Chapter 11
Tabletop Games: Platforms, Experimental Games and Design Recommendations

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11.1 Introduction

While the last decade has seen massive improvements in not only the rendering quality, but also the overall performance of console and desktop video games, these improvements have not necessarily led to a greater population of video game players. In addition to continuing these improvements, the video game industry is also constantly searching for new ways to convert non-players into dedicated gamers. The recent success of Nintendo's Wii controller is often credited to its support of natural and intuitive gestural interactions, and much of the attention to this platform has come from its ability to attract people from markets not typically thought of as gamers. Indeed, stay-at-home parents, retirement homes, and working professionals make up a large portion of the Wii audience, which at the time of this writing is over 13 million (status Sept. 2007).

In addition to the popularity of gestural interaction, the multi-player nature of console games makes them more communicative than single-player desktop games. Even when desktop games are played in a multi-player mode, individual players are still separated from one another in front of their personal displays (see Fig. 11.1, *left*). Despite the growing popularity of computer-based video games, people still love to play traditional board games, such as Risk, Monopoly, and Trivial Pursuit. Monopoly, for example, has been sold over 250 million times[1] worldwide. Board games bring groups of people together around a table, and foster face-to-face communication in a social setting (Fig. 11.1, *right*). While engaging, traditional board games lack the interactive, graphical feedback provided by video games. Additionally, a single console is capable of playing a multitude of different video games, a feat that is obviously not possible for traditional board games because of their physical nature.

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[1] http://www.playmo-portal.com/spielzeug/Monopoly-in-Zahlen.html.

A.D. Cheok, *Art and Technology of Entertainment Computing and Communication*,
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Fig. 11.1 (*left*) Desktop-based games are often an isolated activity – even when gamers play in a multi-player mode. Therefore, traditional board games are still very popular (*right*)

Both video and board games have their strengths and weaknesses, and an intriguing conclusion is to merge both worlds. We believe that a tabletop form-factor provides an ideal interface for digital board games. In contrast to desktop based video games, tabletop gamers have the advantage of arranging themselves face-to-face while playing. This arrangement should lead to better collaboration and ultimately more enjoyment during the game. Several attempts have been made to bridge the gap between traditional board games and computer games [3], and there is evidence that tabletop-based video games merge some of the advantages of traditional board games and video games [1]. They combine the social interaction and the physical activity of board games with the visual, acoustic and haptic possibilities of video games [6]. Players are able to deduct other players' intentions by observing their actions [17]. The technical enhancements of the game board allow tasks that are perceived as cumbersome to the players (such as shuffling cards or counting the points) to be taken over by the computer. Thus, the player is able to fully concentrate on the game itself (e.g., strategies). Another advantage taken from video games is the capability to save the status of the game and resume it later.

The design and implementation of tabletop games will be influenced by the hardware platforms, form factors, sensing technologies, as well as input techniques and devices that are available and chosen. This chapter is divided into three major sections. In the first section, we describe the most recent tabletop hardware technologies that have been used by tabletop researchers and practitioners. In the second section, we discuss a set of experimental tabletop games. The third section presents ten evaluation heuristics for tabletop game design.

11.2 Tabletop Hardware & the Types of Interaction They Support

Multimodal interfaces that combine gestures with additional modalities such as speech have been examined since the early 1980s and have shown significant potential to make human–computer interaction in games more natural and efficient.

A number of systems have emerged in recent years in which we can interact by speech combined with pointing or more complex gestures. Using a variety of available sensors and targeting diverse use environments, existing research has addressed the recognition of detailed hand gestures as well as full body (pose) gestures [9]. Physical user action as an interaction modality have been recently explored in research projects, mostly in an entertainment/sports context and has entered the commercial realm with the EyeToys extension for the Sony Playstation 2 and with the Nintendo Wii console.

This section aims to identify several of the major tabletop hardware platforms that tabletop game developers might choose to target. Rather than provide a detailed explanation of each of the technologies, we aim to give the reader a brief overview and pointers to where they might find more information to aid them in their platform choice.

11.2.1 SmartBoard

SMART Technologies[2] has been selling interactive whiteboards since the early 1990s. While their main products have been and continue to be vertically oriented, touch-sensitive displays sold to the education, defense, and business meeting-room markets, researchers inside and outside the company have been experimenting with the horizontal orientation of SMART's products for several years.

The main sensing mechanism used in these whiteboards is a computer vision-based technology called DVit. Cameras placed in each of the four corners of the surface view a shallow region in front of the display. When a finger or stylus enters this region, the system calculates its position by triangulating the images of the finger or stylus from several of these cameras. Multiple cameras provide some redundancy in positioning; however, problems can arise as each touch effectively hides the parts of the display that are behind the touch as seen by any one camera. Similarly, objects placed on the table hide areas of the table from the view of the cameras and can interfere with the interaction. Four cameras (one in each corner of the display) seem to be enough to robustly support two points of contacts.

11.2.2 DiamondTouch

The DiamondTouch[3] table was first presented in 2001 by Mitsubishi Electric Research Laboratories as a multi-user, debris tolerant touch technology. Since then, it has become commercially available to researchers and application developers as

[2] http://www.smarttech.com.

[3] http://www.merl.com/projects/DiamondTouch/.

Fig. 11.2 Touches from different users on a DiamondTouch table are distinguished from one another through separate signals broadcast through each user's chair and capacitively coupled through the user into the table's antennas. The table distinguished multiple touches from different users

a research prototype and dozens of colleges and universities have received DiamondTouch tables through an educational loaner program. The sensing technology behind DiamondTouch is an XY pair of antenna arrays embedded in the surface of the table. Each user sits in a wired chair that broadcasts a unique radio signal. These signals are capacitively coupled through the user's body and into the antenna array whenever touches occur (Fig. 11.2). Because each user sits in a different chair, the table is able to distinguish touches among the users. Current prototypes support up to four users.

While objects placed on the DiamondTouch table do not interfere with input, problems can arise with multiple points of contact made by the same user as touches effectively mask other touches in the X and Y direction. In some situations, there is an ambiguity among multiple touch points, which has prompted many developers to rely on the touch's bounding box as the unit of input.

