Dispensable, Tweakable, and Tangible Components: Supporting Socially Negotiated Gameplay

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Abstract

Our paper examines a flexible approach to designing general game components inspired by traditional game components. Our goal is to design digital game systems that offer the players greater choice in dictating the rules, pacing, and sociability of a game session – we describe this as supporting socially negotiated gameplay. We employ five design principles to meet this goal: dispensability, live-tweakability, tangibility, mobility, and value. Our work demonstrates this approach with the design of an augmented game system composed of playing cards instrumented with NFC chips and a mobile device with three digital game components: a Card Viewer, a Score Board, and a Turn Keeper. We report on initial user sessions and articulate two emerging challenges for supporting socially negotiated play: (a) solving the interaction costs to enable greater flexibility and (b) managing user expectations for the automatic part of a manual-automatic system.

Keywords: Game Design, Game Components, Flexibility, Tangible Interfaces, Augmented Games, NFC

Introduction

Traditional game pieces like dominoes, playing cards, and dice have developed over centuries of design and acculturation to become enduring pillars for gameplay. Technological developments contribute to this evolution. The origin of playing cards is tied to the technological developments in the seventh century from scrolls to books. Wilkinson (1895) explains that scrolls were originally kept as records of dice games with images of the dice. When these became books with leaves, game symbols printed on leaves became game symbols printed on cards.

Such general game components are different than toys in that there is a clear game-oriented purpose to them. They are different than specialized game components such as a puzzle piece in that these are generally useful for a large number of games and contexts. Today, Pagat.com's index records over 800 distinct card games. The breadth of this collection is a reflection of how games have developed around cards just as cards have been shaped to fit the games they are played with. This shows the success of playing cards as an engaging and enjoyable game medium. Also, the large variety of games demonstrates its versatility and its openness to appropriation.

A large aspect of this openness is the support of socially negotiated play – the idea that players determine the rules and the pace of the game among themselves. This is a distinction about analog games that we have arrived at by comparison to digital games (see Related Work). The complexity and power that comes with current technological opportunities also includes a change in who determines the play, the pace, and the social experience of a game. Many of the technological augmentations for games come at a cost of players' control of the game and the medium. As a result, the design of digital systems that support socially negotiated play remains underexplored.

Our Vision

Thus, we seek to investigate digital game components that act as simple and useful pieces for hundreds of games. We view this as a step in understanding and adding to a collection of well-established game elements such as playing cards, dice, or even simple pen and paper. In the same way that these popular game components can be appropriated for many games and by many people, we seek to extend this flexibility with technological capabilities. In particular, we want to explore the support of socially negotiated play.

To accomplish this, we present our design investigation of digital components for traditional cards that offer new technological capabilities such as

- helping track the game state,
- providing information to players, and
- offering augmented mechanics for play.

We introduce five design principles for designing an open system: dispensability, live-tweakability, tangibility, mobility, and value. These principles are explained in greater detail in the next section.

Starting with a pack of playing cards, our system outfits each card with an NFC[1] chip and uses a smartphone with an NFC-sensor to augment the gameplay experience.

Figure 1: Our system set up with Turn Keeper and Card Viewers.

Named Coardial (a play on the words "cordial" and "cards"), this hybrid physical-digital system offers three digital game components that support a digital connection between game components and the social connections among players. A Card Viewer component offers contextualized rules, explanations, hints, strategies, etc. that go beyond the instruction booklet often packaged with card games. A Turn Keeper scans cards as they are played to keep track of the game state and to direct the game experience with visual or audio effects and computed game logic. A Score Board records both the aggregated score of the game and the record of cards played. An example of Coardial can be seen in Figure 1 where participants are playing a game of Crazy 8s with a centrally-placed phone for the Turn Keeper and individual phones each running a Card Viewer and personal Score Board. Players can scan cards in their hands for information about the card. On their turn to play, they scan their card with the phone in the middle of the table.

Driving Design Principles

To realize our vision, we identified five principles to guide our design thinking more concretely. These are presented here both as a set of principles that have been useful to us and as an invitation for readers to consider their merits when taking a "flexible" approach to game system design. We have used these five concepts in developing each digital component with the objective of producing an ecosystem of playful game pieces.

1. *Dispensability.* Dispensability refers to the ecosystem's capacity to leave out hardware or software components that players deem to be non-essential or antithetical to the game that they want to play. Such a component can be 'unhooked' from the ecosystem without rendering the system unplayable. This is similar to the systems concept of fault-tolerance and graceful degradation. It supports our vision of socially negotiated gameplay in that the choice of components is the player's.

Our system is primarily designed as a tool rather than as a game director. It is important that we convey our vision wherein these components are not meant to be intelligent first and foremost. They are more like the casino personnel who deals out cards in blackjack and nudges players; sometimes counseling on actions available. Intelligence and decision-making control

[1] Near Field Communication is a specification for a very short-range version of RFID (Radio Frequency Identification) that permits chips to read and write data only within very close proximity. For our devices, this is around 2 cm or less.

rest in the players' hand. Similar to the analog components of cards or dice, we envision the game experience to depend on the components only as much as the players want it to. The opposite value is 'indispensability' wherein every component is required. For example, an analog score sheet is a dispensable component in a game of cards. Yet, in most digital games, the scoring system is baked into the code and players are required to play according to predefined scoring rules. This is restrictive. For example, the card game, Bridge, has rules about how games should be scored and when a game is won or lost. If players want to play a few deals of Bridge regardless of whether or not a score is accrued or a game is considered 'won' or 'lost', the indispensability of a digital scorekeeping mechanism interferes with this desire. Instead, players need to fiddle with the computer's notion of "starting" and "ending" a game to accommodate a casual, practice deal of Bridge. In this scenario, the indispensable scoring system is a burden.

2. *Live-tweakability.* Live-tweakability is the capacity to quickly and easily accept changes in the midst of play without having to wait until a game session is finished or even having to pause the game. If a component is affecting the game experience adversely (e.g. the game timer is too fast), players who can adjust it 'in-vivo' are afforded greater freedom to tailor the game experience to the needs of the moment. This principle is explored also by other digital game projects that see it as a way to translate the flexibility of the analog to the digital (e.g. (Frapolli, Brocco, Malatras, & Hirsbrunner, 2010) pursue this same 'live' configurability, but with an expectation that users are proficient at programming in a Lisp-like language).

