follow-up pairwise comparisons showed that there was no significant difference in average responses between the low-automation interface ($M=6.22$, $SD=0.866$), versus either the physical game ($M=6.39$, $SD=0.728$, $p=0.468$), or the high-automation interface ($M=5.89$, $SD=1.090$, $p=0.348$). No significant difference was found between the high-automation and the physical game ($p=0.069$). Similarly, the Friedman test comparing agreement with the statement “I felt that it took a lot of effort to play the game” across the three interfaces found a marginally significant difference in participant responses ($\chi^2=5.964$, $p=0.051$). Follow-up pairwise comparisons showed that average responses for the physical game ($M=3.11$, $SD=1.526$) were significantly less than for the high-automation interface ($M=4.11$, $SD=1.635$; $Z=-2.827$, $p=0.005$), or the low-automation interface ($M=4.14$, $SD=1.839$; $Z=-2.881$, $p=0.004$). No significant difference was found between the high and low-automation interfaces ($Z=0.092$, $p=0.927$).

In the free-form comments section of the questionnaires, numerous participants reported that the automation improved their game experience in a number of ways; of the 36 participants, eleven people reported liking that disease cubes were automatically placed; eight people in the high-automation interface and six people in the low-automation interface reported liking that the game was automatically set up or cleaned up; seven people reported liking that cards were automatically drawn into their hands; six people for the high-automation interface and nine
CHAPTER 7: RESULTS FROM PANDEMIC TRIALS

people for the low-automation interface reported liking that the game automatically shuffled decks of cards.

7.1.3 Players’ Contributions to the Game

Participants reported feeling less satisfied with both their own and others’ contributions to the game with the high-automation interface. A significant difference was found in average responses to “I felt I was able to make effective contributions to the game” ($\chi^2=8.024$, $p=.018$). Average responses in the physical game ($M=6.31$, $SD=0.749$) were significantly higher than those for the high-automation interface ($M=5.69$, $SD=1.411$; $Z=-2.813$, $p=0.015$). There was no significant difference in the responses between the low-automation interface ($M=6.36$, $SD=0.833$) and those for both the high-automation interface ($Z=-2.338$, $p=0.057$) and the physical game ($Z=-0.351$, $p=2.178$). A significant difference was found in average responses to the statement “I am satisfied with the other players’ contributions to the game” ($\chi^2=9.406$, $p=.009$). Average responses for the high-automation interface ($M=6.31$, $SD=0.951$) were significantly lower than those for both the low-automation interface ($M=6.53$, $SD=0.654$; $Z=-1.476$, $p=0.42$) and the physical game ($M=6.78$, $SD=0.540$; $Z=-2.749$, $p=0.018$). No significant difference was found between the low-automation interface and the physical game ($Z=-2.029$, $p=0.126$).

7.1.4 Automated Infection Events and Player Awareness

After automated infection phases or epidemics, players were often confused about the current game state. This confusion was most evident when players paused after watching the animations. The process of ‘catching up’ to changes in the high-automation interface was evident in cases where all players were silent while trying to understand automated game events. The RM-ANOVA comparing the number of player pauses found a significant difference between interfaces ($F(1,11)=8.189$, $p=0.015$). Pairwise comparisons revealed that players paused
significantly more times in the high-automation interface (M=1.08 pauses, SD=1.311 pauses) compared to either the low-automation interface (M=0 pauses, SD=0, p=0.015)), or the physical game (M=0 pauses, SD=0, p=0.015). No difference was found between the low-automation and physical interfaces.

Questionnaire responses also indicated which specific types of automation the participants noted negatively impacted gameplay; 30/36 people reported that automated game events hindered gameplay and that the high-automation interface did not sufficiently support game-state awareness. The Friedman test comparing agreement with the statement “I always understood what was happening in the game” across the three interfaces found a significant difference in player responses ($\chi^2=7.072$, p=0.029). Follow-up comparison tests showed that players agreed less with this statement in the high-automation interface (M=4.81, SD=1.489) than in either the physical game (M=6.42, SD=0.841; Z=-4.279, p<0.0005), or the low-automation interface (M=6.53, SD=0.810; Z=-4.091, p<0.0005). No significant difference was found between the low-automation interface and the physical game (Z=-0.67, p=1.509). The data analysis showed no difference across interfaces in players’ agreement with the statement “I was always aware of the other player’s actions” ($\chi^2=0.576$, p=.750, n.s.), with an average rating of ~6.5 for all three interfaces.

### 7.1.5 Trust in the Digital Implementation

Participants sometimes speculated about the algorithms used to implement game features. There were instances where participants attributed some of the game events to software bugs, or even that a malicious computer was cheating them out of a victory. For example, one epidemic triggered a triple outbreak, leaving Group 2 on the brink of defeat with only a single red disease cube left. Player B then commented “That's cheating! Cheating board game!” Similarly, as Group
CHAPTER 7: RESULTS FROM PANDEMIC TRIALS

5 was running out of red disease cubes, they had the following discussion indicating their suspicion of a potential bias in the shuffling algorithm:

**Group 5: Low-Automation Interface**

C: Ho Chi Minh hasn't been actually drawn yet.
A: No it hasn’t. That is risky.
C: But Seoul has a chance of being added back in, and the sorting algorithm is going to sort by color so red will come first.

[In fact, the software shuffles the cards randomly, and does not sort the shuffled cards in any methodical way]

7.2 Acting as an Impartial Referee

Enforcing the rules of a game can be a significant task for the players, as many games have dozens of rules to keep track of. The high-automation interface of Pandemic automates rule enforcement, ensuring that an illegal play cannot be made. Our results show that rule enforcement helps gameplay. However, it is important to implement the rules carefully, as players will not tolerate incorrectly implemented rules. In this section, we report results related to the automation of rule enforcement.

7.2.1 Reducing the Overhead of Rule Enforcement

Regardless of the interface used, groups tended to consult the rulebook frequently throughout the study. This practice is particularly relevant, since we recruited groups who were already familiar with the game. The RM-ANOVA comparing the number of times players discussed the rules across interfaces found a significant difference (F(1.252,13.776) = 6.804, p = 0.005). Follow-up pairwise comparisons found that players discussed the rules significantly less
with the high-automation interface (M=0.67 times, SD=0.958) than in either the low-automation interface (M=1.92 times, SD=1.782, p=0.032), or the physical game (M=4.5 times, SD=4.400, p=0.009). No significant difference was found between the low-automation interface and the physical game (p=0.068). Similarly, a significant difference was found across interfaces in the number of times players corrected one another’s rule infractions (F(2,22)=5.243, p=0.014). Players corrected each other’s infractions significantly less in the high-automation interface (M=0.67 times, SD=2.015) than in the low-automation interface (M=2.42, SD=2.392, p=0.010). No significant differences were found between the physical game and the high-automation interface (physical: M=1.75 times, SD=1.545; p=0.633), or the low-automation interface (p=0.414). The differences between the high-automation interface and the physical game can be partially attributed to a learning effect, since all groups played the physical game first. Thus players would have had the most opportunity to question rules while playing the physical game. Nine out of 36 participants commented that automated rule enforcement helped gameplay.