11.2.3 SmartSkin

SmartSkin was first presented in 2002 by Jun Rekimoto from the Sony Computer Science Laboratory. SmartSkin embeds a 2D antenna array into a surface, and supports multi-point, free-hand touch input. The technology works through sequentially using each antenna in the array as a transmitter while the remaining sensors are used as receivers. A users or users' arms and hands act to capacitively couple this signal from the single transmitter to every receiver in range, giving the system a picture of the areas of contact on the table. The capacitive sensors measure a range of values; thus SmartSkin can be tuned to not only sense contact with the table, but also hovering above it. Like DiamondTouch, SmartSkin is debris tolerant as non-conductive objects do not interfere with input. Similarly, SmartSkin does not rely on computer vision, making the technology resistant to changes in lighting and occlusion problems.

Fig. 11.3 All pictures are sent to the table's surface, once the WiFi-based camera is put on the table

11.2.4 *Microsoft Surface*

More recently, Microsoft presented the Surface table. This is expected to come to market later in 2008, but its price will initially limit its wider appeal. The system enables interaction with digital content through natural gestures, touches and physical objects. The Surface can track up to 40 simultaneous touches. In contrast to the DiamondTouch, the Surface is based on an optical tracking set-up, where five embedded infra-red cameras track the entire table (the current prototypes have a screen size of 30 inches). A special rear-projection surface and an embedded projector allow an optimal image. With the special projector, the engineers developed a relative low-sized table with a maximum height of 56 cm. The Microsoft team demonstrates the table's advantages with effective demonstrations developed for Sheraton Hotels, Harrah's Casinos, and T-Mobile. In the photo-sharing application, for instance, friends can put their WiFi digital camera on the table and share their photos in a very natural way (see Fig. 11.3).

An alternative is to recognize and pair a device with RFID (Radio-Frequency Identification) tags or NFC (Near Field Communication). In this case, the table includes RFID readers which in combination with RFID tagged objects can be used to save and load different content. NFC allows devices to set up a link when brought together in close proximity. It is primarily designed to be used on mobile phones. The content, however, has still to be sent over Bluetooth (or another suitable link), since the NFC technology is not designed to transfer large amounts of data. RFID/NFC is likely to be included in increasing numbers of mobile phones and other devices, so in the future it may be possible for a user to have content from a mobile device appear on a large screen just by bringing their device within close range of the display.

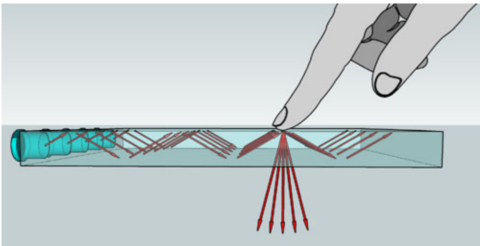

Fig. 11.4 Light that enters the acrylic table reflects internally until it is scattered by the finger-acrylic surface on the display. The light is then reflected downward, through the display to where it is seen by a camera

11.2.5 Frustrated Total Internal Reflection (FTIR)

While FTIR is a long and well known physical phenomenon and has been used for many years to capture fingerprint images in the biometrics community, it has recently gained much popularity in the tabletop research community in large part because of the 2005 work of New York University's Jeff Han [8]. FTIR works through exploiting the physical property of the total internal reflection of light traveling through a medium such as glass or acrylic. Light that enters the side of such a sheet tends to reflect internally and remain inside the sheet. Fingers or other objects that touch the surface "frustrate" this reflection and scatter light away from the glass (Fig. 11.4). When the glass sheet is observed from the side opposite the user, touches appear as bright spots that are easily detected with a computer camera. Han describes the use of IR light paired with an IR-sensitive camera, which makes the input technique compatible with rear-projection displays. The relatively low cost of this input solution paired with the freely available libraries[4] for performing the computer vision necessary for input has made FTIR a popular input choice for tabletop researchers.

11.2.6 Entertaible

Philips announced the interactive Entertaible in early 2006, and quickly began demonstrating multi-user tabletop games. While not yet commercially available at the time of this writing, the Entertaible combines a 30″ LCD screen with multi-point touch detection to provide a multi-user entertainment device for group game playing. Philips has announced that their first market will be restaurants, bars, and casinos; however, they plan to eventually target the home market as well. Sensing input is performed with a series of LEDs and photodiodes that are arranged around the perimeter of the LCD screen. Objects placed on the table, as well as users' hands and fingers, block the view of the LEDs by the photodiodes on the opposite edge of the table. Using this occlusion technique, Philips has demonstrated the simultaneous detection of dozens of finger-sized objects.

[4] http://code.google.com/p/touchlib/.

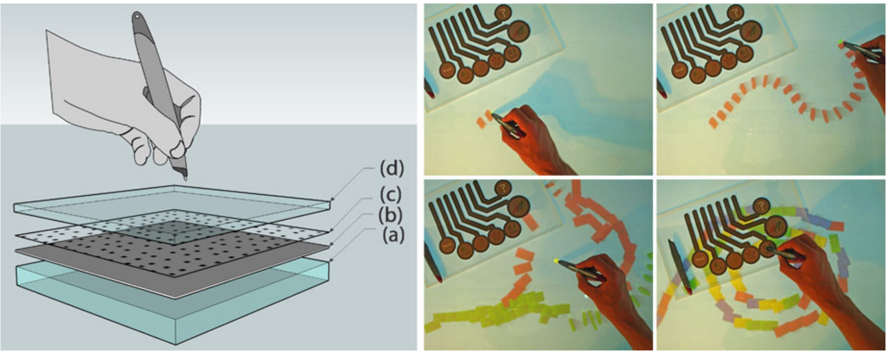

Fig. 11.5 (**a**) The rear-projection table has tiny dots printed on a special foil. (**b**–**d**) The different layers of our trackable table. In the game Comino, digital domino pieces can be placed with a digital pen

11.2.7 Stylus

Another way to interact with a table can be done by using a stylus. Figure 11.5 depicts a solution of a rear-projection table in combination with a stylus. To capture the users' movements on the table, we use the Anoto pen.[5] Anoto-based digital pens are ballpoint-pens with an embedded (IR) infrared camera that tracks the pen movements simultaneously. The pen has to be used on a specially printed paper with a pattern of small dots with a nominal spacing of 0.3 mm. Once the user touches the pattern with the pen, the camera tracks the underlying pattern. It can then derive its absolute coordinates on the pattern and send them to a computer over Bluetooth at a rate of 70 Hz. Anoto pens with Bluetooth are available from Nokia (SU-1B), Logitech (io-2), and Hitachi Maxell (PenIT). From the pen, we receive the pen ID, the ID of the pattern sheet (each page has a unique pattern), and the position of the pen tip on the paper.