3. *Tangibility*. A tangible interface refers to systems that emphasize physicality as an interaction technique. Kirk et al. (Kirk, Sellen, Taylor, Villar, & Izadi, 2009) define tangible interfaces as when "everyday physical objects are used to control and sometimes display digital information". Similar to the vision of pervasive gaming (Magerkurth, Cheok, Mandryk, & Nilsen, 2005), our desire is to take advantage of the bigger physical space afforded by playing cards and the user interface benefits of a tangible interface. For us, these benefits are the semantic meaning and physical affordances that accompany traditional playing cards. These benefits allow us to build on the strengths of existing game components that are ready to appropriate.

4. *Mobility.* Mobility supports the idea of "play anywhere". We envision solutions that do not tether you to a location or to features that are not always available, such as internet access, a stationary computing device, or another large display. Projection interfaces such as SideBySide's handheld camera/projector gun (Willis, Poupyrev, Hudson, & Mahler, 2011) and portable tabletops such as Bonfire (Kane et al., 2009) or PlayAnywhere (Wilson, 2005) employ pico-projectors to untether users from stationary surface computing displays and allow novel, augmented interactions almost anywhere. Our system is designed with a similar ethic, allowing users to use mobile devices and pico-projectors wherever they are.

5. *Value.* Our system is meant to augment the game experience. Potential augmentations include multimedia embellishments, 'introductory courses' to teach a game, trainers to improve skill, tracking statistics or replays, or networking functionality. While this principle does not directly address the idea of social-negotiation, it recognizes the value that the technological augmentations bring to a scenario. We have found this to be important to keep in the forefront of the design process as we explore novel interaction methods and these hybrid systems.

Guided by these principles, we designed Coardial, a flexible system that allows a mobile device, such as a cell phone, to offer digital components to accompany and augment card games.

Related Work

We drew on surrounding literature to inform and situate our work.

Understanding the tradeoffs from analog to digital

Traditional playing cards excel at supporting an enjoyable mix of competition and sociability (as a widely representative survey of card-players (Crespi, 1956) suggests). Our concern is to be deliberate about the impact of introducing digital components. Just as the replacement of dominoes with playing cards changes the dynamic of gameplay (at a minimum, it made the experience more portable and convenient), we want to anticipate the effects of digital augmentation on traditional play experiences – and decide which we want.

Researchers from the University of Waterloo and Queen's explore the effects of automation in tabletop gaming by translating two board games, Checkers and Pandemic (Z-man Games), into low-automated and fully-automated tabletop-computing applications ((Pape, 2012; Wallace et al., 2012)). While players report liking the automatic placement of game tokens, the evaluations surfaced the following insights:

- Automation changes the flow, sometimes resulting in missed actions, confusion, extended pauses and missed opportunities for social interaction.
- Automation prohibits the development of house rules.
- Automation prohibits allowances made to novice or less capable players in more social settings.
- Flexibility of the physical or low automation interfaces enables participants to make sense of the current game state and to make appropriate decisions.

These observations are echoed in other research about online game pace and sociability (Losh, 2008; McEwan, Gutwin, Mandryk, & Nacke, 2012; Wohn, Lee, Sung, & Bjornrud, 2010): Automated games can move too quickly for players to follow. Sociability, when mediated by the software, is heavily influenced by the digital medium instead of being shaped by the players themselves. In response to these themes, we want to maintain access to the non-automated, manual nature of traditional game components in how they allow the players to negotiate the play, pace, and social elements in a game (Xu, Barba, Radu, Gandy, & Macintyre, 2011).

"Flexible" game systems design

We take a "flexible" approach to game design that has not been explored very deeply in the literature on game system design. Some commercial games are being designed to allow social negotiation of rules, pace, and sociability: J.S. JOUST and B.U.T.T.O.N. as digitally-enhanced "folk games" are notable examples (McElroy, 2012). A few studies have been conducted of socially negotiated games played over digital platforms. A pilot study of a rule-free tabletop and handheld card game system for UNO has collected responses from participants showing that they considered missing rule constraints and the possibility to cheat as positive aspects of their experience (Lobunets & Prinz, 2011). The analog to digital comparative study in the prior section (Pape, 2012; Wallace et al., 2012) studied low-automated versions of Checkers and Pandemic. A study of invented custom games of Halo 2 (Cheung & Huang, 2012), an online multi-player computer game, shows that players develop 'honor rules' to enforce new games that are socially sanctioned. Players rely on the software's record of player actions to keep others accountable to otherwise digitally unenforceable rules (such as disallowing gunfire in a certain area). The importance of information, accountability and the experiences of play as performance are shown to be key findings in these studies – contributing to these findings will be our contribution in this project.

Related augmented card game systems

Projects that use RFID-enabled cards coupled with digital readers and systems are a technological precedent for our project (Floerkemeier & Mattern, 2006; Müller, Evequoz, & Lalanne, 2006; Römer & Domnitcheva, 2002). These projects bear similarity among each other in their goals to preserve the social enjoyment of card games, to provide augmentations for novice players and to handle tedious tasks like scorekeeping.

Floerkemeier and Mattern (Floerkemeier & Mattern, 2006) built an RFID-instrumented table whose function is to track the entire game. Their users used mobile phones to interface with the digital system and played with real cards with RFID. After an evaluation, their participants asked for audio output to relieve the burden of looking at the mobile phones as much during play. They asked for more variants of the games offered – the players had a favorite rule set that was not supported. In their report, the authors speculate that a simple way for players to program rules or download new rules would help solve this problem.

Römer and Domnitcheva (Römer & Domnitcheva, 2002) present a similar RFID physical-digital hybrid for the game, Whist. An RFID scanner in the middle of a table is accompanied by a public shared display and the individual's private PDA display (Personal Digital Assistant). Scoring and information about legal moves is provided to the players. Initial user demonstrations showed that players used the "cheating alarm" to learn how to play. Furthermore, "Players did not like to be forced by the system to play the game in a way they are not used to. For example, forcing the players to take off the cards from the table before dealing out the next round of cards already is an annoyance to some people."