7.2.2 Incorrect Implementation of Rules

Six out of 36 participants reported that our implementation of Pandemic did not correctly support the play of ‘special cards.’ In the Pandemic board game, players may draw special cards into their hand. These cards describe events which affect the game board and help the players. The cards can be played at any time, even interrupting the in-game events at the end of a players turn. A number of groups decided that they would play a special card to interrupt an in-game event. However, this was not supported by our implementation, as these events were triggered automatically, and the players were unable to play the cards. Players in Group 3, for instance, were planning to use the ‘One Quiet Night’ only if the beginning of the in-game event revealed that they had drawn an ‘Epidemic’ card. In other words the players wanted to observe the
CHAPTER 7: RESULTS FROM PANDEMIC TRIALS

beginning of the event, and use this information to make the decision of whether to play the special card before the rest of the event was carried out. However, when an epidemic card was drawn, the players lost the game, and realized that they were not given an opportunity to play the special card. This is seen in the following conversation:

**Group 3: High-Automation Interface**

[After B finished his last move, the game displayed the message “We Lost: 8 outbreaks”]

C: Ohhh!!!!

A: Hahaha! Oh yeah!

C: That was brutal!

A: We were supposed to use one quiet night. [points at the card]

C: Look at that! [points to a location where many new disease cubes were placed]

A: That was part of the plan.

C: Ahhh!

A: Hahahaha!

C: We totally forgot. Because you cannot do it after you move.

A: That’s a slight grey rule implementation.

B: Yeah. I think so.

Researcher: What’s the {problem}? 

B: you are not allowed to play special event between epidemic and the infection.

Researcher: Before the epidemic gets totally resolved?

Players: Yeah
CHAPTER 7: RESULTS FROM PANDEMIC TRIALS

It is noted that this problem with the One Quiet Night card was a correctable fault with the program. There is no reason to suspect that this fault would have had a significant effect on the other results presented above, though the possibility should not be ruled out.

7.3 Automating Game Progression

Many games have complex game rounds in which a number of steps must be carried out before moving on to the next round. Keeping track of which phase the players are currently in can be a significant task. The high-automation interfaces of Checkers and Pandemic address this by keeping track of the game phase. We found that players verbally described their current actions less when playing the high-automation interface, than the low-automation interface or physical game. We also found that it can cause problems for players if they cannot choose the turn order, or if they cannot undo actions. In this section, we present results related to the automation of game progression.

7.3.1 Narration of Game Turn

Our video analysis revealed that participants often narrated the progression of games. For example, players often verbally counted their actions as they were carried out. The data analysis revealed that there was a significant difference across interfaces of the number of times players counted their actions (F(2,22)=16.191, p=0.001). Players counted actions significantly more in the physical game (M=8.17 times, SD=5.006) than in either the low-automation interface (M=3.00 times, SD=2.412, p=0.003), or the high-automation interface (M=5.00, SD=3.219, p=0.005). No significant difference was found between the high and low-automation interfaces (p=0.069).
CHAPTER 7: RESULTS FROM PANDEMIC TRIALS

Players also narrated in-game events such as the infection and epidemic phases of play. For these narrations, a significant difference was found across the three interfaces (F(2,22)=16.191, p<0.0005). Players narrated significantly less in the high-automation interface (M=4.92 times, SD=2.466) than in the physical game (M=12.58, SD=5.230, p=0.002), or in the low-automation interface (M=14.25, SD=5.083, p<0.0005). No significant difference was found between the physical game and the low-automation interface (p=0.302). These results may be attributed to the high-automation interface carrying out game events without player input, so there was less opportunity for players to narrate events as they occurred.

We also noted a qualitative difference in the types of narration used with the high-automation interface. In the physical game and in the low-automation interface, players actively narrated the steps of an in-game event as they were carrying it out. In the high-automation interface, narration became more reactive as players quickly described the changes that they were seeing to each other.

7.3.2 Undo Functionality

The high-automation interface prevented players from taking back their moves. However, when playing the physical game or low-automation interface, players commonly took back actions they had performed. The video analysis revealed that participants performed undo actions in 12 of 24 of the games in which this option was possible (physical game or low-automation interface). In the free-form comments, 18 of 36 participants reported that the lack of an undo function in the high-automation interface hindered gameplay. The undo function supports two types of activities: strategic planning and recovering from technical difficulties and slips.
Participants used the undo function, for instance, when discussing their strategy. For example, players in Group 2 decided to take back a move after discovering a more optimal order of moves:

**Group 2: Physical Interface**

B: I will cure Paris because it’s the most connected. [takes a disease cube off Paris]
A: You have to get…
B: Yeah. We are both…
C: Actually, I will be coming to Paris anyway so I can fix Paris. You should fix Madrid. I cannot get Madrid.
B: Then I will. [takes a disease cube off Madrid and puts it on Paris, effectively taking back the action in which a disease cube was taken off of Paris]

The benefit of undoing actions was demonstrated when groups played the low-automation interface after the high-automation interface. While planning their actions, players from Group 6 decided to change their strategy. When they were playing in the low-automation interface, players dragged game pieces back as if they were performing an undo in the physical game.

**Group 6: Low-Automation Interface**

C: [drags a research station to the city]
A: Is that what we want to do?
C: I don’t know. [pauses for 2 seconds] It’s not too late to change your mind.
A: That’s true! There’s a back button in this game.
C: Back! [puts the research station back]
CHAPTER 7: RESULTS FROM PANDEMIC TRIALS

Moreover, undo actions were used when technical issues occurred or when players’ own slips led to mistakes. Eight out of 36 participants commented that actions taken by mistake hindered gameplay in the high-automation interface. In the following example, a player drags his pawn to another city in order to illustrate his planned moves, without realizing that this would commit him to take the action.

**Group 6: High-Automation Interface**

B: [mocks up the discussed move by dragging his pawn from Riyadh to Kinshasa and holding his pen]

C: You can build the center there and then move …

A: In Riyadh? [point]

C: No no. Calculate how many turns it would take to do either.

B: [drags his pawn back to Riyadh] 1, 2, 3, 4 [points and counts]

C: Oh! You just… Oh…

B: What?

C: You just cleaned Riyadh!

B: Did I?

C: Yeah.

B: [clicks on the pawn to see number of turns left] Darn!

[Players pause for 3 seconds]

B: Well…

[Players pause for 4 seconds]

C: Do you have anything that lets you fly there?

B: like a card? [checks his hand]
CHAPTER 7: RESULTS FROM PANDEMIC TRIALS

[Players pause for 5 seconds]

C: I mean we can get 1 more but we cannot get 2 more {outbreaks}.

B: I do. I can fly there from Cairo. And since black is already cured, I don’t really need Cairo. Plus it reduces my cards anyways so I don’t have to discard. So I think let’s do that.

7.3.3 Turn Order and Game Setup

The video analysis revealed several instances of confusion about the game state at the beginning of the game, such as whose turn it was and what the initial placement of game objects was. However, no significant differences in such player confusion were found between interfaces (F(2,22)=2.424, p=0.112). The high-automation interface determined each player’s starting color and their respective order of play. Players were often confused when they had decided on player colors and turn order which did not agree with the game. For example, players from Group 3 commented that the game did not know where they were sitting, after one player was reminded that it was he was the starting player.

