Bridging Private and Shared Interaction Surfaces in Collocated Groupware

by

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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

Multi-display environments (such as the pairing of a digital tabletop computer with a set of handheld tablet computers) can support collocated interaction in groups by providing individuals with private workspaces that can be used alongside shared interaction surfaces. However, such a configuration necessitates the inclusion of intuitive and seamless interactions to move digital objects between displays. While existing research has suggested numerous methods to bridge devices in this manner, these methods often require highly specialized equipment and are seldom examined using real-world tasks. This thesis investigates the use of two cross-device object transfer methods as adapted for use with commonly-available hardware and applied for use in a realistic task, a familiar tabletop card game.

A digital tabletop and tablet implementation of the tabletop card game *Dominion* is developed to support each of the two cross-device object transfer methods (as well as two different turn-taking methods to support user identification). An observational user study is then performed to examine the effect of the transfer methods on groups' behaviour, examining player preferences and the strategies which players applied to pursue their varied goals within the game. The study reveals that players' choices and use of the methods is shaped greatly by the way in which each player personally defines the *Dominion* task, not simply by the objectives outlined in its rulebook. Design considerations for the design of cross-device object transfer methods and lessons-learned for system and experimental design as applied to the gaming domain are also offered.

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Chapter 1

Introduction

"We notice things that don't work. We don't notice things that do. We notice computers, we don't notice pennies. We notice e-book readers, we don't notice books."

- Douglas Adams, *The Salmon of Doubt*

When seated around a typical wooden table, no instruction regarding its use is needed; its role in supporting a group's interaction is intuitively understood. Its users freely pass documents from one to another, spread out a pile of notes, or turn a laptop computer so that others can see its display. They lean closer to another's document when invited; they keep their distance when someone is obviously working privately. There's no mystery about how to move materials (such as papers, binders, or devices) from one table to another, and users can have a reasonable expectation of privacy when they do so. Not everything that is brought to a table need be shared with the group. The table performs its role in a transparent, predicable way, while at the same time, it allows its users to leverage unimpeded the rich, intuitive social protocols which govern group interaction. When making use of a table, users are empowered to focus on their task—rather than the table—because *it just works.*

But the ecosystem in which work is done is changing. Rather than working solely with notebooks and documents, people now work with computer files, networks, and multimedia content. While the traditional table offers a powerful environment for face-to-face collaboration, it is limited in its ability to connect us to the data which are increasingly vital to our work. The digital tabletop computer (Wellner, 1993) is a technology which aims to unite the computational and networking strengths of a computer with the collaborative environment offered by a traditional table, and there is a growing body of work in both research and corporate environments which explores the use of digital tabletops in that capacity.

However, as the digital tabletop provides users with a single shared display, it less-readily supports information privacy to the same extent as a physical table. One solution to this issue is the pairing of private displays with the digital tabletop, giving each user an individual workspace where content can be examined and manipulated prior to sharing it with the group. This solution is particularly attractive given the growing number of people who already use smartphones to interact with their personal content. This solution, in turn, creates a need for intuitive, appropriate interactions to support moving content between the digital tabletop and a personal device. Just as a physical table's user can move items to and from a table with only a trivial degree of cognitive effort, so there is a need for a digital tabletop's users to be able move content from device to device without disruption—focusing on the task rather than the system that supports it—and ideally, never noticing that it could be any other way.

This thesis details the design and adaptation of two cross-device transfer methods to support a realistic task: a digital tabletop conversion of a familiar card game. The thesis discusses the design of the system in which these transfer methods are applied, including the relevant technical and social challenges which influence their use. Finally, it offers an observational study of the use of the system, providing considerations for the design of future cross-device transfer methods.

1.1 Motivation

This work is motivated by two key factors, recognition of the importance of developing powerful, easy-to-use cross-device transfer methods to support interaction across private and shared spaces (a focus of much existing and ongoing research), and secondly, the need to explore the use of transfer methods in the context of a realistic use case. As noted by Nacenta in his excellent taxonomy of "cross-display object movement" techniques (Nacenta, 2009), even though a technique may support the principle act of moving a piece of content between displays, the contextual information that it provides (both to the user and the rest of the group) are vital. To approach the level of intuitive interaction provided when moving physical objects between two locations, the user should be able to effortlessly specify the object's destination, rather than needing to recall arbitrary mappings such as computer names. As an example, consider Figure 1 below, adapted from Rekimoto's seminal paper detailing the pen-based Pick and Drop direct manipulation technique.