Additions of digital components to physical games are not new. For example, Hasbro's MONOPOLY Electronic Banking game that introduced a new banking card system consisting of elecronic bank unit and bank cards. This unit tracks players' cash electronically, help pay bills, collect gifts and debts from opponents, and adds an educational component to teach players about responsible money management. Overall, this and the RFID systems are different than ours because of their single-game, monolithic approach and their inflexibility. These systems dictate the game's rules and the pace. Our approach is to find a balance between digital- and social-mediation. Our expansion beyond these projects will be to further explore tangible interactions, end-user appropriation, and the idea of general gaming components.

Scenario: *Crazy 8s* and *Pirates!*

The following scenario is to be read as an introduction to how Coardial can support socially negotiated play via the interaction possibilities with an instrumented card deck. We first describe *Crazy 8s*, an existing card game, to establish an understanding of the interaction techniques. *Pirates!* is our own variation of *Crazy 8s* designed to take advantage of computing functionality and to make the gaming components be core elements of the game experience. Everything described has been implemented excepting the social networking functionality.

Crazy 8s

Players start with 7 cards each and try to discard a card on their turn to ultimately get rid of all their cards. They can only discard a card over the top card of the center pile if the cards having matching suits or numbers (e.g. A six of hearts must be discarded on top of another six or another heart). If the player can't play, a card is drawn instead. Specialty cards include the 8 that acts as a wild, the Queen skips the next player, the 2 requires the next player to draw 2 cards, and the Ace reverses the turn order.

Pirates!

We designed *Pirates!* as a variant of *Crazy 8s* to take advantage of the computational capability of the phone. In *Pirates!,* players discard cards like *Crazy 8s*, but are also challenged to guess the digits of π. The device keeps track of the current index of π to be guessed and, on occasion, players must guess the next digit correctly or be penalized. The special cards from *Crazy 8s* are replaced by a King, Queen, and Jack. The King represents a Pirate King, a wild card that forces the next player to guess the next digit of π. The Queen can be played instantly to avoid guessing and reverses the turn order. The Jack moves the guessing index back a random amount and skips the next player. The player can ask the mobile device for hints ("The next digit is not an 8."). After a guess, the index for π advances forward. The computer augmentations of *Pirates!* are helpful for keeping track of the current guessing index, for offering hints, and for generating a random number for the Jack.

Setup to Gameplay

Tim and Julie sit down to play. This is part of their weekly series of card games. According to the scoreboard on Facebook, Tim is 45 points behind. Tim jokes, claiming that it is time for him to close the gap. They take out two phones and a deck of NFC-enabled playing cards. Tim scans his player card to register his player token and Julie does the same.

Tim takes a card from the deck and taps his phone to the card. The phone's NFC sensor reads the card's unique identifier. The phone chirps in acknowledgement, looks up the card in its database, and loads the entire 52 card deck into active memory. It asks Tim what game he is playing. Is it Poker? Hearts? Depending on Tim's answer, the software will load a set of rules and reconfigure the interface for playing that game.

On the touchscreen, Tim selects *Crazy 8s*. The system assigns point values and informational text to each card. The eight is worth 50 points; face cards, 10; and, every other card is worth its numeric value. The device's Card Viewer (Figure 2) is a digital component that can display the point-value and instructions for any scanned card, keep a collection of last-scanned cards, or transfer the current score to a personal scoreboard. This game data is minimal. Beyond the point-value and informational text, no other data is encoded, not even rules. In addition, the Turn Keeper component is activated for *Crazy 8s* (Figure 3) and some basic rules about turn-order; Reverses, and Skips are enabled. These offer a sufficient set of computational features for facilitating a socially negotiated game experience but are designed not to tread on the players' authority over the system. Thus the intelligence of the system is not the foremost quality, but rather, it is the role of the system as a support component.

Playing Crazy 8s

The game begins. As each card is played, it is scanned into the system. The mobile phone announces the card played and whose turn it is. When Tim can't play a card, he swipes the Turn Keeper to pass on his turn. To Tim's disappointment, Julie slams down her last two cards: a Queen and an eight, which, as a 'Skip' and a 'Wild', guarantee that she ends the game. She does not bother scanning the cards, dispenses with the formality, and simply announces "Game over!" Reluctantly, Tim switches to the Card Viewer component, scans his remaining cards, groans aloud when the total comes up, and uploads the score online. With his seven, Ace, and eight, he is now down by an additional 58 points. Julie grins.

Playing Pirates!

Hoping for redemption, Tim unloads the game data and loads the *Pirates!* rules. A new set of point values populates the database for the generic Card Viewer. The Turn Keeper (Figure 4) is revised to include a specialized guessing interface for keeping track of which digit of π is to be guessed, to ask for hints, and to check a guess.

The game proceeds until Tim plays a King. The phone gleefully challenges Julie with its electronic voice, "`The Pirate King tests Julie!`" Julie wonders, *What was the 6th digit of pi, again? I know it's high…* She presses the green button for her hint, "`The next digit is not a 0.`" Julie groans. She guesses, "7?" and presses the yellow button to check. "`Pi at position 6 is the number: 9.`" She's wrong! According to the rules, she must draw 9 cards. Tim cheers! Things are looking better for him in this game. In a gesture of magnanimity, he offers to let Julie draw one less card. Although this isn't an official rule, the system is flexible enough to allow this deviance. Instead of the computer dictating this rule, it is up to Julie to accept the offer or not. However, she laughs him off and the game progresses.

In these scenarios, the software does *not* have a full representation of the game rules for *Crazy 8s* or *Pirates!* It refrains from checking legal moves or confirming that players drew cards. The physical configuration of devices is up to the players. If Tim and Julie had more devices, they could decide to use them all — one central Turn Keeper and personal Card Viewers, or choose a subset (*Dispensibile, Tangible, Mobile)*. The software configuration is similarly undefined. Tim can track his score with the Card Viewer application or play a game without keeping score at all. Opportunities for tweaking the rules abound (*Live-tweaking*).