Group 3: High-Automation Interface

B: You are {the current player}. [points at the board]

C: Me? Oh it goes this way. [makes a counter-clockwise gesture]

B: Yeah.

C: Oh, it doesn’t know .

A: It doesn’t know. Hahaha.

C: It doesn’t know where we are sitting.

This and earlier examples of conversations and comments highlight the advantage of carrying out user tests, like those reported here, during the development of digital versions of
CHAPTER 7: RESULTS FROM PANDEMIC TRIALS

games. This is particularly important for games with automated features, in order to work out various bugs and to optimize the features.

7.4 Providing Improved Visualizations through Digital Media

The digital tabletop platform allows for board games to be augmented with digital media. The high-automation interfaces included visualizations in order to provide awareness to the users of the game state. We also took advantage of the size of our projection area to have the active game area take up more of the table. We found that visualizations tended to help gameplay, but that our animations were too short to convey the information we had hoped they would. We also found that it is important to provide an inactive border around the game area. In this section, we present results related to visualizations on the digital tabletop.

7.4.1 Conveying Game Information Through Visualizations

Participants weakly endorsed the animations in the high-automation interface, with only one participant reporting in the questionnaires that the animations helped gameplay. Of the 36 participants, five noted that having arrows on the board as a visual indication of which city cards were in the discard pile helped gameplay, while six players noted that not being able to manually look through the discard pile hindered gameplay in the high-automation interface. Four players noted that the lack of an indicator for a player’s remaining actions hindered gameplay in the low-automation version. Six players commented that they liked the feature of highlighting the path their piece would take prior to completing the move upon releasing the pen. Three players commented that they liked the displayed counters indicating the number of remaining pieces.
CHAPTER 7: RESULTS FROM PANDEMIC TRIALS

7.4.2 Display Size and Use of Space

One of the most noticeable differences between the physical game and the digital interfaces was the use of nearby space for storage of game pieces. In the physical game, spare disease cubes were often spread around the board, where all participants could access them when needed (see Figure 7.1). However, this was not possible in the digital interfaces. Players also used the space above and around the table to hold their private hands of cards when playing the physical, while in the digital games, these hands of cards were displayed in the play area. Of the 36 participants, four commented that the board was too large in the low-automation interface. Five participants commented that the lack of space for game objects and cards hindered gameplay in the high automation interface while three participants had the same comment for the low automation interface.

Figure 7.1: When playing with the physical interface, participants frequently used the space surrounding the game board to store unused game pieces. This was not possible in the digital versions.
7.5 Representing Physical Objects Digitally

We attempted to design both digital interfaces for Pandemic to allow players to be able to take whatever actions were required to play the game, whether it involved manipulating digital artifacts, or entering a command through menus or widgets. Participants noted that there were aspects of the digital interfaces which they wished were more like the physical game. Participants also reported aspects of the low-automation interface that they wish had some of the streamlined aspects of a digital platform. We now present results relating to how we represented player actions in the digital interfaces, which would ordinarily be carried out by players by manually moving physical objects.

7.5.1 Emulating the Physical Board Game

Certain results in the user trials exposed ways in which digital implementations of player actions would have been better if they had more closely resembled those in the board game. The high-automation interface did not allow players to sort the cards displayed in their hand widgets, though this was possible in the low-automation interface and the physical game. There was a significant difference in the number of times players rearranged cards in their hands across the three interfaces ($F(2, 22) = 6.323, p = 0.007$). Players rearranged cards in their hand significantly less in the high-automation interface (M = 0.00, SD = 0.000) than in the low-automation interface (M = 2.42, SD = 2.234, p = 0.004), and the physical game (M = 2.42, SD = 2.275, p = 0.003). There was no significant difference between the low-automation interface and the physical game (p = 1.00). Note that because it was impossible to rearrange cards in the high-automation interface, the comparisons between the high-automation interface and the low-automation interface or the physical game hold little weight. However, the results do point out rearranging
CHAPTER 7: RESULTS FROM PANDEMIC TRIALS

cards as an interaction which players ordinarily carry out but which was missing from the high-
automation interface.

Of the 36 participants six did not like that it was only possible to move one piece at a
time per pen in the low-automation interface, as opposed to being able to pick up and drop off
multiple game pieces in the physical game. As reported in section 7.4.1, six players noted that not
being able to manually look through the discard pile hindered gameplay. Though these results
reveal shortcomings of the high-automation interface, six of the 36 participants reported liking
that the low-automation interface was similar to the physical game. We interpret this as meaning
that, if well-executed, emulating player interactions from the physical game can be a good
approach to designing digital interfaces for board games. However, such interfaces should still
offer some of the streamlined benefits of digitization.

7.5.2 Providing the Benefits of Digitization

Other results exposed how providing automation of digital game objects might have
streamlined interactions. Players often fine-tuned the position of pieces without actually changing
their state within the game. A significant difference was found in the number of times players
adjusted the position of pieces across the three interfaces (F(2, 22) = 10.167, p = 0.001). This
occurred less frequently in the high-automation interface (M = 9.42, SD = 3.554) than in the low-
automation interface (M = 24.75, SD = 10.922, p < 0.0005), or the physical game (M = 20.25, SD
= 15.835, p = 0.020). No significant difference was found between the low-automation interface
and the physical game (p = 0.245). Of the 36 participants, three noted that the lack of snapping to
location in the low-automation interface hindered gameplay. 14 participants did not like manually
dragging pieces in the low-automation interface. These results are further backed up by some of
the results presented in section 7.1.2, in which we reported that players liked many of the routine
activities which were automated by the game. However, awareness deficits arose when game objects were automatically placed on the board during in-game events at the end of a player's turn. This may be because the animations to provide awareness of these events did not properly emulate the process of the players physically carrying out the actions themselves. Providing more player control, or animating game objects to appear to be moving across the board as in the physical game, would likely improve players’ awareness of these automated events.

7.6 Sociality

One of the original motivations for this research was the likelihood that digital tabletop versions of board games would maintain the important benefit of sociality associated with board games, while introducing some of the streamlining and excitement associated with video games. As discussed in section 2.1.1, video games lack some of the aspects of board games to achieve this level of sociality, even when played by a collocated group of players. We were interested in confirming whether the social advantages of board games can, in fact, be preserved in versions of board games implemented for a digital tabletop. Our results show that digitization and automation did not have a negative impact on sociality. The following results report the effect of game automation on sociality in board games.

7.6.1 Maintaining Sociality of the Physical Game

One indicator of sociality is the frequency of communication between players that is unrelated to the game itself. As communication between players becomes more difficult, communication unrelated to the game becomes less frequent while communication related to the game persists [47]. We coded for instances of players having discussions that were not related to the game, and found no significant difference between interfaces (F(2, 22) = 1.457, p = 0.254). However a significant difference was found across interfaces in the amount of communication
related to the game (F(1.184, 13.026) = 18.416, p = 0.001). We also coded for discussions related to interacting with the game. We had initially coded for discussions related to the game itself, including strategy, but this was overwhelming to code as strategic discussions occur almost constantly in Pandemic. Discussions related to interacting with the game occurred significantly less in the physical game (M = 0.00, SD = 0.000) than in the high (M = 5.50, SD = 3.261, p < 0.0005) or low-automation (M = 2.42, SD = 1.564, p < 0.0005) interfaces. Such discussions occurred significantly less in the low-automation interface than in the high-automation interface (p = 0.024). There was no significant difference in agreement with the statement “I enjoyed our team dynamics throughout the game (χ² = 5.964, p = 0.051). These results indicate that all versions of Pandemic maintained similar levels of sociality.