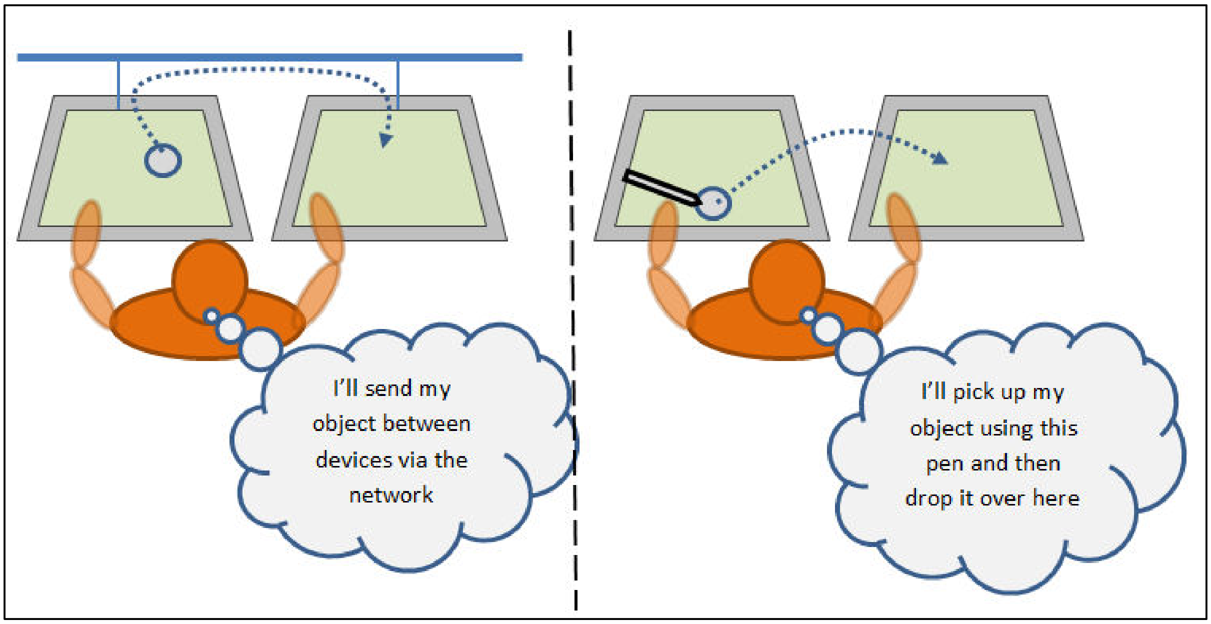

Figure 1: Conceptual distinction between network-focused object transfer methods and an objective-focused transfer method like Pick and Drop (Adapted from (J. Rekimoto, 1997)**)**

An effective object transfer interaction allows the user to focus on the desired result, rather than the technological mechanism by which it is achieved.

In pursuit of the development of an effective transfer interaction, many techniques have been explored, including direct manipulation techniques such as the Pick and Drop method above, portal metaphors to link together locations on two different displays (eg. (Besacier, Rey, Najm, & Buisine, 2007; Voelker & Borchers, 2011)), temporary bindings used to virtually "stitch" the edges of displays together (Hinckley, 2003), and many others (see Chapter 2 or (Nacenta, 2009)). However, research into such interactions is commonly conducted in the form of laboratory experimental studies using controlled (and sometimes arbitrary) tasks. While these studies offer valuable data to analyze the usability of the transfer methods, they often lack greater generalizability and realism (McGrath, 1984). Stated another way: they tell what users *can* do given a certain interaction design but not necessarily what they *would* do when given the opportunity to leverage the interaction in task which is meaningful to them.

There exists, then, an unaddressed need to investigate the use of cross-device object transfer methods as applied to real-world tasks, developing an understanding of how real users' motivations and goals affect the manner in which they make use of the transfer methods, the degree to which the interactions enable users to pursue their goals, and users' satisfaction with the experience. The work presented in this thesis is offered as step towards addressing that need.

To add one additional consideration: object transfer research often leverages highly-specialized technologies to support these interactions (eg. user-sensing sensor mats on users' chairs (Dietz & Leigh, 2001), an overhead spherical mirror (Xiao, R., Nacenta, M.A., Mandryk, R.L., Cockburn, A., and Gutwin, 2011), or similar), and while these works are valuable in advancing the leading edge of this domain, the general scarcity of the technology which they employ limits the degree to which the interactions may be readily adopted by others in the research or commercial community. With this in mind, and to position this research as an accessible reference against which similar investigations may be compared, it is also a priority of this work to leverage technologies which are readily available.

1.2 Objectives

To explore the use of cross-device object transfer methods for interaction between private and shared interaction surfaces, this thesis pursues the following four research objectives:

- **Objective 1 – Examine existing methods for bridging private and shared interaction surfaces.** A literature review was conducted to establish the research context, identifying design challenges for digital tabletop systems, existing methods for cross-device object transfer, the facilitation of privacy in collocated collaborative systems, and prior explorations of using digital tabletops systems to support tasks in the gaming domain
- **Objective 2 – Examine the context in which object transfer occurs in realistic physical tasks**. Recognizing that object transfer and maintaining privacy are important needs in card games, a preliminary observational study was conducted, examining gameplay of 6 physical card games, identifying key themes in interaction to inform the design of a digital tabletop system which can similarly support object transfer and privacy. Chapter 3 details the performance and results of this activity.
- **Objective 3 – Design and develop a system to explore object transfer between private and shared interaction surfaces for a collocated task.** Based on the literature review and preliminary observational study, a digital tabletop and tablet system was developed, along with two distinct cross-display object transfer techniques (adapted from techniques used in existing literature). A software application to support play of a digital conversion of a retail card game

was also developed. Chapter 4 provides a detailed description of the system and application design.

- **Objective 4 – Examine the designed system interactions' effectiveness in supporting a realistic task.** A mixed-methods exploratory study was performed to examine and compare the use of the two cross-display transfer mechanisms in a realistic context of use. Chapter 5 details the study method, while chapters 6 and 7 detail results and discussion, respectively.

1.3 Thesis Organization

This thesis is organized into seven chapters, as outlined below:

- **Chapter 1: Introduction** – introduces the context, motivation, and objectives of this research
- **Chapter 2**: **Background** – documents a literature review of materials relevant to the design of interactions which span multiple devices, privacy and other challenges in digital tabletop systems, and digital tabletop games
- **Chapter 3: Preliminary Domain Research and Task Selection –** documents an small observational study of players of a variety of physical card games, offering insights for the design of object transfer methods for digital tabletop as well as informing the selection of an appropriate task (Rio Grande Games' *Dominion*) for the study which is the focus of this thesis
- **Chapter 4: Design** – introduces the design and adaptation of two cross-device object transfer methods, as well as the design of the digital tabletop system and software application which supports it
- **Chapter 5**: **Method** – describes the procedure used to perform a mixed-methods exploratory study examining the use of the two transfer methods
- **Chapter 6: Results –** presents the quantitative and qualitative results of the study outlined in Chapter 5
- **Chapter 7**: **Discussion** – expands on the results presented in Chapter 6, discussing research and design considerations derived from the research, limitations, and issues such as generalizability
- **Chapter 8**: **Conclusion** – discusses how the research objectives were met and offers recommendations for future work

Chapter 2
Background

The following chapter provides an overview of the literature relevant to the design and examination of cross-device object transfer methods in a realistic, multi-user digital tabletop context. This chapter is thus divided in the following manner: first, literature pertaining to *digital tabletop computer interface design* is considered. Then, existing research related to *cross-device object transfer* is examined. As one of the core motivations for introducing mobile displays in our system design is to facilitate privacy, *methods to support privacy in a multi-display environment* are also considered. Finally, an exploration of relevant *digital tabletop research in the gaming domain* is provided.