System Description

Technology Overview

Coardial is a mobile web application. A majority of program functionality is developed with JavaScript and uses HTML5 features such as CSS3 transitions and in-browser data stores. Coardial runs within a specialized QtWebkit engine and renderer. It is built for smartphones that support 3.5+" touchscreen display, Bluetooth communication, and NFC reader and writer. Additionally, some smartphones such as Nokia C7, N9, 701 support RCA output that can be connected to external displays (e.g., projector, television).

Each playing card is inserted into a plastic card sleeve containing an NFC sticker. Each plastic sleeve is numbered 1 to N (e.g., 52 for normal card deck) to allow players to configure their deck by associating it to a card, replacing with another game deck card, or replacing a custom deck. With this setup, the sleeves can be used for normal deck of 52 playing cards or other game decks (e.g., Bang, Magic: The Gathering, Rook, Skat, Tichu). Players tap the sensor on the phone to the chip in the card to allow the phone to read the data on the NFC chip. Players can scan one card at a time at a rate of 1 per second. The short range of the NFC-enabled phones makes it possible for players to hold a mobile device in close proximity to other players without accidentally scanning a card.

NFC chips containing vCard information (electronic business cards) are treated by the system as player tokens. This allows the system to register new players to a game and to use the vCard metadata to augment the digital representation of the player (e.g. profile pictures).

We have chosen to use NFC in this project as a way to instrument traditional play materials. We chose this technology because it is accessible to the consumer market (as opposed to dedicated card scanners in casinos), because it is precise (as compared to RFID or computer vision), and because it more mobile than a digital camera (these depend on ambient light and require careful positioning). However, our design approach is not exclusively dependent on NFC as an enabling technology. Instead, we see it as a tool for exploring our design principles and interaction affordances. Guided by these principles, we chose an architecture for connecting game components to pass messages to each other via a publish and notify blackboard (Silva, Garcia, & Lucena, 2003).

Architecture: Components, Blackboard, Listeners

Our architecture provides a shared environment for game components to broadcast game information to each other within a device and even across many devices using Bluetooth. The application is a collection of components. Each component uses the blackboard (Silva et al., 2003) to maintain information about the component's state (e.g. the NFC sensing component keeps track of a history of scanned chips). The blackboard has an ordered list of listeners that are triggered when an update to the blackboard occurs. For example, when an NFC chip is detected, the NFC component appends the chip's unique identifier (a string) and a timestamp to an array named "history". This update triggers a series of method calls that have been registered by other components. For example, when the player brings the Card Viewer to the foreground of the mobile device, this component will register one of its methods to be triggered when an NFC tag is scanned. This method will then allow the Card Viewer to display information about a scanned card and to update its own state.

We employed the blackboard architecture as platform solution for the challenge of giving numerous digital components access to information about each other and about the physical game state (e.g. What cards are in the player's hands? What card has been played?).

Infrastructure Components

A set of components that provide device-based functionality, track players, and organize NFC card sleeves, card decks, and game rules are examined, in turn. They realize our vision of creating digital and tangible game components by providing sensing data and other basic contextual information such as game information and player information.

Backend device functionality enablers.

Specialized capabilities such as NFC sensors and a text-to-speech engine are natively implemented using Qt and exposed to the application through Javascript objects and their methods. These injected objects have methods that are mirrored in the Qt code and allow our application to leverage device functionality and to acquire data from device sensors such as NFC tag data or profile information. They are exposed to the rest of the application by being wrapped as components of the blackboard (as previously described in the NFC sensing example).

The backend components that we have implemented include NFC to read and write NFC tags, Bluetooth to facilitate device-to-device communication, and text-to-speech to provide informative audio augmentations.

Player.

The player component stores and retrieves player information from the database. It keeps an ordered list of active players and the index of the current player.

Sleeves.

A sleeve is a clear plastic card sleeve with an NFC chip attached to it. Players are expected to have as many sleeves as they have cards that they want to play with (typically 52). This component manages a library of different sets of sleeves and interfaces for scanning a new set of sleeves. It is capable of importing and exporting data about sets of sleeves onto an NFC chip for sharing sleeve information from device to device.

Deck manager.

The Deck Manager manages the collection of known games and known sleeves. It is aware of a newly scanned card. If no game is loaded into memory, it will prompt the player to decide what game to start.

Playful Components

The following components represent our design investigations to create playful components that take advantage of the architectural support system, sensors, and backend components. They provide game components that players would feel comfortable appropriating and integrating into card play. We have noted that playful components can be used communally or individually. When communal, they manage multiple players and take a more vocal persona. When they are used on individual devices, they maintain individual player states and information and have a quiet, private profile.

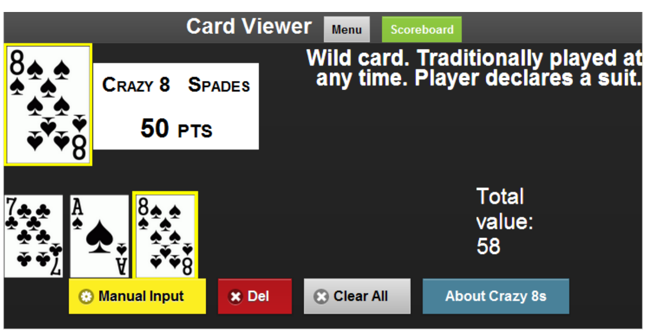


Figure 2: Card Viewer for a game of *Crazy 8s*. The bottom row collects every scanned card (7, A, 8 right now). Each card can be selected to be inspected. The inspected card is displayed ("Crazy 8", 50 points) along with informational text ("Wild Card…"). The Card Viewer is capable of analyzing a set of cards together (this version sums the card score together for 58 points) and the total score can be transferred to a player's scoreboard by scanning an NFC vCard.

Card Viewer.

At a minimum, we envision the Card Viewer as a card-centric information resource providing direct access to a variety of information about the card (e.g., role, value, rules of play). It organizes the information, in electronic form, that is typically found in a poker reference card or instruction booklet of a custom game deck and can be conveniently looked up when combined with card scanning activities. More generally, we envision this component as an external memory aid and potential conversation starter. With direct access to card information, the Card Viewer supplements the players' own recollection and knowledge. When used in a communal setup, player interaction with the component can lead to conversation and knowledge sharing.