7.6.2 Equity of Participation

Other results revealed differences in the equity of participation across interfaces. We coded for instances of a player assisting the current player with carrying out actions, such as placing disease cubes, or moving the current player’s piece for them. A significant difference was found across the three interfaces (F(2, 22) = 14.32, p < 0.0005). Players assisted each other significantly less in the high-automation interface (M = 2.25, SD = 2.006) than in the physical game (M = 4.75, SD = 2.864, p = 0.007), or the low-automation interface (M = 8.83, SD = 4.086, p = 0.001), and significantly less in the physical game than in the low-automation interface (p = 0.014). A significant difference was found in agreement with the statement “I felt I was able to make effective contributions to the game” across the three interfaces (χ² = 8.024, p = 0.018). Players agreed less when using the high-automation interface (M = 5.74, SD = 1.40), than when using the physical game (M = 6.31, SD = 0.75; Z = -2.813, p = 0.015). No significant difference was found between the low-automation interface (M = 6.30, SD = 0.91) and the physical game.
CHAPTER 7: RESULTS FROM PANDEMIC TRIALS

(Z = -0.351, p = 2.178) or the high automation interface (Z = -2.338, p = 0.057). There was also a significant difference in agreement with the statement “I was satisfied with others’ contributions to the game” ($\chi^2 = 9.406, p = 0.009$). Players agreed less in the high-automation interface (M = 6.34, SD = 0.94) than in the physical game (M = 6.78, SD = 0.54; Z = -2.749, p = 0.018), or the low-automation interface (M = 6.49, SD = 0.69; Z = -1.476, p = 0.42). No significant difference was found between the physical game and the low-automation interface (Z = -2.029, p = 0.126).

We also performed an analysis of the relative number of pen presses between players in the digital conditions. Gini coefficients (a measure of equity, as indicated in section 5.5), were calculated for the pen press numbers as a test for the equity of participation. Our RM-ANOVA results for the Gini coefficients showed that there was no significant difference in equity of pen presses across the conditions (F(1, 11) = 0.115, p = 0.741).

7.7 Conclusion

The study results collected during Pandemic trials uncovered interesting effects of each of the four potential benefits of board game digitization. In particular, the automation of in-game activities reduced the time and perceived effort required to play games, but negatively impacted participants’ awareness and enjoyment of the game. Similarly, automation of rule enforcement removed the overhead for players to enforce the rules themselves, but an incorrectly implemented rule caused players frustration in some cases. Automation of game progression also saved players time and effort; however, the results revealed cases where players were confused about the state of the game. Participants had mixed opinions about the animations in the high-automation interface. Finally, groups playing with both digital interfaces experienced difficulty with the use
of physical space. In the next chapter we discuss the results which we have presented in this and the previous chapter.
Chapter 8

Discussion

Our results reveal that the digitization and automation of board games for the digital tabletop platform has the potential to streamline gameplay while maintaining sociality. However, there is a danger of negatively impacting the player’s experience. In this chapter, we discuss these trade-offs and their implication on the design of board games for digital tabletops.

8.1 Automation of Complex or Routine Activities

During the study, we observed that automation of in-game activity reduced the number of pen interactions required to play the game, but that certain types of automation had a negative impact on players’ enjoyment and understanding of the game. Our results suggest two pitfalls when designing interfaces for board games on digital tabletops.

First, players were frustrated by the restrictive nature of the high-automation interface. Players often wanted to perform activities such as sorting the cards in their hands or looking through discard piles, but this was only possible when playing the low-automation interface or the physical game. Designers must look for a balance between providing automation to streamline gameplay, and providing expressive interactions that allow players to perform the common actions from the original board game.

Second, players were often confused and frustrated by the automated events carried out at the end of each player’s turn. These included drawing cards into players’ hands and placing disease cubes around the board. These also included card interactions specific to Pandemic, such as drawing a card from the bottom of the infection deck, shuffling the infection discard pile, and placing the shuffled discard pile back on top of the infection deck. The automation of these
activities led to deficits in players’ awareness of the state of the game. This lack of awareness occurred because players could not manage the progression of the game at their own pace. In some instances, such deficits occurred even though the automation action was animated in an attempt to provide players with awareness cues. However, the animations proved to be too short to properly inform players about changes in the game state. It was difficult for players to quickly scan the board and see the small animations taking place in a number of locations. Ultimately this led to a negative impact on players’ enjoyment, understanding of the game state, and satisfaction with their own and other player’s contributions to the game.

8.2 Automation of Rule Enforcement

We coded for behaviors related to the automation of rule enforcement, and found that players consulted the rulebook significantly less in the high-automation interface than the low-automation interface or the physical game. This suggests that automation of rule enforcement reduces confusion around the game rules. However, many players were frustrated with an incorrectly implemented rule (see section 7.2.2), illustrating the attention to detail that must go into correctly implementing the original game’s rule set.

Taking the control of rule enforcement away from players also reduces flexibility regarding house rules. In a social setting, board game rules are often not interpreted in a rigid way. When playing the physical game, the players can simply manipulate the physical objects, adhering to whatever rule set that they find the most fun. This option is possible in the low-automation interface, but not in the high-automation interface. However, accidently making an illegal play can be upsetting to players. Often when playing Checkers, players would ignore, or be unaware of the rule which states they must make a capture on their turn if one is possible. While some Checkers players find it more fun to play with the house rule in which capturing is not
required, many of our participants were interested to discover the official rule for the first time when playing the high-automation interface. Similarly, some abstract strategy games such as Chess and Go have variants which are playable with the physical components of the original games, but would not be possible in a version with automated rule enforcement, unless those variants were specifically implemented.

We suggest that automated rule enforcement in a digital version of a board game may be appropriate for a certain audience, but lacks the flexibility which contributes to the popularity of games such as Monopoly [46]. Overall automated rule enforcement did streamline gameplay, so it is likely a good feature to have in some form. However, if a game has commonly played house rules, it is important to be aware of these and include the option to play with them. On the other hand, when playing a highly competitive game, such as Chess, players may only be interested in playing with the correct rules. Designers should carefully consider their audience when implementing rule enforcement.

### 8.3 Granularity of Game Progress Automation

As we have described, the high-automation interfaces for Checkers and Pandemic automatically manage progression of the games by enforcing the current phase and triggering game events. Players had problems with our approach at automating game progression. First, players were unable to perform undo actions, in which the previous action that a player or the computer performed is taken back. This is a behavior often permitted by social protocol, despite the fact that performing an undo action is technically contrary to the rules of the game. This was often something players wanted to do to plan strategically, or to take back a poor move. It also presented an issue when players would accidentally make the wrong move due to interface issues, or the unreliability of the pen input.
CHAPTER 8: DISCUSSION

Second, players were not able to interrupt the automated game events in order to play special cards. This was an error in the implementation, since in the original game players can play special cards to interrupt game events at the end of a player’s turn.