2.1 Digital tabletop interface design considerations

Digital tabletop computers are horizontal interactive surfaces, having coincident display and interaction surfaces—that is, tabletop computers allow users to interact with content by touching (either directly with a hand, or indirectly, such as using a digital pen) the content's visual representation. While digital tabletop systems' similarity to physical tables allows them to leverage users' previous experience with this ubiquitous household furniture, its deviation from the traditional desktop computer interaction style offers challenging design considerations.

2.1.1 Differentiating multiple users' input

Like traditional physical tables, the form of digital tabletops readily affords multi-touch, multi-user interaction and collaboration. However, not all tabletop systems are able to recognize more than one touch at a time, and simultaneous input from multiple users can create ambiguous situations (e.g. Figure 2: Are two users attempting to drag the item in opposite directions, or is a single user initiating a pinch-to-zoom interaction?). Such difficulties drive the need for software, hardware, and/or social mechanisms to ensure that multi-user interaction is smooth and predictable.

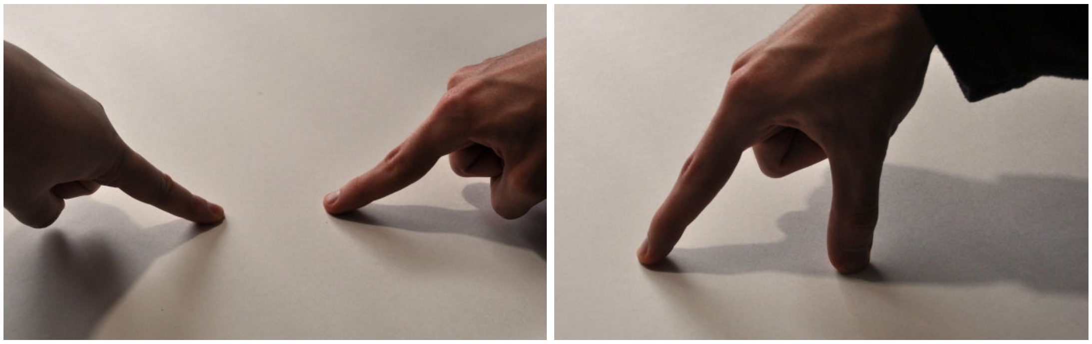

Figure 2: Demonstration of an ambiguous input case. Are two touches the result of two users' single-finger inputs (left) or one user's multi-finger input (right)?

One method which has been applied to mitigate the effects of this issue is to leverage turn-taking, restricting interaction to one user at-a-time (eg. (C Shen, Lesh, Vernier, Forlines, & Frost, 2002; Tse, Greenberg, Shen, & Forlines, 2006)). However, this technique can feel burdensome to users, hindering their ability to working independently even in circumstances where their interactions would not otherwise interfere with others'. As such, multi-user interaction strategies which permit simultaneous interaction are recommended (Scott, Grant, & Mandryk, 2003).

One strategy to support simultaneous interaction at a digital tabletop is to provide each user with a uniquely-recognizable input device, such as a magnetically-tracked stylus or digital pen (eg. (Haller et al., 2006; Inkpen, Hancock, Mandryk, & Scott, 2002)).

Figure 3: Pen-based interaction on a digital tabletop computer (McClelland, P.J., Whitmell, S.J., Tangao, K., & Scott, 2009)

Since every interaction with the system can be programmatically associated with a device (and by extension, a particular user), this method allows the digital tabletop interface to react appropriately to different users' interactions. This enables the system to resolve interaction conflicts (e.g. as in Figure 2) in a manner appropriate to the task and the users involved, and support tailoring of information to suit a particular user's role or other needs (Scott et al., 2010) across multiple displays (Haller et al., 2006). There are some disadvantages to this approach, however. The input device introduces some physical separation between the user and the content. While this might be appropriate in contexts where such separation is expected (eg. a free-hand writing application), in other contexts the separation may feel like an artificial barrier between the user and their content (eg. tasks with which users already have experience using direct-touch manipulation, such as a jigsaw puzzle). In multi-display systems which include digital tables and handheld devices, digital pens may also introduce the need to repeatedly switch between input styles (eg. between pen and direct touch) when moving between devices, as most capacitive-touch interaction surfaces (eg. as used by most consumer multi-touch devices) are unable to detect the specialized pen input device.

Finally, some direct-touch digital tabletops are able to automatically match touches with their users. The DiamondTouch table (Dietz & Leigh, 2001) (now commercially available by Circle Twelve Inc.[1]) for example, each user sits on a special sensor mat which receives uniquely-identifiable signals whenever a user touches the table. Numerous other user-sensing systems exist, differentiating users based on a wide range of features, from body shape (Fukuchi & Rekimoto, 2007; Jun Rekimoto, 2002), to physical proximity (Annett, Grossman, Wigdor, & Fitzmaurice, 2011), to the appearance of their shoes (Richter, Holz, & Baudisch, 2012). While such systems can be very effective in uniquely identifying users, these techniques also depend on the highly specialized hardware which supports the identification of users, limiting the extent to which they can be adopted for use in more typical direct-touch tabletop systems. Other than the DiamondTouch, no commercially available digital tabletop system provides user identification or differentiation.