There are three areas in the Card Viewer (see Figure 2). A history of scanned cards allows players to keep track of the cards that have been scanned. This history can be organized and cards can be deleted. An inspection area displays relevant information about any selected card within the history. An analysis area ("Total value: 58") provides information about all of the cards in the history as an aggregate. This can be useful when game rules discuss sets of cards such as a flush or full house in poker. If the player scans a player vCard, all of the cards are moved into the player's score bin and the history is erased.

The Card Viewer is general in purpose. In some games, it can be used to mirror the cards in the player's hands. In others, it can be placed in the center of the table as a communal, digital rule-book.

Score Board.

The Score Board stores a player's score and the cards that comprise that score. For example, after a game of *Crazy 8s* has ended, if a player has a six and a three left, those cards total 9 points. When the score is recorded by Score Board (as transferred from Card Viewer), the two cards are copied into memory and the 9 point total is displayed. Later, the player can revisit those two cards if he wants to recall the details of the game.

With this component, we leverage the digital capacities of the phone for computation and memory. For novice players, these capabilities can speed up the game for them or allow them to learn in the course of playing.

Figure 3: The Turn Keeper in a shared, communal setup that enables scanning cards as they are played. See Figure 4 for detail about the on-screen interface.

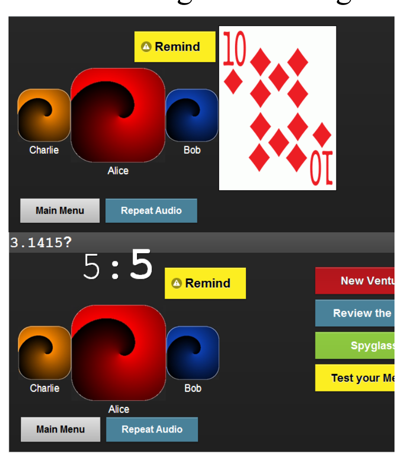
Turn Keeper.

The Turn Keeper is designed to be placed in the center of the play area. It scans cards as they are played and tracks whose turn it is. (In Figure 4, the current player is Alice, whose player icon is a red swirl.) It will advance to the next player's turn when a card is scanned or when players manually tell it to advance to the next turn. As a general component, the Turn Keeper becomes a central location for the system to keep track of the game state. As a central component, it is a good place for more game-specific rules to be applied. The scenarios for *Crazy 8s* and *Pirates!* show how we have used game modules to make the Turn Keeper more intelligent.

For example, in *Crazy 8s*, once a card has been scanned, the Turn Keeper will analyze the card, read it aloud, and potentially:

- Announce the next player's turn when advancing to the next player
- Skip the next player
- Reverse the turn order
- Announce an instruction: "Player X, must draw two cards"

The Turn Keeper version of *Pirates!* includes game-specific functions for restarting the guessing counter, for getting hints about the next digit of π, and for reading the next digit aloud.



(i) Crazy 8s Turn Keeper. Tracks current player and displays scanned card and a button to trigger an audio prompt to remind the current player that it is his or her turn.

(ii) Pirates! Turn Keeper. Tracks similar features as Crazy 8s. Also, it displays the numbers of π as part of the guessing game. ("3.1415?"). Buttons on the right allow players to reset the game (red button), read aloud the numbers of π so far (blue button), get a hint (green button), or confirm a guess (yellow button).

Figure 4: The Turn Keeper display for (i) Crazy 8s and (ii) Pirate! game. Both versions keep track of the current player (Alice) and the previous/next players (Charlie/Bob). When a card is scanned, the Turn Keeper plays the appropriate audio prompt and advances to the next player. To skip a turn, players can swipe their finger across Bob's icon.

Finally, as a social component, the Turn Keeper can be a kibitzer, a role player, or rule informant such as those found at a casino (e.g., dealers, boxperson or stickperson at a craps table). This component can mimic their real physical counterparts who maintain the flow of the game or add a social role by stirring up conversation for fun or learning.

Supporting Tangibility

In addition to the backend and play components, our design investigations have shown that the effort to add a digital device to an already familiar physical activity imposes new challenges for user interface design. An important part of our solution has been to iterate on physical components that make it easier to hold cards, hold devices, and to scan cards. Images of these holders can be seen in figures throughout this paper. Figure 3 shows a physical holder that holds a phone at a proper height above the table for the Turn Keeper to operate smoothly. Figure 5 shows a version of a card holder that holds, in one hand, both the mobile device and the hand of cards.

Pilot Sessions

Fairly soon after we started our prototype development, we began playing different card games (e.g. *Crazy 8s, Hearts, Gin rummy, Memory)* with the system; first amongst ourselves and later with other colleagues in the lab. As one of the system design principle was for the components to be dispensable, gameplay was not impaired by the rough form of the prototype. In fact, as we played the system, we tried different configurations involving varying numbers of phones and components. We introspected about the fluidity of the interface, the value of the components tested, and features that were lacking.

About two thirds of the way into the project, we started recruiting outsiders and colleagues to play *Crazy 8s* and the *Pirates!* variant. We describe 5 different play sessions with 5 different groups of 2-3 people each (see Table 1). In all cases, a member of the project team was a participant.

As with the early sessions, we field tested different configurations of devices, different combinations of components, and evolving version of the *Pirates!* game. One configuration involved a single device that sat in the middle of the table and referred to as the communal device. Initially, this communal device was used to scan the cards discarded during play, kept a list of discards, and could be inspected by any player. The component's functionality evolved to include audio feedback of the card scanned, turn-keeper capability, user-tweakable turn-keeper override capability, and eventually simple, game-specific, information about specific game cards.

Figure 5: A prototype for a holder that can clip on to an array of cards and has a docking area to guide players who want to scan a card into the device.

A second configuration involved one device per player along with a communal device. Each player's device included NFC component for player's cards, a Card Viewer component explaining the value and function of a card in a game, and a Score Board to value the scanned cards for a particular game.

Over the course the 5 pilot sessions, the components on the player's device evolved in functionality and in their informational value with respect to the *Pirates!* game. They include:

- the ability to send the scanned cards to the Score Board;
- analysis functionality for assessing a set of cards;
- an "About" feature that temporarily replaces the cards in the Card Viewer component with the special cards in a game (K,Q, J for *Pirates!*) to provide quick reference.