Finally, players were often confused by the automatic selection of turn order at the beginning of the game. The turn order was dictated directly by the player colors and the pens that players were holding. Whereas, the first player of the board game is often determined randomly (or by “who was sick last” if the players wish to follow the rulebook rigidly), with turn order of subsequent players determined by their orientation around the table, generally progressing in a clockwise direction.

Video data showed that the moderation of game progression in the physical game and the low-automation interface was much more flexible than in the high-automation interface. In particular, game progression in the high-automation interface involved discrete steps of irreversible actions, whereas the game progression with the other interfaces was much more fluid. These issues reveal a pitfall when automating the progression of a game. Game progression moderated by the computer lacks the flexibility of socially moderated game progression. Deciding turn order and allowing players to undo their actions are decisions that players would like to be able to make on their own. Giving them no choice in what is permitted can be problematic, as this deviates from the socially regulated gameplay in a typical board game session.

Automation of game progression also hinders collaborative planning. Players often use the flexibility of the physical game board to physically illustrate strategies using the actual game objects. Though Pandemic is a collaborative game, it is not difficult to imagine players discussing strategy and play options in a competitive game. Designers need to be aware of the social
processes surrounding the game when deciding to what degree game progression should be automated.

8.4 Physical Design of Game Interfaces

Our study revealed that efficient use of game space is an important aspect of interface design for digital tabletop games. For the implementation of both the high-automation and low-automation interfaces of Pandemic, the active game space took up the entire display space, save for a small margin along the bottom. The Checkers interfaces on the other hand had a wide border around the game board. When playing the physical game, players stored hands of cards, and piles of game pieces around the border of the game board. Players playing either digital interface of Pandemic commented that there was not enough room for game objects. Though storage areas were included in the low-automation interface for disease cubes, other game objects, such as players’ hand widgets, had to be placed on the active game space, thereby obscuring other features of the board. In contrast, players playing the low-automation interface of Checkers used the inactive space around the game board to store captured game pieces. We interpret this as meaning that the unused space around the active play area is important to consider when designing game interfaces. However, supporting this negative space poses a challenge on digital tabletops, as real estate on a digital surface can be expensive with currently available technologies. Individual tablets for each of the players could go far in resolving this issue, as well as providing a means of privatizing individual information.

Though the issue of finding space for the hand widget did arise in the high-automation interface, the issue of storage space reveals an advantage of game automation. Automating the progression of the game and routine activities such as placing game objects reduces the need for physical space around the play area to store these objects. However, space for non-game objects
such as coffee cups should be taken into account. We did not observe these behaviors in our study. However, we suspect that designers of digital tabletop applications need to be aware of the space afforded by the physical design of the hardware, and implement flexible interactions and visualization techniques [35]. As digital board games are played in a social setting for the players’ enjoyment, players are unlikely to readily accept interfaces for which the spatial limitations hinder these and other desired activities, which are possible with a physical board game.

8.5 Player Expectations of Digital Board Games

The study revealed the need for a digital tabletop interface of an existing board game to balance players’ expectations. On the one hand, the interactions should be like the board game. On the other hand, the game should offer the affordances of video games. Our participants were experienced with board games, and most of the participants were experienced with video games. Many of the participants had expectations of how a digital implementation of a board game would work. Some players negatively pointed out missing features of the low-automation interface. Some of the results indicated a need for automated features such as snapping to location. Nearly half of the participants did not like that all of the game objects had to be manually dragged across the board, as opposed to being automatically placed as in the high-automation interface.

On the other hand, the study revealed expectations that interaction with the game be more like the board game. A number of participants liked that the low automation interface behaved like the original game. However, even the low-automation interface had shortcomings when compared to interacting with physical objects. A number of participants pointed out that only one object could be moved at a time by each player. Similarly, certain interactions which the players
usually carry out when playing the physical game, such as rearranging cards in a player’s hand and looking through the discard pile, were not permitted in the high-automation interface.

These results point towards a key issue for designers to consider. On one hand, it is important to provide an interface which replicates the ease of interacting with physical objects when playing board games. On the other hand, players have expectations about how the game can provide the streamlined benefits of video games.

8.6 Sociality in Digital Board Games

One of our main motivations was to find out whether the sociality of board games could be preserved in digital tabletop games, due to the collocated group play on a large horizontal surface. Our results reveal ways in which digital tabletop implementations of board games maintain the inherent sociality of board games.

As reported in section 7.6, we found no significant difference in communication between players which was unrelated to the game. We did, however, find that discussions about interacting with the game were more frequent in both the high and low-automation interfaces than in the physical game. Discussion was more frequent in the high-automation interface than in the low-automation interface. Nilsen and Looser [47] claim that the sociality is not as rich when playing video games compared to playing tabletop games, stating that video games are less conducive to communication. As communication becomes more difficult, discussions unrelated to the game become less frequent, and discussions related to the game becomes a priority. Our results suggest that automation in digital tabletop board games does not have a negative impact on the sociality of the original game. Furthermore, the added discussion in the high and low-automated interfaces, required to simply learn to use the digital tabletop, did not interfere with discussion unrelated to the game. We interpret these results to mean that the collocated face-to-
face and direct manipulation of digital tabletops make them a promising platform for social gaming.

Our analysis of equity of participation revealed that while players within a group generally performed similar amounts of work to each other when playing the game (our metric for work being number of pen presses), players’ satisfaction with equity of participation was lower in the high-automation interface than in either the low-automation interface or the physical game. We also observed players assisting each other in taking actions more in the low-automation interface than the physical game or high-automation interface. Players assisted each other more frequently in the physical game than the high-automation interface. We interpret these results as meaning that the high-automation interface made it simpler to carry out a task, as there were fewer pen presses required for each action. However, lack of participation by players when it is not their turn left players unsatisfied with their contributions to the game.

8.7 Comparative Analysis of Checkers and Pandemic

Our analysis of Checkers and Pandemic yielded varied results. While participants who played Pandemic tended to prefer the low-automation interface for its simplicity and similarity to the board game, Checkers players tended to prefer the high-automation interface. This is likely because the interactions with Pandemic are more complicated than Checkers. In a game as simple as Checkers, a drag and drop interface worked equally well for the high-automation interface as it did for the low-automation interface. However, for Pandemic, drag and drop interactions were insufficient to express all possible player actions. The severe lack of awareness caused by the automation of complex automated infection events in Pandemic also likely contributed to their preference for the other versions of the game.
CHAPTER 8: DISCUSSION

Though complexity obviously distinguishes Pandemic and Checkers, other aspects of the games likely contributed to the difference in player preference. Pandemic is a cooperative multiplayer game with the theme of curing infectious diseases, while Checkers is a competitive abstract two-player game. Thus, there is a strong element of competition in Checkers not present in Pandemic. This competition likely results in a preference for a Checkers implementation to have automation of rule enforcement, game progression and game state, in order to lift this weight from the players. On the other hand, sociality and fun are likely to be more important priorities for players of Pandemic, than streamlined gameplay. We also recruited players familiar with the games, so perhaps new players would react differently, as decreasing the complexity of learning and playing Pandemic might be more important for a new player.