2.1.2 Territoriality

Human territoriality (Taylor, 1988)—specifically, the way in which people's location-specific attitudes and behaviours change in a manner related to their proximity to others—is a phenomenon that has significant implications for the task-related interactions of multiple people seated around a table, whether

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

traditional or digital (Scott & Carpendale, 2010). For instance, there is a natural tendency to divide working space on the table, with tacitly-agreed conventions governing access and use. (Scott & Carpendale, 2010) defined these as follows. *Personal* space is the region on the table immediately adjacent to each person. It is the space in which people perform individual work, with social norms dictating that each person should avoid making use of another's personal space. *Storage* space is, as the name might imply, a space reserved for storing items not currently in use. The presence of these spaces helps participants to keep the workspace organized, grouping like objects, reducing clutter (Hartmann, Morris, & Cassanego, 2006), or freeing additional room to work on more pertinent materials. *Group* space is the space that remains, and is available for use by all participants. Among other features, group space provides a common place in which materials may be shared between participants. None of these spatial divisions need be explicit delineated, whether visually or verbally. Instead, such spaces naturally form during table-based activity. Additionally, the spaces are not fixed in size or location, but rather, these may change over the course of the task. When designing digital tabletop applications, it is thus important to ensure that these natural patterns of interaction are respected (and even leveraged) in the application's interaction design (Carpendale et al., 2006; Hinrichs, Carpendale, & Scott, 2006; Morris, Ryall, Shen, Forlines, & Vernier, 2004; Scott, Carpendale, & Habelski, 2005; Scott, Sheelagh, Carpendale, & Inkpen, 2004; Scott & Carpendale, 2010; Scott, 2003). While personal, storage, and group spaces are naturally facilitated during tabletop interactions, *private* spaces are not. It is a natural consequence of using a shared surface that even in a personal space, some information about the space's content and use is visible to others, unless the system is designed to explicitly provide mechanisms for privacy (Section 2.3).

2.1.3 Group communication on a shared surface

As a platform to support of collocated groupware (Stewart, Bederson, & Druin, 1999), much can be learned from groupware literature to inform the design of multi-user digital tabletop systems. While groupware literature is extensive (C. Gutwin & Greenberg, 2000; Pinelle, D., Gutwin, C., Nacenta, 2008; Ryall, Forlines, Shen, & Morris, 2004; Tang, Boyle, & Greenberg, 2004) , one groupware concept of particular relevance to this thesis is workspace awareness (C. Gutwin & Greenberg, 1996). Workspace awareness is defined as "the up-to-the-moment understanding of another person's interaction with a shared workspace" ((Carl Gutwin, 1997) pg. iii). When each of a group's members interacts around a table, they are in constant, often unintentional communication with the other members of the group, communicating their location, sequence of actions, clues about their intention, where they direct their gaze and interactions, and other such information (Carl Gutwin, 1997). These ambient cues are vital to effective coordination within the group, and whenever traditionally-physical tasks are adapted to digital surfaces, it is important to consider the ways in which this tacit communication might be affected.

Support for more explicit communication between group members is provided by a table through its shared surface, which provides a shared reference to support conversational grounding (Clark & Brennan, 1991). That is, members may use indicative gestures in parallel with their verbal communication (e.g. by pointing at an object, saying “that one”), allowing communication to be performed more quickly and easily than might be possible through verbal means alone. Thus, digital tabletop adaptations of familiar physical tasks must consider how the application design affects the surface’s role as a shared grounding reference (Pinelle, Gutwin, & Subramanian, 2006).

2.2 Cross-device object transfer

Common techniques to facilitate transfer of digital objects between displays typically use one of the following approaches. For a broader overview of transfer techniques and their use in multi-display environments, refer to (Nacenta, 2009).

2.2.1 Contiguous virtual workspace

One approach to supporting cross device transfer is to create an environment in which connected devices span a single contiguous virtual workspace that allows users to simply drag an item off the side of one device and onto an adjacent device. This approach requires the environment to maintain an awareness of the physical configuration of connected devices so that when an item is dragged off the side of one device it appears at the spatially-appropriate edge of the adjacent device. By connecting displays within a system which maintains an awareness of the physical configuration of the displays, a single contiguous virtual workspace can be created, which spans two or more displays.

In one form of this approach, displays maintain a persistent connection to one another (which is either static or tracked in real-time) (e.g. (Rekimoto, J. and Saitoh, 1999; Streitz, N.A., Tandler, P., and Müller-tomfelde, 2001)). This connection defines an adjacency map, allowing, for example, a pointing device cursor to travel from one display’s edge to another’s. This technique may be most commonly recognized as the “Extended Desktop” metaphor that which many consumer PCs use to configure multiple monitors, although it has also been applied to more complex multi-display environments (e.g. (Johanson, Hutchins, & Winograd, 2000)).

Figure 4: "Extended Desktop" contiguously spans a single workspace across multiple displays

In this Extended Desktop case, displays are considered to be directly adjacent to one another, that is, a cursor leaving one display immediately appears on the next, regardless of the displays' physical proximity. Others have explored maintaining a navigable display-less space between displays (Baudisch, Cutrell, Hinckley, & Gruen, 2004; Robertson et al., 2005; Xiao, R., Nacenta, M.A., Mandryk, R.L., Cockburn, A., and Gutwin, 2011). This technique, however, is not ideal for many multi-touch surfaces applications. Unlike systems which leverage mouse input, multi-touch systems require the user to be in direct contact with each display, necessitating a break in dragging actions across displays as the user moves his or her hand to the other device where the drag may be resumed.

Rather than the system maintaining a persistent mapping between displays, other techniques allow a contiguous virtual workspace to be created on-demand. By bumping (Hinckley, 2003), "stitching" (i.e. drawing a single line across multiple displays to associate them) (Hinckley, Ramos, Guimbretiere, Baudisch, & Smith, 2004), or otherwise associating devices together (Interaktive, Kit, Bader, & Heck, 2010; Jun Rekimoto, Ullmer, & Oba, 2001; Tandler, Prante, Müller-tomfelde, Streitz, & Steinmetz, 2001), users can create "lightweight personal bindings" ((J. Wallace, Ha, Ziola, & Inkpen, 2006) pg1487), which define how and when the contiguous virtual workspace should be formed.

These methods give the user a large degree of control over devices' adjacency mapping, generating a mapping that respects devices' true spatial proximity without the complexity of a vision-tracking system. However, the ad-hoc nature of these bindings also means that they tend to be limited in duration, requiring users to repeatedly re-establish the bindings if the task requires many object transfers to be performed.