The next section discusses findings as our play sessions and design iterations progressed. Participants in these 5 pilot sessions are labeled with letter to encode the pilot session, player combination (see Table 1 for specifics).

Findings

Participants would play the same 'game' with different rules.

The amount of rule-enforcement by the software was minimal. The result of this was that participants would sometimes start a game and then realize that they were not playing with the same rules. Participants A and B needed to verbally coordinate after a few played turns of the memory game to agree that two cards of the same rank, but different colors (a red five and a black five) were considered matches.

Imprecise game mechanics impeded, but did not 'break' the game.

In earlier versions of the Turn Keeper that did not track the current player, the participants had to negotiate the meaning of a Reverse card (the Ace) when there were only two players. In most iterations of *Crazy 8s* and *Pirates!*, players were at a loss for what to do when they could not play a card. Were they supposed to draw a single card or more? Could they immediately play a card that they drew? These 'breakdowns' show how the rule enforcement and negotiation bring back the task of interpretation to players. For the game to continue despite the breakdown shows this flexible approach's strength.

Playful social interaction mingled freely with game actions. Awareness was sometimes easy to manage, sometimes not.

Participants C and D joked about ganging up on each other. They humored each other about the cards they were playing in *Crazy 8s*. Participants A and B teased each other about winning or losing. In these cases, people's attention transitioned smoothly from the game to each other and back. In other configurations, the extra device in their hands made it difficult to be aware of the overall experience. Participant L wrestled with this as he tried to focus on his personal display and the overall game at the same time.

Both the Card Viewer and Turn Keeper exhibit usefulness as information brokers.

The device became an information authority. Participants resorted to whatever rules *were* encoded in the device as an authority on how the game was to be played. They looked to the record-keeping in the Card Viewer's history to double-check what had been played. Participants used the Turn Keeper to resume playing after periods where the group was distracted and lost track of the state of the game.

Participants often treated the individual Card Viewer as a mirror of the cards in their hands.

Without prompting, participants A, D, E, and K tried to keep the Card Viewer in their hands to be a digital version of the physical cards in their hands. This was difficult because they had to delete cards when they played them. Also, this component did not have a way to order the cards as displayed. Participants would sometimes delay the game to reorganize their digital card view.

Different physical configurations changed the role of a general software component.

The same Card Viewer acquired different roles when it was used in a player's hand versus as a communal resource. Privacy expectations changed depending on this configuration difference. For the Turn Keeper, the addition of a pico-projector rendered the small visual display of the communal device redundant (see Figure 6). The communal device still provided audio output and scanning functionality. Participants responded positively to the idea of flipping the phone upside down to make scanning easier since the sensor is located on the bottom of the phone.

Figure 6. Suggestion for flipping the communal device to make scanning easy as display is not viewed.

Players tried different physical holders in their own ways.

The tangible aspect of the system leads players to explore their own ways to hold and manage the devices. Figure 7 shows 3 players using 3 different techniques to scan and sort their cards into the holder. The player on the left holds all the cards in left hand and slides the card into the holder at desired position. The middle player sorts cards in place in the holder. The person on the right holds cards in right hand and leaves holder standing and uses the right hand to place each card into the holder.

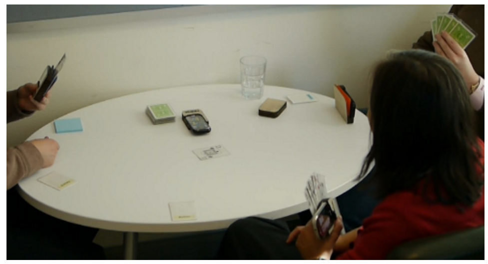


Figure 7. A variety of holding methods

The unpredictability of these physical interactions can lead to accidents. In the sequence shown in Figure 8, the player on the left was trying to stand the holder on the table. Unfortunately, the entire hand tipped over. In the midst of the accident, the participant pressed the “Clear All” button on the screen and wiped out his carefully arranged card view history.

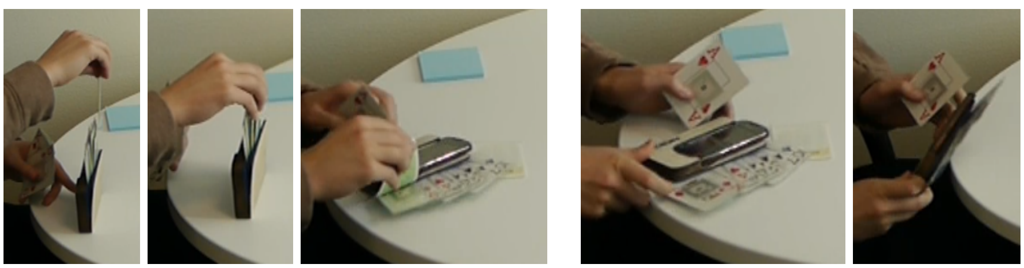


Figure 8. An accident with the card holder not only revealed all the cards for a moment but reset the software.

Summary

We advance a "flexible" approach to game component design and show how we used 5 design principles to accomplish that. Our work demonstrates this approach with an architecture that supports a set of software and physical game components that satisfy these principles. Our findings show that players are able to appropriate the components and to determine much of the game experience for themselves. We observed not only social negotiation of gameplay but also playfulness and social interaction.

The dispensability and live-tweakability of the components meant that the system overall was capable of accommodating the rules that the players preferred. It meant that players could take actions to adjust the pace of the game, deciding not to use a component, or relying on audio instead of visuals for smoother gameplay.

The tangible aspects of the equipment offered players the chance to adjust the devices to their preference. The physicality made it natural for players to find new holding methods or to try different ways to scan their cards quickly. Some participants slid their cards one at a time past the phone; others laid the cards out on the table and tapped them each with the phone.

The mobility of the system meant that the sessions could be played in different places and in different configurations without requiring much more than a flat surface to lay out the cards. The game system and the dispensability of the game components could accommodate different numbers of mobile devices running different components.

The value-add of the components proved to be an important challenge. Why play "augmented" *Crazy 8s* when it could be played with zero devices? Players understood the purpose of the devices with more clarity when playing *Pirates!* since the game's features depend on the phone. Additionally, the value of the device as an authority and as an information broker emerged from our findings. Despite the similarities to a 'dumb' card deck, participants insisted on an accurate digital representation of the physical state. Some participants worked to curate their Card Viewer as an exact representation of their hand. Others were frustrated with the gaps in the system's knowledge of the game state.