The digital pen (a) tracks the pattern, printed on a special Backlit foil (d), which generates a diffuse light. Thus, no spotlights from the projectors are visible at the front of the screen. Moreover, the rendering and the brightness of the projected image are still of high quality. In our setup, we used one A0 sized pattern sheet (118.0 × 84.1 cm). The pattern is printed with the black ink cartridge (which is not IR transparent and therefore visible for the IR camera). Notice that the colors Cyan, Magenta, and Yellow (even composed) are invisible for the IR camera. The pattern is clamped in-between two acrylic panels (b) and (c). The panel in the back has a width of 6 mm and guarantees a stable and robust surface, while the panel in the front has a width of only 0.8 mm to protect the pattern from scratches. We noticed that the acrylic cover in the front does not diffract the pattern at all. However, using thicker front panels (e.g., 4 mm), produces bad tracking results. While we also successfully

[5] http://www.anoto.com.

tested our tracking with a transparent foil, we did not achieve good tracking results using the pattern foil in front of a plasma or an LCD display.

11.3 Experimental Tabletop Games

In terms of a game's interaction style, there are many dimensions with which one can classify and describe tabletop games. We can consider a game as either *collaborative* or *competitive* to describe the presence or absence of competition among players. Similarly, players may act as part of a *team* or as an *individual*. The pacing of tabletop games is typically *turn-based* or *live-action*, describing whether or not input is performed concurrently by multiple players, or if players take turns. Finally, games might be classified as either *strategy* or "*twitch*" games to describe the relative importance of planning game commands vs. executing them.

In reality, a game will most likely embody more than one of these classified dimensions, or even switch between classifications during different parts of the game play, thus making pigeonholing a particular game difficult. Game designers usually use certain genres as they explore the design space to arrive at the goals of the game. Digital tabletop games are emerging internationally as both research projects and commercial efforts. A selective set of contemporary work is reviewed in this chapter. This set is not meant to be exhaustive, rather the intention is to provide a variety of genres for the readers to explore. In this section, we use a broad categorization of games: *educational, therapeutic*, and *entertainment*.

11.3.1 Educational

In recent years, researchers at universities and in research labs have started to build tabletop games for educational purposes. PoetryTable, Habitat, a language (Spanish and English) learning table are some of the examples in this category (see Fig. 11.6).

PoetryTable [16] is an educational game, inspired by the popular "magnetic poetry" toy.[6] The PoetryTable allows students to create free-form sentences and phrases by moving word tiles around the table with their fingers. Working individually or collaboratively, up to four users work to create poems in either English or Japanese. Popup menus give users the option to make duplicates of popular word tiles, to add a suffix or prefix to a particular word, to conjugate verbs, and to save a screenshot of the game in order to preserve their poems. The activity is made more challenging by presenting both correct and incorrect options for students to choose from in the conjugation menus.

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[6] http://www.magneticpoetry.com.

Fig. 11.6 The PoetryTable allows students to create free-form sentences using current vocabulary words. Double-tapping a word tile invokes a menu that allows the student to alter the word by adding prefixes and suffixes

Implemented using the DiamondSpin Toolkit [16] and running on a DiamondTouch table, this tabletop game has been a fixture at the reception area at the Mitsubishi Electric Research Labs for three years. Some of the observations and experience from this game have been reported in [15].

Habitat is an educational game also implemented with the DiamondSpin Toolkit. The gametable is divided into five distinctive areas (cf. Fig. 11.7). The center area is a large diamond which reads "*help the animals get home*." When the game starts, this region is filled with a set of animal images. The four large corner areas are "home environments" labeled as *land, placeForest, sea, and ice floes*. Each of these four corner areas has a back ground image representing the typical home environment for species of animals according to the text labels. Players work together to match animals with their home environments by dragging the animal images to the correct regions of the table. When a correct match is made, the player is rewarded with a sound that reflects some quality of the animal (e.g., the cry of a wolf). When the match is incorrect, the animal snaps back into the center of the table and an error sound in played. Organized by *WIRED* magazine, the three-day NextFest 2004 was designed to give the general public a close-up, hands-on view of innovative technology. The game Habitat was run at this conference as one of the applications on a DiamondTouch table, which was part of the Future of Design Pavilion. During the course of this event, the tables were used by almost 2,000 people. Visitors included children, educators, executives, designers, and engineers. It was observed that children (aged 2 to teens) needed no tutoring or coaching in playing the Habitat at all. Most of the children simply approached the Habitat table and immediately started

Fig. 11.7 The Habitat allows multiple people match images of animals to their home environments

to move the animal images to the corner regions. More than on child sometimes wanted to "grab" the same animal image. Fortunately, a double-tap invoked menu allowed images to be duplicated on the spot. We observed that some adults had more hesitations without coaching. In particular, some adults were not sure what to do when a beep was heard and the animal image "jumped" back to the center after they had dragged it to an incorrect home environment.

The ClassificationTable [13] game begins with a pile of virtual "clues" placed in the middle of the table. "Clues" are sentences, phrases, or single words that are related to the current lesson. Each corner of the table is labeled with one of four categories for the lesson, and the players work together to classify each of the clues into one of these categories. Example categories include countries, characters from a novel, authors, vocabulary themes, number of syllables, and so on. Players receive feedback for both correct and incorrect classifications, and at the end of a session, the students view a histogram showing the relative contribution from each member of the team.

11.3.2 Therapeutic

Researchers [7, 13] have also explored how interactive table technologies, specifically cooperative tabletop computer games, can help mental health therapists facilitate adolescent and children's social skills development in a comfortable and motivating way. Tabletop technology encourages face-to-face interaction around one

Fig. 11.8 (*left*) SIDES is a turn-taking game. (*right*) A screenshot of StoryTable which uses multi-user collaborative gestures to help children with High Functioning Autism to work together

computer in a way other computer workstations and video gaming systems do not. Adolescents with Asperger's Syndrome (AS) often describe the computer as a comfortable and motivating medium.