Despite these differences, our analysis of Checkers and Pandemic yielded some similar results. Both games had differences between how rules are enforced in the game depending on the level of automation. Players were occasionally confused in both games about why the automated version was not allowing an illegal play. However, fewer instances were observed of players actively enforcing the rules themselves in the high-automation interface than in either the physical game or the low-automation interface. Players also listed rule enforcement as a positive aspect of both games’ high-automation interfaces. Neither game had a significant difference in sociality between players. This is a promising result indicating that games played on the digital tabletop platform are capable of maintaining the sociality of traditional tabletop gaming. In both Checkers and Pandemic, players tended to list the digital interfaces as requiring more effort than the physical game, with the low-automation interface requiring more effort than the high-automation interface in Pandemic. This is likely attributable to the awkwardness and unreliability of using pens as input devices.
8.8 Conclusion

In this chapter we analyzed the results which we presented in Chapter 6 and Chapter 7. Our general conclusion is that implementation of board games for a digital tabletop platform can provide advantages for gameplay. However, if not handled properly, game automation can lead to problems including severe deficits in game state awareness and frustration over the lack of control in the game. We did find that the digital tabletop implementations did not detract from the sociality of the original games, making digital tabletops a promising platform for social gaming. In the next chapter, we discuss some of the limitations of our study, and present possible directions for future studies.
Chapter 9

Limitations of Methodology

Our study provided valuable insights into the impact of automation on the gameplay of board games. Since this study raised several issues that should be addressed further in order to design more user-friendly interfaces, it can be considered as only a preliminary step to fully exploring automation in games played on digital tabletops. In this regard, the study achieved its main initial goal since it was, in fact, intended as an exploratory study to examine design issues and user behaviors. In this section, we discuss limitations of the study as well as tradeoffs which should be considered when designing future studies.

Aspects of our experimental setup may have colored the experience of some of the players. Many players listed the use of pens as an element of the digital interfaces that hindered gameplay. The Anoto pens were chosen for their reliability and precise input, but in the hands of a new user, the pens did not always provide reliable input, which led to some instances of mistakenly taken actions. A number of players also specifically suggested in their comments that they would prefer a touch interface. The choice of pen input and top projection was the best option for us due to our need to comfortably sit participants at a table. It was important to simulate the setting of playing board games. An awkward seating arrangement may have colored our results. It is noted that digital tabletop technology appears to be rapidly improving, and will allow future studies to use hardware that participants will be more comfortable with.

The software also caused some issues in the study. The minor rule mistake programmed into the Pandemic software, which we discussed in section 8.2, was noticed a number of times by
CHAPTER 9: LIMITATIONS OF METHODOLOGY

players. The Pandemic interfaces were also imperfect, as we received feedback about a number of interface design issues unrelated to automation, such as the lack of a border around the play area in Pandemic. While our results do reveal a number of issues with automation of the gameplay of board games, some of our results may apply more to our specific implementation than to automation in general. Iterating on the interface design would likely address some of the issues that arose during the study. However, our results are relevant as these are issues that designers should be aware of.

In order to measure the effect of different levels of automation on gameplay, the questionnaire asked about players’ enjoyment and perceived game state awareness. However, these questionnaires were only given to the players at the end of each game session. Thus, our results only provided a summary of participants’ feelings about each game session. Questionnaire responses relied heavily on the memory of the participants and were potentially affected by events close to the end of the game. An alternative method, mostly used in situation awareness studies [61], would be to stop the game multiple times throughout to assess awareness, and in our case, enjoyment. This method provides a better cross-section of automation’s effect on gameplay, but may inadvertently have other effects on the game. Another approach has been recently developed specifically for game design, in which biometrics (ex: heart rate, galvanic skin response) are measured during a game session in order to link specific game effects to emotional responses such as fun, boredom and excitement [38]. However, this approach cannot measure awareness, and the presence of sensors can be invasive, itself affecting enjoyment.

Another limitation of the study was our decision to recruit experienced players. The decision was made to remove the learning curve of the games as a factor, allowing us to better focus on differences between interfaces. However, this approach may have introduced biases
CHAPTER 9: LIMITATIONS OF METHODOLOGY

towards game automation which may have colored players’ experiences while playing the digital versions (e.g. distrust of the card shuffling algorithm). Including novice players in the study may yield different player feedback and behaviors. Novice players would also allow us to explore how digitization can help players learn the game, a benefit which we previously listed in section 2.6 as a potential benefit of game digitization.

Finally, the study was limited in the games that we explored. We selected Pandemic as the main focus of the study due to the rising popularity of cooperative games. We also felt that a cooperative game was suitable for the digital tabletop platform, since digital tabletops have been shown to be a good fit for other types of groupware. Other advantages arise from choosing a cooperative game. Players often discussed strategy when playing Pandemic, as opposed to Checkers, in which we frequently observed long pauses in conversation. The cooperative nature of Pandemic also makes it less critical for personal information to be kept secret, a feature which was not well supported by our hardware. Our choices of games do not offer full coverage of board game genres, since Checkers is a simple competitive abstract strategy game, and Pandemic is a thematic cooperative game of medium complexity. Future studies could look at the behaviors that arise when playing more complex competitive games or games with private information.

In this chapter, we have discussed a number of the limitations of our user study and presented some of the possible directions that could be taken in future studies. In the next and final chapter we will conclude with a summary of the project, and summarize what we learned from our user study.
Chapter 10

Conclusion

In this thesis, we described a human-computer interaction project, in which a number of digital tabletop versions of the abstract strategy board game Checkers and the cooperative board game Pandemic were implemented. We described a reference software architecture for the digital implementation of board games, as well as the interface and interaction designs of digital tabletop versions of both Checkers and Pandemic.

We ran a mixed methods study, in which we compared the gameplay of Checkers and Pandemic across interfaces that incorporated three levels of automation. The first interface was the original physical game. The second interface, which we call the high-automation interface, is a digital tabletop interface which automates in-game activities, rule enforcement, and game progression, and includes enhanced visualizations. The third interface, which we call the low-automation interface, is a digital tabletop interface that was designed to closely resemble the physical game. By necessity or for convenience, the low-automation interface did contain some minimal automation of game activities.

Our in depth analysis of the results from the user study revealed a number of implications related to the effects of automation on the gameplay of board games. Game automation can have a positive effect on gameplay. However, automation can negatively impact player awareness and enjoyment of the game. Players appreciated the streamlined gameplay of the high-automation interface. However, players were frustrated by the restrictive nature of the interactions in the high-automation interface, as they were unable to carry out activities which they normally would while playing a board game, such as sorting the cards in their hands or looking through the
CHAPTER 10: CONCLUSION

discard pile. Players also found it more difficult to understand what was happening in the game, as the computer would carry out many of the routine in-game activities, such as placing cubes or shuffling cards, which they would ordinarily carry out themselves.