Challenges for Supporting Socially Negotiated Gameplay

We now close with two challenges for supporting socially negotiated gameplay.

Anticipating Return on Investment

> *It's useful when I don't know how to play, but when I know the game it becomes a "roadblock in terms of the excitement of the game"*
>
> *- an early participant of our pilot session who played Crazy 8s*

The above participant found that scanning a card was tedious when he felt there was no good reason to do so. In a game where he did not know the rules, he found the augmentations helpful to his understanding of game and was willing to slow down his pace to scan a card. This became less useful to him as he grew proficient in the game. With more complex card games, the return on investment of card scanning would prove itself by providing greater information brokering value.

Furthermore, we found that it was conceptually helpful to distinguish between interaction costs and the benefits of augmentation. This allows us to accept that a participant from the pilot session may be unsatisfied with the overall experience, but would be able to discuss interaction problems or augmentation needs separately without engaging too heavily in polishing and revising the rules to a game like *Pirates!*. Boardgamegeeks.com tracks tens of thousands of carefully tested and polished board games. Many of them are designed carefully to match the physical components that support them. For example, Asmodee' Seven Wonders board game designs custom cards to be stacked under each other. Or, their game Fire and Axe comes with specialized dice with unique symbols. To progress towards this balance between component design and its benefit to the game experience, we offer an abstraction that was useful to us despite the unpolished nature of Pirates!. We used the following division, evaluating two related concepts as separate:

Interaction cost → Benefit of Augmentation

and translated it into specific situations in the following examples:

Cost to scan a card → Benefit of score keeping

Or, for example:

Audio clip length/clarity → Acquiring game information

The audio clip tradeoff became evident during a design iteration where we added text-to-speech capabilities to the devices and tried to augment the game experience with informative and entertaining audio. We found that a lengthy narrative forced players to stay attentive to the informational audio that had a low payoff for the amount of time and effort it cost to pay attention to it.

A major issue for physical interaction cost is what we termed the *third hand problem*:

Cost to add a handheld device to an existing activity → Augmentation

We invested design attention to reducing the interaction cost imposed by asking people to hold an extra mobile device while they play a game of cards. We've labeled this the *third hand problem*, in that people needed a third hand to bring an extra device into a setting where both hands are already occupied. We saw participants dropping phones, not knowing how to hide their screen from others, and putting the device down. This is a pervasive problem and deserves attention on many fronts. Solving it allows a device to join the other tangible components in contexts such as driving, shopping, or personal record keeping such as photography.

A changing requirement for benefit can fluctuate heavily even during a game session. This is especially likely in a game context with moment-to-moment changing expectations:

Interaction Cost (small screen) → Communal Activity A? (e.g. Announcing score)

Interaction Cost (small screen) → Private Activity B? (e.g. Arranging hand)

The above statements emphasize that interactive requires of a tangible game fluctuate through its different activities. Shuffling and distributing cards is a central, public, and quiet event. Arranging cards is a personal, private event. Playing is sometimes personal, sometimes public. Scoring at the end of a game is a very public event. These changing expectations mean that there are also changing criteria for a purportedly general component. We might ask players to crowd around a small mobile display because there is nothing else to draw their attention away. In contrast, asking players to wait for a device to finish speaking before playing the next card is much more heavyweight.

In summary, the equation allows us to conceptually separate the interaction cost from the augmentative benefits of a tangible technology inserted into a hybrid manual-automatic game system. This allows us to consider how to make a tangible and appropriable system more robust and more likely to be adopted into unexpected and new situations that players will think of. However, we acknowledge that interaction costs can be borne happily when the augmentation is great or when the game situation changes.

Managing player expectations for digital components in analog-digital hybrid situations

> *"What's missing is the logic. Like when he played the 8 and he chose what suit he wanted it to be. This guy (points at device) doesn't know about that. It should." - participant*

The second challenge is a matter of expectations. If the device claims to know something about whose turn it is or seems to reflect what cards are in a player's hand, participants expect that the device should be right. Even if a device is correctable or if it is also wrong, users can still be frustrated. There are three responses:

- improve sensing accuracy,
- reshape player expectations, and
- re-design the game to accommodate (or play with) such expectations.

The first is mostly a matter of better engineering. The last is a creative option for the game designer. The second lies more within the scope of component design. It involves understanding player expectations of computing devices and designing the proper affordances and metaphors for the system. Games such as the B.U.T.T.O.N. game (McElroy, 2012) accomplish this by naming a genre ("folk games") and by naming the whole game as a rules-free game: B.U.T.T.O.N. stands for "Brutally Unfair Tactics Totally OK Now." Taking this approach to other flexible systems such as Coardial, one asks where this kind of message fits if live-tweaking is not primarily the tone of the entire game ("None but the most minimal rules apply!") but relegated to more subtle decisions ("Make some small changes when you'd like to."). Additionally, we find that we had previously expected players to understand (and accept) the manual necessities of playing with Coardial because this is the requirement for the traditional deck of cards. We were expecting players to leverage the manual chores for playful and entertaining moments (Xu et al., 2011). While this did occur, there was also the aforementioned frustration with the phone. The challenge is to find a proper balance between manual work and automation. Part of this, we conclude, is to improve digital sensing, to properly communicate the ethos of these hybrid game components, and to design a game that fits these components well.

Conclusion and Future Work

We have presented Coardial, a game system that augments simple playing cards, and sought to inform future development of dispensable, tweakable, and tangible game components. We offer a flexible design perspective that elevates the players as the pace-makers in a game experience and discuss what general, hybrid game components should look like. Our system is an initial investigation in this design space with a focus on augmenting existing games, exploring the interaction challenges for the kind of game components we envisioned, and fostering playfulness and social interaction in physical gameplay. However, as we have noted before, technological features and interaction design (both physical and virtual) are deeply intertwined with game design. So far, our general components are a Card Viewer and a Turn Keeper, along with a rudimentary Score Board. We continue to develop these and other game components for leveraging augmentations that can become a seedbed for great diversity in play. We have articulated five principles for supporting socially negotiated play and two challenges for succeeding in this area: to solve interaction costs to provide greater flexibility and to manage user expectations for the automatic part of a manual-automatic system.