2.2.2 Virtual portals

Another method to support the transfer of digital objects between displays is by using a virtual portal metaphor. In this method, special visible regions or containers in the interface provide a virtual representation of the connected device, typically located in the group's shared workspace (Bachl, S., Tomitsch, M., Kappel, K., and Grechenig, 2011; Everitt, Shen, Ryall, & Forlines, 2006; Kortuem, Kray, & Gellersen, 2005). When digital objects are dragged and dropped into these regions, the object is transferred "through the portal" to the associated device. In an alternate design which employs the same concept, these portals take the shape of digital slots through which objects may be pushed (Besacier et al., 2007; Voelker & Borchers, 2011). Virtual portals have a similar drawback to that of fixed-mapping contiguous virtual space methods—they require object transfer to be divided into two steps, one on each of the two devices involved in the transfer.

2.2.3 Transfer using a physical object

Often, digital object transfer is facilitated via the use of a physical object. Digital pens, for example, can be used to support Pick and Drop interactions (Haller et al., 2010; J. Rekimoto, 1997). In Pick and Drop, the user touches a digital object using a digital pen device, lifts the pen, and then touches in a different location (e.g. on a different device) to drop it again. In this way, the pen not only facilitates the transfer technically, but when the object is in transit, it provides a strong interaction metaphor: the digital object has moved "into" the physical object, and it only needs to be delivered to its destination in order to be released. However, it also requires that each interaction with the system be reliably matched with the initiating user in order to prevent one user's "pick" action from being matched with another user's "drop". As discussed in Section 2.1.1, this level of user-identification cannot be detected by most digital tabletop hardware. Other systems make similar use of other physical objects (e.g. keys) to support object transfer—the physical objects act as carriers to be loaded with digital objects on one display and unloaded onto another (Kobayashi et al., 2008; Streitz et al., 1999; Streitz, N.A., Tandler, P., and Müller-tomfelde, 2001). Again, these systems require specialized hardware to detect and interact with the physical objects.

2.3 Facilitating privacy in a multi-display environment

While shared interactive surfaces such as wall or tabletop provide an effective place for group collaboration (J. R. Wallace, Scott, Lai, & Jajalla, 2011), they do not as readily support interacting with private information—that is, the traditional shared surface provides no opportunity for individual group members to work with data without revealing that data to other members of the group. Current research offers a number of ways to resolve this issue.

2.3.1 Selective disclosure via tool or gesture

A common method of facilitating privacy on a shared display is by the introduction of special tangible tools or gestures, causing the display (usually a digital tabletop computer) to reveal information in a manner visible only to the user holding the tool or performing the gesture. For example, in Vectorform Game Studio's implementation of Mayfair Games' *Settlers of Catan* each player in the game has a personal hand of cards, which is face-down (hidden) by default (Havir, 2010). However, when the tabletop detects the user cupping one or both hands around the cards (such that they are presumably shielded from opponents' view), the cards flip to reveal their content.

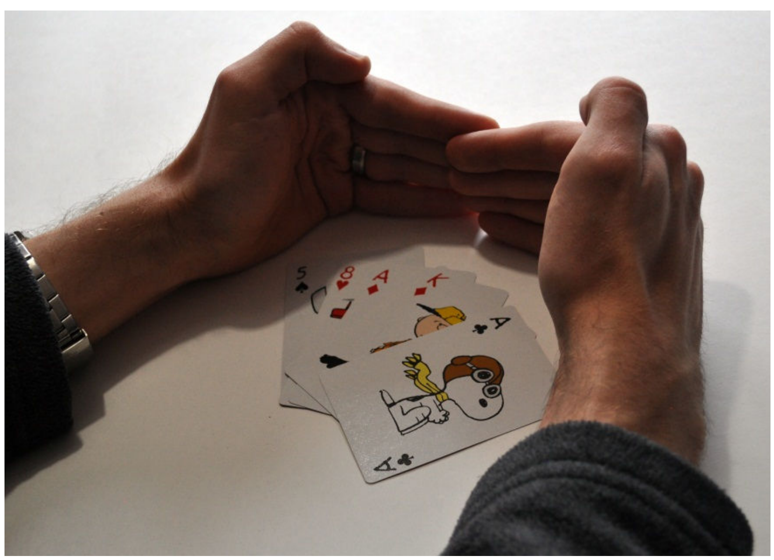

Figure 5: Demonstration of a "cupping" or "shielding" gesture to hide playing cards from others' view

When the player removes the hand, they revert to their hidden state. Similar interactions have been used by others, such as in a Poker application (Dang & Andr, 2010). Like most gesture-based interactions, these systems usually require the user to have training or advance knowledge of how to perform the gestures. Additionally, as one or both hands are required to perform the shielding gesture, the level of interactivity that can be supported by the revealed area is limited. Finally, the degree of privacy supported by such methods is naturally only as extensive as the degree to which the gesture shields the revealed content from view—which may be a concern depending on factors such as participants' seating arrangement, level of mobility during the task, and even hand size.

As an alternative to gesture-based interactions, others have made supported such selective disclosure of information through the use of tangible interface components (eg. a transparent block which reveals hidden content underneath it (Bachl, S., Tomitsch, M., Kappel, K., and Grechenig, 2011)), or by positioning a physically held "lens" over the private content to reveal information (Max & Borchers, 2011; Spindler, Stellmach, & Dachselt, 2009). Such a lens can be created using an iPad[2] or a separately-projected portable surface (Spindler et al., 2009). While providing more flexibility in terms of the level of privacy offered (e.g. the size of the tool is more easily scaled than a user's hand size), these systems are complicated by the need for specialized tangible tools and the ability to detect them (which many interactive surfaces are unable to support), or, in the case of len-based systems, the need for sophisticated motion-tracking systems.

2.3.2 Directional privacy

Another method of facilitating privacy involves the use of specialized hardware to provide different views of its content based on the position from which it is viewed. This effect might be applied to the entire surface, allowing each to see different content at the same physical location (e.g. a parallax barrier (Smith & Piekarski, 2008)). Alternatively, the effect may simply reveal content to one user while preventing others from reading it (e.g. the TaPS widget's use of polarized light (Max & Borchers, 2011)). While providing users with information secrecy, these solutions tend to be very costly—requiring highly specialized hardware or introducing opportunities for confusion as users interact with *different* content in the *same* physical space.