SIDES [13] is a four-player cooperative computer game for social group therapy on the DiamondTouch table (see Fig. 11.8). It was developed at Stanford University as an experiment for therapists in working with Asperger's Syndrome children. Utilizing the multi-user identification feature of the DiamondTouch platform, the designers of SIDES built in game rules to require and/or restrict input from certain players. This affordance forced the children to cooperate during the game. SIDES is a highly visual, four-player puzzle game. The game rules were designed to increase collaboration and decrease competition. At the beginning of a round, each player receives nine square tiles with arrows (three copies each of three arrow types). Unique arrow types (e.g., pointing left, pointing right, around-the-corner, etc.) are distributed among participants so that no participant has all 12 arrow types in his "hand." Students are asked to work together to build a path with their pieces to allow a "frog" to travel from the start lily pad to the finish lily pad. There is a limited supply of each arrow type, thus encouraging students to cooperatively build an optimal path to win the most points. To gain points, the path must intersect with insect game pieces on the board. The insects are worth various point values (e.g., each dragonfly is worth 20 points). The group of students must agree on one path that collects the most points with their given amount of resources. Once all players agree with the solution, the frog will travel along the path and collect points by eating all the insects it encounters. Each player has a control panel in the region of the interface closest to his or her chair. In each player's control panel, there are round and point indicators as well as voting buttons to test a path, reset, or quit the game. The voting buttons force the group to "vote" unanimously in order to change the state of the game. For instance, players must vote unanimously to test their path once a solution is reached by each activating their own "Test Path" button. This feature was implemented to ensure that no one player had more control over the state of the game than another player, and to encourage social interaction by necessitating communication and coordination with other members of the group.

The control panel includes a turn taking button. Each player's turn taking button indicates whether or not it is that player's turn. A player may make as many moves with his own pieces during his turn as he likes. The player whose turn it is has control over when he ends his turn by pressing his turn taking button. This is a "give" protocol as described in order to prevent one student from "stealing" control from another player.

A version of the StoryTable interface [7] was developed jointly by University of Haifa, Israel and ITC-irst, Italy. The game was designed according to the concept of ladybugs wandering around the table surface. The game is developed on the multi-user multi-touch DiamondTouch tabletop. Ladybugs were chosen as a familiar, friendly object to children; the users had no difficulty in understanding the function of the ladybugs that differed in size and color in accordance with their functions. A mixture of standard touch events and the new multi-user events were used as a means to control the objects. One ladybug carries the backgrounds, the context within which the story will be set, e.g., a forest, a medieval castle, etc. This ladybug can be opened to access the backgrounds by double touching on it. Since the selection of the background is crucial for determining the story, the system forces previous agreement by requiring that selection of the background setting be done jointly by the children, i.e., through a multi-user touch event. Another ladybug carries the various story elements (e.g., the Princess, the Knight) that can be dragged onto the current background. Again, this ladybug can be opened by a single-user double touch event. In this case, however, the elements can be dragged autonomously by each child. A third type of ladybug of a different size and shape (the blue ones shown in Fig. 11.8 (right)) contain the audio snippets that will form the story. In order to load an audio snippet into one of these ladybugs, a child has to drag it into the recorder and then keep the button pressed while speaking. The audio snippets are recorded independently by each child. Once loaded with audio, the ladybug displays a colored aura that represents the child who recorded it. An audio ladybug can be modified by the child who recorded it, but the system refuses modifications attempted by other children. Therefore, a ladybug is "owned" by the child who recorded it. Yet, children may agree to release ownership of a ladybug by a multi-user drag-and-drop action: if they jointly drag the ladybug onto the recording tool, the system removes the content and the aura. The resulting story is the sequence of the audio snippets recorded in the ladybugs placed in the sequence of holes at the bottom edge of the interface; while each audio ladybug may be listened to individually, the story as a connected sequence of snippets can be listened only if children touch the first ladybug in the sequence. Baumingger et al. reported an experimental study on 35 dyads. They provided evidence that this setting facilitates more complex and mature language (both in their recorded story segments and in their interactions with one another during the task) and that the contributions to the story and to interaction were more equally distributed between the children in the StoryTable than in the control condition.

11.3.3 Entertainment

In order to improve the social gaming experience, Magerkurth et al. proposed a tabletop setup which combines the advantages of a digital environment with the social impact of board games [11]. The game combines a wall and a digital display. Users play with their personal devices and with the public displays, and the communication can be done through headsets (for personal communication) and loudspeakers (public communication). Moreover, users are sitting face-to-face, they share the same experience, and they play in a new digital/real world. Most of recent work on interactive surfaces deals with merging real with the virtual (digital) enabling people to share the same experience.

Barakonyi et al. present in [2] the game MonkeyBridge and extend the idea of Magerkurth. They implemented a collaborative Augmented Reality game employing autonomous animated agents. Although playing around a table, the authors implemented their game using HMDs. Again users can use real objects, which have to be placed correctly, to guide digital, augmented avatars.

Wilson demonstrated PlayAnywhere, a flexible and transportable tabletop projection setup [18] and PlayTogether, an interactive tabletop system that enables multiple remotely and co-located players to engage in games with physical games pieces [20]. Wilson also presented the pairing of a depth-sensing camera with an interactive tabletop to create a car racing game in which virtual cars raced realistically over physical objects placed on the table's surface [19].