We also found that automated rule enforcement can help gameplay, but can lead to frustration if too much control is taken away from the players. Implementing and enforcing the rules of the game reduced the overhead required to play the game. However, it was poorly received when players discovered a minor rule mistake implemented in the high-automation interface of Pandemic.

The rigid enforcement of game progression in the high-automation interface was poorly received. Players often wished for an undo feature, since they were unable to take back mistakes, and it was difficult for them to strategically map out their moves before committing to them. Players also preferred to choose the order in which players take turns, rather than having the turn order determined by the game.

Finally, we found that socialization amongst the players was not hindered by either the gameplay on a digital tabletop, or the automation of certain aspects of the gameplay. We interpret this result as meaning that digital tabletops are a promising platform for designing games with the sociality of traditional tabletop games, combined with the streamlined gameplay of video games.

Our analysis also revealed some interface design issues with the digital versions. We found that the inactive space around the play area is important to consider when designing tabletop game interfaces. When playing Pandemic, players often noted that there was not enough room for mobile digital game objects such as hands of cards, or the many free-floating game objects in the low-automation interface. A border around the active play area would likely have
proven to be a better design choice. The use of a border is further validated by the player’s use of the border in the low-automation Checkers interface to store captured pieces.

We also found that a balance must be reached when representing physical objects digitally. On the one hand, players expect the game to replicate the interactions of playing the physical board game. On the other hand, players expect some of the streamlined automated gameplay of video games. Based on results from this study, it seems reasonable to conclude that designers need to take into account a number of factors when deciding when to replicate the interactions of the physical game, and when to provide automation. These include might include the target population of players (e.g. young players or adults), the type and complexity of the game being implemented, and the strengths and limitations of the hardware which the game will be played on.

Based on our experience with the development of the software and its evaluation with the user study described in this thesis, we have compiled the following list of guidelines for the design of digital tabletop implementations of board games:

- Understand the interactions that players ordinarily carry out in the physical game, and make these interactions possible within the digital tabletop interface. For example, if the game involves a hand of cards, include an interaction which allows players to arrange the cards in their hand as they please, as this is a behavior often carried out by players of board games.

- When automating in-game activities, provide significant awareness cues for the players that these automated activities are taking place. For example, if an upkeep or event phase which takes place between players’ turns is automated, present these automated activities in a way that gets the players attention and is
easily interpreted. Displaying actual game objects moving across the board is likely more effective than abstract animations.

- Pay close attention to detail when interpreting and implementing the rules of the game to ensure that gameplay replicates the original rulebook. Players respond negatively if the gameplay of the digital version forces the players to deviate from the rules of the original game.

- Allow for fluid management of game progression, including an undo feature and a turn order which the players decide on. Many board gaming groups allow for players to take back a move, if it does not have a major impact on the game. It can lead to frustration if the digital implementation does not allow for players to override the rigid enforcement of the current state of the game.

- Consider the need for inactive space around the active game area, for storage of mobile digital artifacts, and physical objects above the table. For example, if players have a hand of cards, which is represented digitally, an inactive border, to store players’ hands is necessary. Even in the absence of such digital artifacts, an inactive space to place a drink, or to simply lean on the table, is likely beneficial.

- Find a balance between replicating physical interactions with the original game, and providing streamlined gameplay made possibly by digitization. For example, the best interaction for carrying out an action, which involves moving a piece across the board, may be to simply drag that piece across the board, and drop it in the desired location. However, players may still wish for the digital implementation to ensure legal play, and to present the game state in a clean and organized way.
CHAPTER 10: CONCLUSION

The study was intended to be an exploratory look at the effects of automation on gameplay. Future studies may expand the scope by looking at different types of games, such as more complex competitive games. Future studies may also improve upon the current iteration of our experimental software, by adhering to some of the design guidelines which we have proposed. The potential benefits of digitization, in the context of learning a game for the first time, may also be better understood if novice players are recruited. Future studies may also be carried out on a more natural touch-based digital tabletop, or may utilize a measure of fun and enjoyment which provides a more complete picture than our post-trial questionnaires.

Overall, we conclude that this project achieved its initial goal of exploring the potential benefits of the implementation of board games on digital tabletops. We have presented results which further validate digital tabletops as a promising platform for social gaming. These results have helped us establish design guidelines for designers and programmers wishing to bring board games to digital tabletops.
Bibliography


Proceedings of the 19th annual ACM symposium on User interface software and technology (Montreux, Switzerland), ACM, 245-254.


of the ACM International Conference on Interactive Tabletops and Surfaces (Banff, Alberta), ACM, 165-172.


Applications (Dublin, Ireland), ACM, 139-148.


Appendix A
Background Questionnaire

Background Questionnaire

Project Title: Group Interactions in Tabletop Games

Please fill out this questionnaire as accurately as possible. None of the information will be personally linked to you in any way. Please do not write your name anywhere on the questionnaire.

1. What is your sex? (please circle one)
   - Female
   - Male

2. What is your age? _____

3. What is your occupation? _________________________________
   If student, what degree/program are you in? _________________________________

4. Which hand do you primarily use when writing? (please circle one)
   - Left hand
   - Right hand

5. On a scale of 1-5, Please indicate how often you have played board games over the past two years?
   - Never
   - Once or twice
   - Several times
   - Weekly
   - Daily

   1  2  3  4  5

6. Which board game titles have you played most often?

_________________________________________________

_________________________________________________

121
7. On a scale of 1-5, Please indicate how often you have played video games over the past two years?

<table>
<thead>
<tr>
<th>Never</th>
<th>Once or twice</th>
<th>Several times</th>
<th>Weekly</th>
<th>Daily</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

8. Which video games have you played most often?

9. On a scale of 1-5, please indicate how often you have played the game *game being played (Checkers or Pandemic)* in the following formats:

a) Traditional, board game format:

<table>
<thead>
<tr>
<th>Never</th>
<th>Once or twice</th>
<th>Several times</th>
<th>Weekly</th>
<th>Daily</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

b) Computerized / video game format:

<table>
<thead>
<tr>
<th>Never</th>
<th>Once or twice</th>
<th>Several times</th>
<th>Weekly</th>
<th>Daily</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

10. On a scale of 1-5, please indicate how often you have used a touch-based computing device (e.g., iPhone, iPad, Blackberry Storm, Microsoft Surface computer, digital tabletop computer, etc.)?

<table>
<thead>
<tr>
<th>Never</th>
<th>Once or twice</th>
<th>Several times</th>
<th>Weekly</th>
<th>Daily</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>
11. How well do you know the other player?

<table>
<thead>
<tr>
<th>Never Met</th>
<th>Very Well</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4 5</td>
<td></td>
</tr>
</tbody>
</table>
Appendix B

Post-Condition Questionnaire Used in Checkers Trials

Subject ID: ________________  Condition: ________________

Project Title: Group Interactions in Tabletop Games

Please fill out this questionnaire as accurately as possible. None of the information will be personally linked to you in any way. Please do not write your name anywhere on the questionnaire.

1. Please circle the number on the scale from 1 to 7 to indicate how much you agree with each of the following statements. A “1” indicates that you strongly disagree with the statement, and a “7” indicates that you strongly agree with the statement.