[2] http://www.apple.com/ipad/

2.3.3 Personal devices

Numerous studies have investigated the pairing of various kinds of personal devices (e.g. smartphones, laptops, tablets, and similar) with shared surfaces (Magerkurth, Memisoglu, Engelke, & Streitz, 2004; Rick, 2010; Shirazi, Döring, Parvahan, Ahrens, & Schmidt, 2009; Whalen, 2003). As each personal device's display faces only its owner and those to whom it is shown, this solution provides a private workspace for each user. It is also very powerful, as personal devices can serve not only as information displays, but also as rich interactive workspaces. However, this interactive, private space comes with additional cost in complexity: the system must be able to effectively associate the devices to facilitate data transfer between them (e.g. via bluetooth pairing or Wi-Fi networking), and users must understand the interactions required to transfer data or objects between devices (Section 2.2). Evidence suggests that the introduction of private displays to a group task also changes the manner in which that group performs the task—altering, for example, group awareness and the distribution of group versus individual work, depending on the design of the interface on each display (Bachl, S., Tomitsch, M., Kappel, K., and Grechenig, 2011; J. R. Wallace et al., 2011).

2.3.4 Physical separation

Finally, it is important to consider that, even on a single shared interaction surface, the relative distance between individuals' immediate "personal spaces" can provide a measure of *privacy*, though not actual *secrecy*—a phenomenon related to users' natural territoriality (Section 2.1.2). For some applications, the spontaneous generation of these ad-hoc personal spaces may provide a suitable level of privacy, though for tasks or contexts which require true data secrecy, this solution is inadequate.

2.4 Digital tabletop games

There is a growing body of research which leverages digital tabletop computers as a platform for investigation in the gaming domain, often including strategies for interaction with private and shared information (a common need in multiplayer games) as well as for cross-device object transfer.

In one approach, tangible game pieces (such as pawns) may be used to navigate dynamic board-game-style worlds (Babcock-McConnell et al., 2010; Bakker, Vorstenbosch, Van, Hollemans, & Bergman, 2007; Mandryk & Maranan, 2002; Mazalek, Mironer, & Devender, 2008). While such systems provide an opportunity to support cross-device object transfer (e.g. by moving these tangible pieces between devices), they also require the presence of highly specialized hardware, particularly in the case of augmented reality systems.

The STARS system (Magerkurth & Ipsi, 2004; Magerkurth, Stenzel, & Prante, 2003) allows gameplay to take place on a digital tabletop, with supplemental information provided on a wall display. Personal PDA devices provide a point of interaction with private information, as well as a means to discreetly communicate with another player in the group. In STARS, the PDA acted as a means to virtually augment specific physical playing pieces, providing information about the player's piece's location as well as attributes (e.g. health points possessed by the character which the piece represents).

Some research has explored the use of digital tabletops to augment existing games, converting board and card games into formats playable on the digital surface. As previously mentioned, Vectorform Game Studio's implementation of Mayfair Games' *Settlers of Catan* was one such endeavor (Havir, 2010). Since the physical game required players to conceal and manage hands of cards, a gestural interaction was provided which allowed a player to reveal his cards on the tabletop display while simultaneously blocking them from others' view. A tabletop conversion of Z-Man Games' *Pandemic* board game was developed to explore themes in automation, comparing a computer rule-enforced version of the game to a more manual interpretation, in which game pieces were freely movable atop an image of the game's board (Pape, 2012; J. R. Wallace et al., 2012) . While *Pandemic* includes private information in the form of cards, it is also a collaborative game, leading researchers to design a tabletop implementation which relaxes the game's secrecy rules, displaying all players' hands of cards on the same interactive surface.

2.5 Chapter summary

In this chapter, a review of a selection of literature relevant to the design of cross-device object transfer was conducted, including considerations for the design of digital tabletop systems, existing approaches for cross-device object transfer, and methods to facilitate privacy in a multi-display environment. A brief survey of digital tabletop gaming literature was also included. While many have suggested techniques for transferring objects between personal and shared devices, these techniques often require highly-specialized hardware. Furthermore, evaluation of these systems is often performed using tightly-controlled laboratory experiments. There exists, then, an opportunity to examine the use of cross-device transfer methods as applied to more generalizable, real-world tasks, as well as an opportunity to explore the design of techniques which can be supported using generally-available hardware.

Chapter 3
Preliminary domain research and task selection

As mentioned previously, a key goal this research is to gain an understanding of the use of cross-device transfer method techniques under real-world constraints, and to support this goal, it was important that the use case in which participants would experience these the cross-device transfer techniques was similarly realistic and accessible to users.

With this in mind, a card game use case offered an excellent opportunity. Many card games rely heavily on the transfer of objects (i.e. cards) between territories (e.g. between a player's hand and the table), allowing the study of cross-device transfer techniques in a context where object transfer plays a central and frequent role. Furthermore, card games have an existing (and enthusiastic) player base from which experienced participants can be drawn. In order to leverage this experience, however, the design of the experimental digital tabletop card game must be appropriately modeled on existing card game play. To this end, a preliminary observational study of a series of card games was conducted. The results of this study were used to inform the design of the cross-device transfer method testing platform (Chapter 4).

This chapter is organized as follows: first, a brief overview of the design and methodology of the observational study and analysis is offered. Following this is a discussion of the main themes observed in players' activities and interactions during card game play, with the intent that these themes inform the design (Chapter 4) of the cross-device transfer methods and related system examined in this thesis. Finally, a brief overview and discussion is offered for the selection of the card game *Dominion* as the experimental task to be implemented for the experimental system.

3.1 Design and method

To better understand the interactions present in existing card games, an observational study was conducted in which 14 participants played a series of commercial card-based games. Participants were recruited by word-of-mouth from existing groups of board gamers known to the researcher and were encouraged to invite friends with whom they had played before. During each of 4 sessions (arranged via email or word of mouth), a subset of the total group (self-selected, those who were available and willing) met to play one or more games. Sessions were held in participants' usual play environments to help preserve natural social and gameplay behaviours: two sessions at a local university and two in private residences. The game titles (6 in total) were selected and provided by the participants. Games included

Dominion[3], *President*, *Gloom*[4], *Munchkin Zombies*[5], *Apples-to-Apples*[6], and *Bang!*[7]. This research was reviewed and received clearance from the University of Waterloo Office of Research Ethics. Study materials may be found in Appendix A.