REFERENCES

Cheung, G., & Huang, J. (2012). Remix and Play: Lessons from Rule Variants in Texas Hold'em and Halo 2 (p. 559). ACM Press. doi:10.1145/2145204.2145290

Crespi, I. (1956). The Social Significance of Card Playing as a Leisure Time Activity. *American Sociological Review*, *21*(6), pp. 717–721.

Floerkemeier, C., & Mattern, F. (2006). Smart Playing Cards - Enhancing the Gaming Experience with RFID. *Proceedings of the Third International Workshop on Pervasive Gaming Applications - PerGames 2006 at PERVASIVE 2006* (pp. 79–88).

Frapolli, F., Brocco, A., Malatras, A., & Hirsbrunner, B. (2010). *Decoupling Aspects in Board Game Modeling*. Retrieved from http://services.igi-global.com/resolvedoi/resolve.aspx?doi=10.4018/jgcms.2010040102

Kane, S. K., Avrahami, D., Wobbrock, J. O., Harrison, B., Rea, A. D., Philipose, M., & LaMarca, A. (2009). Bonfire: a nomadic system for hybrid laptop-tabletop interaction. *Proceedings of the 22nd annual ACM symposium on User interface software and technology*, UIST '09 (pp. 129–138). New York, NY, USA: ACM. doi:10.1145/1622176.1622202

Kirk, D., Sellen, A., Taylor, S., Villar, N., & Izadi, S. (2009). Putting the physical into the digital: issues in designing hybrid interactive surfaces. *Proceedings of the 23rd British HCI Group Annual Conference on People and Computers: Celebrating People and Technology*, BCS-HCI '09 (pp. 35–44). Swinton, UK, UK: British Computer Society. Retrieved from http://dl.acm.org.offcampus.lib.washington.edu/citation.cfm?id=1671011.1671016

Lobunets, O., & Prinz, W. (2011). Evaluating a smart working environment with a digital card game prototype. *Proceedings of the ACM 2011 conference on Computer supported cooperative work*, CSCW '11 (pp. 673–676). New York, NY, USA: ACM. doi:10.1145/1958824.1958942

Losh, E. (2008). In polite company. *Proceedings of the 2008 International Conference on Advances in Computer Entertainment Technology* (p. 345). ACM Press. doi:10.1145/1501750.1501832

Magerkurth, C., Cheok, A. D., Mandryk, R. L., & Nilsen, T. (2005). Pervasive games. *Computers in Entertainment*, *3*(3), 4. doi:10.1145/1077246.1077257

McElroy, G. (2012, February 22). Folk Lore: How Johann Sebastian Joust is defining a new gaming genre. *The Verge*. Retrieved from http://www.theverge.com/gaming/2012/2/22/2814816/johann-sebastian-joust

McEwan, G., Gutwin, C., Mandryk, R., & Nacke, L. (2012). "I'm Just Here to Play Games:" Social Dynamics and Sociability in an Online Game Site. *The 2012 ACM Conference on Computer Supported Cooperative Work*. Seattle, Washington, USA.

Müller, M., Evequoz, F., & Lalanne, D. (2006). TJASS, a smart board for augmenting card game playing and learning. *Adjunct Proceedings*. Presented at the ACM UIST.

Pape, J. A. (2012, January). *The Effects of Digitization and Automation on Board Games for Digital Tabletops* (Master's Thesis). Queen's University, Kingston, Ontario, Canada.

Römer, K., & Domnitcheva, S. (2002). Smart Playing Cards: A Ubiquitous Computing Game. *Personal and Ubiquitous Computing*, *6*(5/6), 371–377.

Silva, O., Garcia, A., & Lucena, C. (2003). The Reflective Blackboard Architectural Pattern. In A. Garcia, C. Lucena, F. Zambonelli, A. Omicini, & J. Castro (Eds.), *Software engineering for large-scale multi-agent systems* (pp. 73–93). Berlin, Heidelberg: Springer-Verlag.

Wallace, J. R., Pape, J., Chang, Y.-L. B., McClelland, P. J., Graham, T. C. N., Scott, S. D., & Hancock, M. (2012). Exploring automation in digital tabletop board game. *Proceedings* *of the ACM 2012 conference on Computer Supported Cooperative Work Companion*, CSCW '12 (pp. 231–234). New York, NY, USA: ACM. doi:10.1145/2141512.2141585

Wilkinson, W. H. (1895). Chinese Origin of Playing Cards. *American Anthropologist*, *8*(1), 61–78. doi:10.1525/aa.1895.8.1.02a00070

Willis, K. D. D., Poupyrev, I., Hudson, S. E., & Mahler, M. (2011). SideBySide: ad-hoc multi-user interaction with handheld projectors. *Proceedings of the 24th annual ACM symposium on User interface software and technology*, UIST '11 (pp. 431–440). New York, NY, USA: ACM. doi:10.1145/2047196.2047254

Wilson, A. D. (2005). PlayAnywhere: a compact interactive tabletop projection-vision system. *Proceedings of the 18th annual ACM symposium on User interface software and technology*, UIST '05 (pp. 83–92). New York, NY, USA: ACM. doi:10.1145/1095034.1095047

Wohn, D. Y., Lee, Y., Sung, J., & Bjornrud, T. (2010). Building common ground and reciprocity through social network games. *Proceedings of the 28th of the international conference extended abstracts on Human factors in computing systems*, CHI EA '10 (pp. 4423–4428). New York, NY, USA: ACM. doi:http://doi.acm.org/10.1145/1753846.1754164

Xu, Y., Barba, E., Radu, I., Gandy, M., & Macintyre, B. (2011). Chores Are Fun: Understanding Social Play in Board Games for Digital Tabletop Game Design. In C. Marinka, K. Helen, & W. Annika (Eds.), *Think Design Play: The fifth international conference of the Digital Research Association (DIGRA)* (p. 16). Hilversum, the Netherlands: DiGRA/Utrecht School of the Arts. Retrieved from http://www.digra.org/dl/display_html?chid=11307.16031.pdf