KnightMage is based on the STARS-platform [11] and is played collaboratively by multiple users sitting around the STARS-table. The players have to survive together in an inhospitable environment, relying on each other's special abilities to face a different task in the game. In special situations, the players can also act as lone warriors to collect treasures which are hidden from the other players. These private interactions are performed through a handheld device that allows each player to access the inventory and special abilities of his own game character. The hardware setup of KnightMage consists of a tabletop display and a wall display, on which participants can share relevant information to other players. All the hardware components are part of the STARS platform, and were originally developed as part of the Roomware project. The STARS platform is designed to support classical board games with the use of various multimedia devices. With the use of several displays which can either be public or private displays, the STARS setup allows developers to create very complex game scenarios which can, for example, be both collaborative and competitive elements in one game. Setup components include a touch sensitive plasma display which acts as the game board and which is coupled with a camera capturing the setup from the top. The camera allows the system to detect and identify game pawn on the interactive screen. In addition, the table includes RFID readers which in combination with RFID tagged objects can be used to save and load different scenarios and games. The STARS system also puts a strong focus on providing audio channels to communicate with the users of the system. Both public messages via loudspeakers and private messages via earphones are can be delivered by the system.

Weathergods [1] is a turn-based game that can be played by up to four players simultaneously on the Entertaible system. Each player has three different pawns that can perform different actions in the game. The goal of the game is to earn enough gold to be able to buy oblations to please the weather gods. Gold can either be earned by selling camel milk, robbing other players or detecting gold in the soil. The virtual game environment helps the players learn the game's commands by displaying possible pawn movements and reacting to the action of the players. Special attention was paid to the very iconic style of the pawns, which are tracked by the tabletop surface. The pawns that are placed on the screen are manufactured from a translucent material which transports the light to the top of the pawn based on total inner reflection. This way, by changing the underlying pixels on the screen, the color of the pawn can be changed.

11.4 Case Studies

11.4.1 Jam-O-World: CircleMaze

The goal of the Jam-O-World project was to encourage people to come together to take part in a collaborative musical gaming experience in an immersive 3D environment. The Jam-O-World game play environment includes a modified Jam-O-Drum (originally developed at Interval Research [4]), which is an interactive tabletop display with reactive MIDI drum pads embedded in its surface. The project is the creation of a team of graduate students and faculty from the Entertainment Technology Center at Carnegie Mellon University, who set out to augment the Jam-O-Drum with new input modalities and create a set of musically enhanced games. The tabletop form factor of the Jam-O-Drum is particularly appropriate for the goals of this project as it arranges players in a circular formation, allowing them to see and interact with one another around the table. Tabletop games written for Jam-O-World are controlled through interaction with the embedded drum pads as well as interaction with a "lazy-susan" like dial at each of four player stations. Interaction with these two input devices controls the visual and aural facets of the games. Engagement is further enhanced by projecting computer graphics not only on the tabletop itself, but also on the walls and ceiling of the surrounding environment.

Jam-O-World games are designed to require physical and social interaction, as well as either collaboration or competition among players. Because Jam-O-World was originally built for a museum exhibit, two major design goals were to facilitate walk-up-and-play ease of learning and encourage interaction among players who may not know one another. In the following sections, we describe the design of one game in detail. Readers interested in learning about some of the many tabletop games written for the Jam-O-World platform should visit the project website.[7]

[7] http://www.jamodrum.net/.

Fig. 11.9 In CircleMaze, players work together to align pathways through four concentric rings. CircleMaze has been presented as part of several museum exhibits

11.4.2 CircleMaze

The CircleMaze game was one of the early games designed for the Jam-O-World environment. In this game, players work together to control four concentric circular rings projected on the table. Each one of the four color-coded lazy-susan turntables around the edge of the table controls one of these rings in a direct manner. Players must collaborate to rotate these rings in such a way that the rings' pathways align to allow virtual balls to travel from the outside edge of the table into the center of this concentric maze (see Fig. 11.9). A central clock counts down the seconds remaining, and teams gain extra time for each ball that reaches the middle. If the clock expires, the team regresses one level and if all the balls reach the middle of the maze, the players advance to a more difficult level. Players quickly learn that success is impossible without communication and collaboration among players as it is not possible for any one player to align all of the pathways necessary to allow the balls to reach the center of the table.

While playing the game, the rotation of each of the four rings controls the mixing of four recombinant tracks of music – percussion, base, melody, and vocals. Through playing the game and turning the rings, the players create a changing mix of cohesive music that follows their actions. While this music making is secondary to the main goals of the game, it does provide players with a non-repetitive background track which is appreciated by museum staff.

11.4.3 User Testing and Observations

Early testing of CircleMaze showed that players had difficultly grasping the rules of the game and their role in the collaborative effort when they first approached the table. To counter this difficulty, we designed a simple first level of the game which included one path on each ring and only one ball. Because players come and go in a museum environment, the game was designed to regress to this early level if teams were having difficulty playing the game.

Another early observation was that when left running, the table did little to attract new players when not in use. When the game is in full swing, graphical animations and dance music kept some new players from approaching the table. To better attract players and teach novice players the reactive areas of the table, CircleMaze enters an attraction mode when it has been idle for several minutes. In this mode, music plays quietly while the only graphics projected on the table serves to highlight the disk and drum pad controls so that museum visitors are attracted to touch these areas of the table and start a new game.

11.4.4 Porting to a Direct-Touch Tabletop

Several months after the initial museum installation of CircleMaze, one of the authors ported the tabletop game to Mitsubishi Electric's DiamondTouch table. The new input device allowed for the direct under-the-finger manipulation of the rings in the game and removed the indirect input modality of the circular disks. One of the major goals of the game (the forcing of collaboration among players) seemed particularly appropriate for one of the distinguishing features of the DiamondTouch table, namely user identification. Touches from each player are distinguished from one another, and the game's rings only respond to touches from the ring's user. Again, successful completion of the game requires the collaboration and planning among all players.

11.4.5 Comino and NeonRacer

Comino and NeonRacer have been designed and developed at the Media Interaction Lab.[8] Both of these games are tabletop games, combining physical and digital content. Inspired by the Incredible Machine, the general objective of Comino is to allow players to arrange a given collection of digital and real objects in a desirable fashion to perform a simple task (e.g., to put a ball from one point to the exit). Each level presents a puzzle requiring multi-modal interaction provoking user creativity. In some levels, there are some fixed objects, which cannot be moved; therefore, the only way to solve the puzzle is to arrange carefully the given real and digital objects around the fixed objects. Using the wireless pen-interface, players can *draw* a path

[8] http://mi-lab.org/.