Participants ranged in age from 23 to 30, and included 7 females and 7 males. Between 4 and 5 players participated in each game, while games ranged in length from 40 minutes to 4 hours. Sessions were video and audio recorded. Written consent for the roughly 7 hours of observation and recording was gained in advance. Following the sessions, videos were reviewed using an open coding method derived from grounded theory (Cresswell, 2008). From these observations, an affinity diagram (Beyer & Holtzblatt, 1997) was constructed to synthesize and thematically categorize the observations. This affinity diagramming process identified a number of key themes in the behaviors observed across all games. The following subsections provide an overview of these themes, including comments regarding their applicability to the design of the cross-device transfer method testing platform developed for this research.

3.2 Observational themes

The themes in the preliminary study's observational data may be divided into two primary categories: game-mandated behaviours and volitional behaviours.

3.2.1 Game-mandated themes

Game-mandated themes included the rules dictated by the game's design and behaviours necessitated in order to reasonably follow them. These themes are as follows:

Use of Space: Consistent with existing tabletop interaction literature (Scott & Carpendale, 2010), players' use of space was organized by recognizable territorial divisions. Table areas directly in front of players were *personal* spaces, used for activities such as planning a player's turn or organizing the cards in a player's possession. Central areas of the table were *group* spaces, those areas frequently accessed by all players, with no single player taking ownership of them. Areas closer to the periphery were typically *storage* spaces, spaces used less-frequently than other spaces, such as a place to store discard piles containing cards put out of play for the remainder of the game. In each game, players had an additional

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[3] http://www.riograndegames.com/games.html?id=278
[4] http://www.atlas-games.com/product_tables/AG1250.php
[5] http://www.worldofmunchkin.com/munchkinzombies/
[6] http://boardgamegeek.com/boardgame/74/apples-to-apples
[7] http://boardgamegeek.com/boardgame/3955/bang

private space off the table in their hands. Holding cards tilted away from other players in this manner ensured that the secrecy could be maintained—a necessary element of many games.

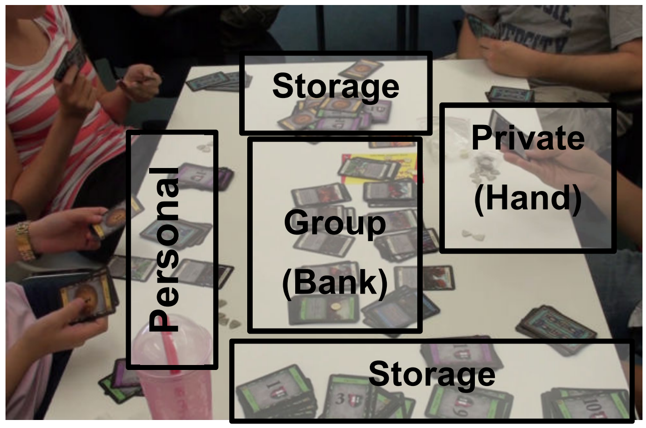

Figure 6: Example of personal, group, storage, and private spaces in *Dominion*

Card flow: Cards were observed to pass between every pairing of territory types. For example, cards were observed to move between personal and group spaces, between storage and private spaces, and between two private spaces.

Randomization: A key component of every game observed was that decks of cards could be shuffled in order to randomize their contents.

Sequence of play: While most games had a defined turn order, with one player performing a set of actions before the next player would be permitted to take a turn, some games provide opportunities for players to interrupt another player's turn by playing a card. At times, these opportunities are anticipated ("Is anyone going to play on this? No? Ok, I'm going to keep going…"), but at other times, these interruptions are more sudden, with the intervening player dramatically throwing a card into the play area or making a verbal exclamation to draw attention to the disruption.

Card meaning: While some cards (e.g. *Dominion*'s Victory Point cards, which display only a point total) have essentially fixed functions, others may be used in a variety of ways. In *Munchkin Zombies,* players collect "weapon" cards to use in battling monsters, but at other times, the player may choose to "sell" the card to gain a different type of benefit. *Dominion*'s Action cards routinely offer players choice in how they may be used. For example, an excerpt from the text of one *Dominion* card (Figure 11) reads as follows:

> Choose one: Set aside the top card of your deck face down on your Native Village mat; or put all the cards from your mat into your hand.

A card's meaning need not even be constrained among a small list of choices, however. In *Apples to Apples,* each card contains a single word or phrase. The word itself has no fixed value; rather, it is up to the players to *assign* their values based on the word's perceived association with words on other cards.

Card grouping: Cards are not isolated resources, but are frequently handled in groups. In some games, once cards are stacked together, these cards become a unit, and richer meaning is derived from working with the stack as a single entity than as a set of unrelated parts.

3.2.2 Volitional behaviours

Volitional behaviours are those which were not mandated by the games rules, but were instead introduced by the games' players, forming an important part of the gameplay observed. These themes are as follows:

Narration: In all games observed, players chose to narrate their turns, verbally describing their game actions, often step-by-step though their turn. In each instance, this narration, which was naturally more extensive for turns that were complicated than for those which were simple, appeared to occur for one or more of the following reasons:

1. **Proof of legal action:** When taking a particularly strategically-successful action, players may walk through the cards played in order to show their opponents that the actions taken abided by the rules of the game. By narrating their turn, players draw special attention to their actions, absolving them from any possible future accusations of cheating.
2. **Request for assistance:** During games involving players of mixed experience, novice players would often narrate their turns as a way to implicitly ask their peers "Am I doing this right?" An example of this behaviour from a *Dominion* game is illustrated below. In this example, P1, a novice player takes her turn, as P2, a more experienced player, provides guiding feedback.

    P1: I have 'Secret Chamber'.

    P2: Yeah

    P1: 'Discard any number of cards, and plus one [gold] per card discarded.'

    P2: Yeah. You get money back

    P1: So I discard this, and then I can pick up an equal number of cards?