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I had fun playing the game.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>I was always aware of the other player’s actions.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>When the other player took action, I was always aware of his/her motivations for doing so.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>When taking my turn, I was always aware of my play options.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>I always understood what was happening in the game.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>I felt that it took a lot of effort to play the game.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>
*Below are free-form comments questions given only after digital tabletop trials.*

2. What aspects of the tabletop interface assisted the game play?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

3. What aspects of the tabletop interface hinder the game play?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
Appendix C
Post-Condition Questionnaire Used in Pandemic Trials

Subject ID: ________________  Condition: ________________

Project Title:  Group Interactions in Tabletop Games

Please fill out this questionnaire as accurately as possible. None of the information will be personally linked to you in any way. Please do not write your name anywhere on the questionnaire.

1. Please circle the number on the scale from 1 to 7 to indicate how much you agree with each of the following statements. A “1” indicates that you strongly disagree with the statement, and a “7” indicates that you strongly agree with the statement.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Disagree</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I had fun playing the game.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>I was always aware of the other player’s actions.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>When the other player took action, I was always aware of his/her motivations for doing so.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>When taking my turn, I was always aware of my play options.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>I always understood what was happening in the game.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>I felt that it took a lot of effort to play the game.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>I enjoyed our team dynamics throughout the game</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>I felt that I was able to make effective contributions to the game.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>
I am satisfied with the other player’s contributions to the game.

*Below are free-form comments questions given only during digital tabletop trials.*

2. What aspects of the tabletop interface assisted the game play?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

3. What aspects of the tabletop interface hinder the game play?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
Appendix D

Video Codes Established During Open Coding Process

Codes marked with a * were not used during coding of Checkers trials.
Codes marked with a † were not used during coding of Pandemic trials

**Game State Confusion (start game):** Players discuss at the beginning of the game which of them is supposed to take the first turn, or something else about the starting state of the game.

**Game State Confusion (in game):** At some point after the game has started, players discuss whose turn it is, or something else about the current state of the game.

**Problem Dragging:** A player has difficulties dragging a piece (or taking other actions) due to the pen not correctly recognizing their input (applies only to digital versions).

**Problem with Understanding User Interface:** A player performs a different interaction than they had intended, due to an incorrect understanding of the interface, e.g., clicking on the wrong spot to open the player hand (applies only to digital versions).

**Hold a piece for a long time:** A player holds onto a piece (with finger or pen) for an extended period of time.

**Tentative Move:** A player moves a piece to a new location on the board, but does not let go of it or moves it back.

**Undo:** Players decide to undo the player actions taken to revert the game state (only applies to physical board game and low-automation digital version).

**Adjust game object position:** A player makes minor adjustments to the location or alignment of a game object.

**Rearrange cards in hand:** A player changes the order of cards in their hand (Note: In the physical board game, if a card just drawn is inserted into the middle of their hand, it was coded. This behaviour was not coded in the low-automation digital version).

**Stretch across board:** A player makes an obvious extra effort to move things on other side of board.

**Gesture without game input:** A player gestures toward the board to facilitate strategy formation. For example, pointing to a city or a direction, or circling an area.

**Playing with game objects:** A player plays with game objects such as cubes and pawns.
**Forceful Move:** A player moves their piece more forcefully than normal.

**Consult Rule book:** A player consults the paper copy of the rules that they were given.

**Discuss rules:** Players discuss rules among themselves.

**Rule Correction:** One player tells another player that the move that the other player just made was illegal.

**Rule Established:** The players decide that they are going to play the game in a particular way (possibly contrary to the official rules).

**Rule Infraction (official rule):** A player makes a move which is illegal according to the official rules, and which has no house rule covering it.

**Rule Infraction (house rule):** A player makes a move which is illegal according to the house rules which they are playing (if they are playing house rules).

**Rules Enforcement Confusion:** The players exhibit confusion over why a move they are attempting to make is not being allowed by the game (Applies only to the high-automation digital version).

**Show Impatience:** A player’s body language exhibits impatience.

†**Look at Other Player (their turn):** A player looks up from the board at the other player, when the player looking is not the active player.

†**Look at Other Player (not their turn):** A player looks up from the board at the other player, when the player looking is the active player.

**Physically assists another player with their actions on their turn:** other players physically help the current player to perform actions or events on his/her turn.

**Players talk about interacting with the game:** Players discuss how to use the interface

**Isolated player comment about game:** Players comment about the game state (not extended enough to be a discussion, e.g. an isolated “Nice!”)

**Long pause in conversation (≥5 sec) (comment):** There is a 5 or more second silence in the game, there may be very short comments or sounds made by players during this time.

**Counting actions:** The players count actions as they carry out their turn.

**Narrating game events:** Players explain things as they happen including private information (cards in hand) and game state changes (epidemic & new infection cards). Narrating events
includes any kind of communication about recent changes to the state of the game.

**Pause to process automated board changes:** Players pause to process what just happened in the game after an automated change takes place (only for automated digital version).

**Player Talk (not game related):** The players engage in conversation about something that is not related to the game.
Appendix E

General Research Ethics Board Approval

June 26, 2010

Mr. Joseph A. Pape
Graduate Student
School of Computing
Queen's University

GREB Ref #: GCISC-640-10
Title: “Group Interaction in Tabletop Games”

Dear Mr. Pape:

The General Research Ethics Board (GREB), by means of a delegated board review, has cleared your proposal entitled “Group Interaction in Tabletop Games” for ethical compliance with the Tri-Council Guidelines (TCPS) and Queen’s ethics policies. In accordance with the Tri-Council Guidelines (article D.1.6) and Senate Terms of Reference (article G), your project has been cleared for one year. At the end of each year, the GREB will ask if your project has been completed and if not, what changes have occurred or will occur in the next year.

You are reminded of your obligation to advise the GREB, with a copy to your unit REB, of any adverse event(s) that occur during this one year period (details available on webpage: http://www.queensu.ca/orc/researchethicsgeneralreb/forms.html - Adverse Event Report Form). An adverse event includes, but is not limited to, a complaint, a change or unexpected event that alters the level of risk for the researcher or participants or situation that requires a substantial change in approach to a participant(s). You are also advised that all adverse events must be reported to the GREB within 48 hours.

You are also reminded that all changes that might affect human participants must be cleared by the GREB. For example, you must report changes in study procedures or implementations of new aspects into the study procedures on the Ethics Change Form that can be found at http://www.queensu.ca/orc/researchethicsgeneralreb/forms.html - Research Ethics Change Form. These changes must be sent to the Ethics Coordinator, Gill Irving, at the Office of Research Services or Irving@queensu.ca prior to implementation. Mrs. Irving will forward your request and protocol changes to the appropriate GREB reviewers and/or the GREB Chair.

On behalf of the General Research Ethics Board, I wish you continued success in your research.

Yours sincerely,

[Signature]

John Stevenson, PhD
Professor and Chair
General Research Ethics Board

c.c.: Dr. Nicholas Graham, Faculty Supervisor and Co-applicant
Phil McClelland, Graduate Student, Dept. of Systems Engineering, Waterloo University,
Co-applicant
Kerri McEnnulty, Research Administrator, School of Computing

SHIPPED JUL 28 2010