Fig. 11.10 (*left*) Players have to draw a path on the surface for placing digital domino tiles. (*right*) Different physical objects have to be used for pushing the real/digital domino pieces. The photo sensor of a tower, for instance, can track the falling physical piece and push the digital ones

on the table's surface for placing digital domino tiles (see Fig. 11.10). Moreover, users are also required to place *real* physical domino pieces on the table surface if the digital domino tiles have been consumed. Special physical objects, the so-called "portals," are used to connect the virtual world with the real world. Using these portals, the real domino bricks can be knocked over by the virtual ones and vice versa. In the setup, two portals have been used which were connected over USB with the computer.

Of course, multiple players can work simultaneously. While one person is placing the *digital* domino tiles, another player can start setting up *real* domino pieces directly on the surface. In some cases, players even have to switch between the two spaces (e.g., if they have to check that the real towers trigger the digital domino tiles). The first version of Comino included five levels which had to be solved by the players as fast as possible.

NeonRacer creates a rich gaming experience by using everyday objects in an unusual way. The physical objects act as the setting of a racing game for multiple players standing around the gaming table (see Fig. 11.11). The world is selectively augmented with the players' vehicles, which are controlled by traditional game pads. The racing course itself is defined by virtual checkpoints. Real, tangible objects placed on the course are detected by an infrared camera mounted inside the table and act as obstacles in the game. The position and edges of real objects are detected using the camera and a natural feature tracking approach. Thus, in order to hinder the other player's movements, users have to maneuver their vehicles past the real objects and through the checkpoints. Both players and spectators can move objects around the course. Passive bystanders can also actively contribute to the outcome of the race and even take sides, which again increases the social interaction and fun for players and spectators alike.

11.4.6 User Testing and Observations

Both Comino and NeonRacer have been designed to be used as an installation for a museum. In our initial pilot study, we tested 12 people (6 groups) from our local

Fig. 11.11 (*left*) Players have to control their digital cars on the tabletop interface. (*right*) Physical objects can be put as obstacles on the surface

university, who were not affiliated with the game design and development team. The overall participants' reaction was very positive. Users really liked the idea of playing with a tabletop interfaces that combined the real physical objects in a digitally augmented environment. Participants had the impression that they were playing within *one* space, transitioning between the physical and digital smoothly. While the interface of Comino was perceived as very intuitive, many players had problems with the game pads playing NeonRacer. Instead, they would prefer a more intuitive interface to control the digital cars. During our study, we observed that participants often had orientation difficulties while controlling the digital cars with the game pad.

In a first version of Comino, the physical towers were not implemented wirelessly. Players often had difficulties handling the cables. Interestingly, they never placed digital domino tiles close to the cables – even if they could have done so (cf. Fig. 11.12). In our current version, we have a Bluetooth version of the towers which is greatly preferred.

Another challenge was to find the optimal perspective for the 3D digital content, since in special cases (while looking to the scene with a really flat angle) players can have a distorted view of the scene.

11.4.7 Interaction Design for a Walk-up-and-Use Tabletop Game

Designing for a museum exhibit requires creating an interface that visitors can grasp quickly. Tabletop games are no exception. CircleMaze, for example, uses a simple consistent UI during all portions of the game, with players' actions always resulting in the same results. Players are not required to learn a series of actions and modes for the game's controls (as one sees in console or PC games, during which the player has a long-term engagement with the game and can invest a lot of time learning the game's controls). Players have only two options: turn the disk or hit the drum pad.

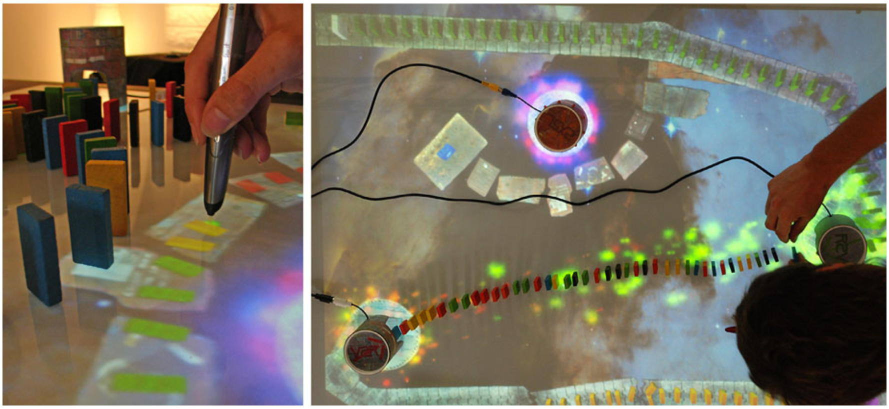

Fig. 11.12 (*left*) The cables of the physical towers were disturbing participants while placing the domino pieces. (*right*) In some cases, the perspective of the domino piece can become distorted

Visitors often spend about two hours in a museum. Usually, they are on the move to get a sense of the whole exhibitions and pausing casually at some installations. Actually, they only give time and attention to those installations they find particularly engaging. Therefore, it is essential that they understand quickly how to interact with the installation. In CircleMaze, novice players can quickly explore every possible action without help from another player or in-game persona, and these actions (and there results) quickly become second nature, allowing the player to focus on higher-level goals, advanced strategy, and social interaction. If the table only supports a stylus interaction, novice users often get confused because they expect to interact with the table by touching the surface with their fingers. In the next section, we are presenting eleven heuristics which are useful for everybody developing tabletop games.

11.5 Heuristics for Tabletop Games

The development of tabletop games is an iterative process throughout the development cycle, combining different usability evaluation methods such as heuristic evaluation, cognitive walkthrough and user testing.

We propose a heuristic evaluation already in the early phase of the design process. Heuristic evaluation is an expert based usability evaluation method, first introduced by Nielson et al. in 1990 [12]. In 2002, Melissa Federoff presented around 40 heuristics for video games where she tried to assess the applicability of Nielsen's heuristics to video games [5]. In the same way, Desurvire et al. released a new set of verified heuristics to evaluate the playability of games, the HEP (Heuristic Evaluation of Playability). As mentioned by the authors, their heuristics are helpful in early game design and they facilitate thinking about the design from the user's point of view.

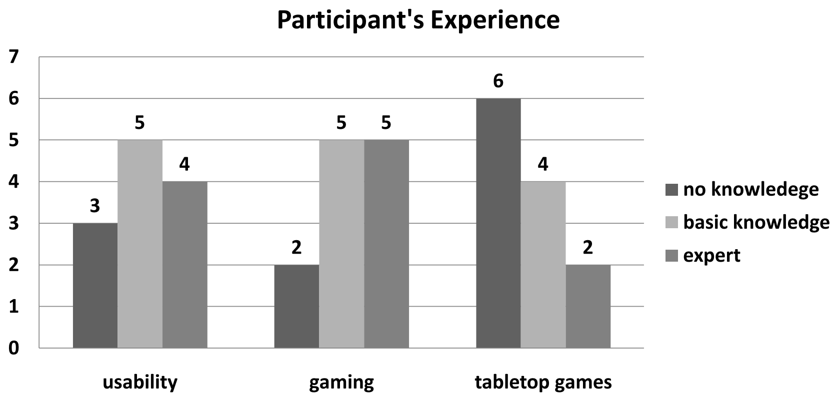

Fig. 11.13 The experience of the volunteers participating in the heuristic evaluation. Altogether four usability experts, five gamers and two experts in the field of tabletop gaming participated in the evaluation

Röcker et al. adapted HEP for pervasive games. The results of a study conducted by them have shown that the heuristics proposed for the game mechanics are the same for all types of games. The authors found out that it might be helpful to extend existing usability guidelines, as they are also related to interface elements, which might be fundamentally different in smart home environments (e.g., speech control, gesture recognition, or integrated and ambient interface elements might require adapted design guidelines). Further heuristics for the evaluation of video games have been developed by Nokia [10].

11.5.1 Evaluation Process

For the heuristic evaluation of tabletop games, we propose employing heuristics applicable to video games for the game play/game story and virtual interface related aspects. Nevertheless, the special properties of tabletop games are to be evaluated separately. Therefore, we iteratively developed ten heuristics targeting the special aspects of tabletop games. In total, we developed and reviewed four evolutionary sets of heuristics for tabletop games.

The first set of heuristics, including eleven heuristics, was developed according to existing research trials and could be described as important aspects in the development of tabletop games rather than as proper formulated heuristics. For the second set of heuristics, the heuristics have been re-phrased in order to be more appropriate and understandable. Furthermore, it has been formally proven against available literature on heuristic evaluations [14], and feedback from usability experts and experts in the field of tabletop gaming has been taken into consideration. The third set of heuristics has been developed based on the results of the review mentioned before and was tested through a formal heuristic evaluation. Twelve evaluators, aged

Fig. 11.14 The four evaluated games: (*upper left*) Casa Memo based on the DiamondTouch, (*upper right*) Comino, (*bottom left*) NeonRacer, and (*bottom right*) PenWars based on the interactive table of the Media Interaction Lab. Readers will find more information on the following website http://www.mi-lab.org/

between 22 years and 41 years (SD = 5.22) were asked to perform a heuristic evaluation of four tabletop games each. Two evaluators had no knowledge in the field of usability, five evaluators had basic to medium knowledge of usability and four could be considered as usability experts (cf. Fig. 11.13).

One evaluation session lasted between two and four hours depending on the number of times the evaluators played the games and the amount of feedback obtained. Since all games offered multi-player functionality, the evaluators were arranged in groups of two.

Four games have been evaluated (cf. Fig. 11.14). Besides Comino and NeonRacer, we also tested Casa Memo and PenWars. Casa Memo is a desktop-based memory game developed by ABC-Ware,[9] which was played on the DiamondTouch table. The overall goal of the game is to find pairs of cards as fast as possible by flipping over hidden cards. The flipping was realized by touching the card on the table. In contrast, PenWars is a real-time strategy tabletop game based on a stylus interface. Players can sketch tanks in order to compete against the opponent's units. All players have a certain amount of digital ink which affects the number of units

[9] http://www.abc-ware.com/.

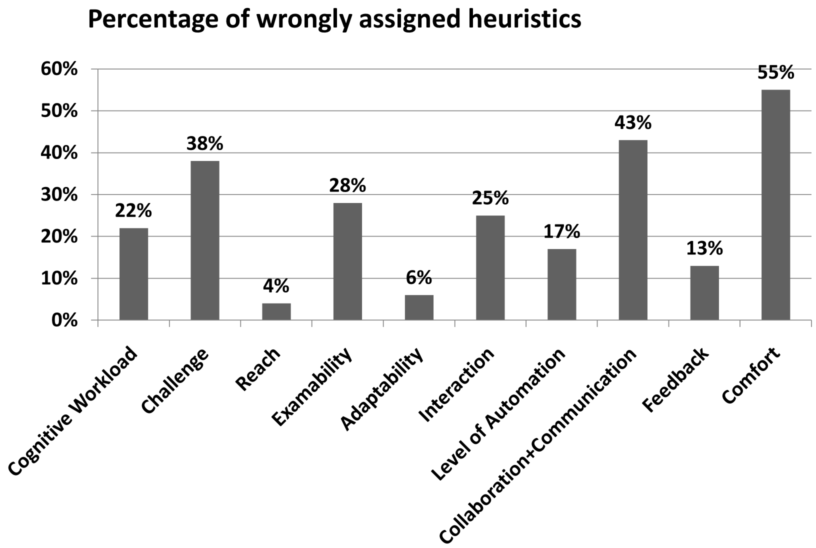

Fig. 11.15 The percentage of incorrectly assigned usability issues per heuristic

that can be created and their attributes. The tank's properties are represented in its size and shape. A large tank, for example, is stronger than a smaller one, but at the same time slower and less flexible in its movements. To win the game the player has to carefully consider the properties of the opponents' units, in connection with the map on which the game is played, when creating his own tank units.

At the beginning of the session, each participant obtained a paper explaining the proposed heuristics. The sequence of the games to be evaluated was counterbalanced so that learning effects or other influences would not affect the overall results. Each game was introduced separately to the participants. After playing the game, the participants had to examine the game again (up to six times) and verbalize encountered usability problems. Once finished examining the game, they were asked to categorize the usability problems they found into the proposed heuristics. At the end of each session, they were invited to check the heuristics for finding potential other problems that they might have overlooked before. During the heuristic evaluation 299 usability problems (138 classified problems) have been found (e.g., it is not possible to reach over the table playing Casa Memo). Since the quality of heuristics can be distinguished by the ease of assigning problems to them, the failure rate was an important indicator for their efficiency. The results obtained have shown that a total of 74 out of 299 heuristics have been assigned incorrectly, which is a failure rate of 25% (see Fig. 11.15).

For the final set of heuristics, the third set of heuristics containing eleven heuristics has been modified according to the results obtained throughout the formal heuristic evaluation. Most of the heuristics (especially those concerning comfort, collaboration, communication and challenge) have undergone drastic changes and in order to clarify the heuristics, sub-categories have been introduced.

11.6 Ten Heuristics for Tabletop Games

Summarizing, we identified ten heuristics which are essential for developing tabletop games. In the following sections, we describe them in more detail.

11.6.1 Cognitive Workload

The cognitive workload, which is not related to the game play (i.e., in connection with the acquisition of skills, the view, the screen orientation and the input methods), should be minimized.

The player's cognitive workload should be adapted to the game play so that the player is not overburdened in a way that the challenge of the game is negatively influenced. The learning curve should be kept short and unnecessary overexertion caused by display-connected issues, orientation, or input devices should be avoided.

11.6.2 Challenge

The system should be designed in a way that the challenge satisfies the preconditions of a tabletop setup and the target group.

The extended possibilities of tabletop setups should be used to design an appealing game play. Thus, the challenge should be defined by the tabletop setup. This also includes the challenge produced by input devices. Furthermore, collaborative and competitive tasks can provide additional challenge for a game.

11.6.3 Reach

The reach of the players should be adapted to the requirements of the game play.

Not every game requires the gamers to reach over the entire table. Participants can collaborate table-wide, not requiring a private workspace or they could need a certain private workspace in front of them (e.g., even mobile devices are a nice idea as proposed by Magerkurth [11]). The reach of each person is different depending on whether the person is sitting or standing. In our tests, we employed both types of setups. When players are required to share input devices, every player should have access to the device – even if they don't need it permanently, users should have the impression to have the same access to all devices.

11.6.4 Examinability

The players should not be hindered to examine the area required by the game play.

The examinability is the area of the tabletop surface, which the player is able to examine visually according to the game play. The virtual examinability allows the player the comprehension of information provided by the displayed interface and the real examinability can be understood as the player's possibility to see the displayed objects on the table surface without physical objects hindering the perception.

11.6.5 Adaptability

The system should be adaptable to the player in terms of the setup.

The tabletop systems/setup should have an ideal configuration for the players represented by the target group (e.g., allow the support for different seating positions during a game session, enable children as well as adults play the game on the same setup). On the other side, the game should be adaptable to other hardware configurations – it should be usable on a top-projection setup as well as on a rear-projection setup, and be playable while sitting or/and standing around the table.

11.6.6 Interaction

The interaction method should satisfy the expectations of the player and follow the game logic.

Most of the players have already more or less experience in gaming, and consequently some of them are familiar with different input devices. Therefore, the interfaces should conform to industry standards (e.g., from video games), if available, and be usable in a very natural, easy and understandable way [14]. The controls used in the setup should be intuitive, consistent, and meet the player's expectations. Furthermore, also the proportions of the game elements (real and virtual) should be kept realistic according to the game play.

11.6.7 Level of Automation

The player should be able to execute all actions relevant to the game himself/herself.

All actions that are perceived as boring, cumbersome and rather unimportant to the game should be performed by the computer. Nevertheless, the actions that are essential to the game play should be accomplished by the player [11].

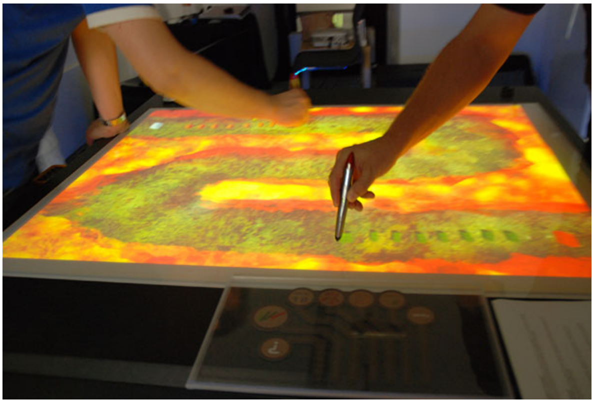

Fig. 11.16 The game play of Comino encourages close collaboration of the players

11.6.8 Collaboration and Communication

The interpersonal communication and collaboration should be supported by the entirety of the game (such as game play and setup).

The technology is not supposed to interfere with the collaboration; moreover, it should sufficiently support it. The game play should be designed to encourage collaboration or even competitiveness (see Fig. 11.16). The entirety of tabletop games (design, setup, game play) should aim at enhancing collaboration and communication between players. The game play should demand players to interact and talk with each other about different situations which might be either collaborative or competitive.

11.6.9 Feedback

Feedback and feedthrough should be adapted to the possibilities of tabletop games, used adequately, and be provided to the players when appropriate.

Feedback is meant for the person executing the current action and helps to understand what users have just done, and reassures them that they have done what they have intended to do. It can be purely visual, acoustic or haptic, but most of the time it is applied in a combined form. Feedthrough helps other players follow the current player's actions. Each kind of feedback depends on the environment it is used in. Furthermore, the right amount of feedback and feedthrough need to be applied at appropriate time.

11.6.10 Comfort of the Physical Setup

The construction of the setup (including the display) should be comfortable to be used and not hinder user while playing the game.

In this heuristic, we mainly focus on the hardware setup, which concerns the dimensions of the tabletop setup as well as the position of the player and the display system in use. The comfort is measured by the impressions of the current gamer. Players should feel comfortable during the entire duration of the game.

11.7 Conclusions

Digital tabletop games are emerging as both research projects and commercial efforts. In this chapter, we presented different approaches of how to develop interactive tabletop games. We reviewed several pieces of related work, describing two in detail. Finally, we presented heuristics for designing the many facets of tabletop games. These heuristics are drawn from our experiences and a review of the literature.

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