P2: No. You can only pick up cards if it says you can pick up cards.

P1: Oh, so I… is it… I have three. *[Touches her three discarded cards.]*

P2: Yeah. You can discard three, and that one *[points]*, and now you can get four gold.

[P1 discards the fourth card as discussed and proceeds with the remainder of her turn.]

3. **Thinking aloud:** Sometimes, a player's turn is complicated enough that they choose to combine vocal narration with the external cognition (Scaife & Ro, 1996) provided by spreading cards out in one's personal space. Figure 7 shows an example of this, as a participant points from card to card, speaking aloud his thought process as he pieces together the complex parts of his turn.

Figure 7: A player sequentially points to cards in his personal space as he narrates his turn

4. **Pleasure:** Finally, some narrations appear to be included purely for enjoyment. Whether describing a particularly humorous event to his peers (e.g. a *Munchkin* Zombie choosing to drape himself in Christmas lights to increase his strength) or a convoluted chain of reasoning in *Apples to Apples* (e.g. In what way is the Australian outback more primitive than a science fair project?), these narrations do not play any key role in the *rules* of the game, but they do seem to contribute importantly to the *experience* of the game.

Reference or browsing actions: While standard playing cards contain only a small amount of information (e.g. the number "5" and suit "heart"), cards in many other games are far more information-dense. As such, novice players may feel the need to refer back to cards in-play to read (and re-read) a card's text. As might be expected, these browsing actions appeared most notably in the games with the most information-dense cards. Interestingly, the action of reading a card for reference purposes was taken with impunity—players freely examined cards from their personal spaces, group spaces, and even removed cards from their *opponent's* personal spaces in order to read them more closely. Even though players had no rule-granted permission to interact with these cards, this appeared to be an entirely acceptable practice.

Figure 8: A player reaches into another player's personal space to read one of her cards

Sorting: In every game observed, players took the liberty to sort their cards. This was most notable in the extent to which players reorganized cards in their hands. Players would segregate gold cards, victory point cards, and action cards in *Dominion*; order their playing cards by number in *President*; or separate treasures from monsters in *Munchkin Zombies*. Not only does such behavior provide a measure of external cognition, there may be more personal, preference-related motives as well. Consider that even in *Apples to Apples*, where no clear game-provided relation between cards exists, some players chose to impose one upon their set of trophy cards, even though the cards have no further active role in the unfolding gameplay. While most games observed used a shared draw deck in the middle of the table, the large number of card piles in *Dominion* necessitated that shared cards be spread more broadly across the table.

Figure 9: A player (right) who has assumed a "banker" role hands another player (top-right) a card

While all players could reach the most-frequently accessed cards, the storage areas on either end of the table could only be reached by some players with difficulty. As such, the players nearest these areas assumed unofficial administrative roles, moving cards to and from these storage areas for the players seated farther away. (This is similar to the role of the "banker" in the Parker Brothers' classic game *Monopoly*.) These duties were generally adopted and performed without verbal comment and were simply pragmatic strategies to overcome the limitation of reach on a large, physical work surface.

Turns in parallel: While in some cases a game may permit players to act in parallel on under special circumstance (e.g. interruptions), in practice, players sometimes chose to violate game rules in order to take turns in parallel. This behaviour was observed only in *Dominion*, where turns may become fairly long as the game progresses, and where one player's turn may not substantially alter the overall game state for the next player's turn. In our observation session, a player part-way through a particularly long turn would often tell the next player to go ahead and begin his turn, stating in essence, "Whatever I decide to do with the rest of my turn won't affect your turn, and so you should go ahead rather than wait." The goal in this case is to avoid a situation in which one player forces all of the others to wait excessively, and players appeared to believe that this benefit was worth the loss of whatever minor strategic advantage would be gained by waiting to observe the end of the previous player's turn.

Again, it should be noted that this practice violates the written rules of the game, but like all games using physical components, a game's rules are always subject to re-interpretation by its players. In fact, the remaining volitional interactions discussed in this section each refer to behaviours that bend or break the *written* rules of the games, while leaving the spirit of the games intact.

Revealing private cards: In some cases, players chose to selectively reveal unplayed cards from their hand (a typically private space) to their opponents. There were a variety of reasons for this, both strategic (e.g. proving one's ability to follow-through with a threat in *Munchkin Zombies*) and humourous (e.g. a player showing others that they had, despite low odds, drawn a hand containing only gold cards).

Ad-hoc team play: As participants discussed what game to play, deciding on *Gloom*, they realized that their group of 5 had one more player than the game would support. In response to this limitation, two players decided to form a team, playing together as one. One player held the hand of cards, but during the game, both players assessed their hand, examined cards in shared spaces, and offered suggestions for their strategy.

Figure 10: Two players (bottom) work together as if they were a single player

Undo: The often-quoted card game adage, "A card laid is a card played", implies that once a turn has been taken it cannot be undone. In practice, however, players often flout this rule, undoing an action to varying degrees.

In its most basic form, a player may decide that he has made a poor strategic decision and wish to take it back, removing any involved cards from both personal and group spaces. This, perhaps the most "offensive" of undos, is often accompanied by an apology or prefaced by an appeal to the other players to give permission for the player to undo the action.

Another way in which actions are commonly "undone" is when players lay out cards in their personal space in order to plan a move. In this case, there is an expectation that the card placement is temporary—this is only a dry run before the "real" turn happens—and as such, choosing to undo the action is an entirely acceptable practice.

3.3 Task selection

Based on our experiences in the preliminary study, Rio Grande Games' *Dominion* was selected as the experimental task to be used in the subsequent investigation of cross-device transfer methods.

3.4 Brief overview of *Dominion*

Dominion is a "deck-building game", a genre which has recently grown in popularity. In this game, each of 2-4 players draw hands of cards from personal decks each turn, and the actions that they may take in each phase of the turn are defined by the cards that they draw. These actions include "buying" additional cards from a shared bank of cards or "attacking" other players (e.g. forcing them to discard cards). By building an effective deck, players are enabled to increase their ability to buy more valuable cards each turn, an important consideration, as winning the game usually requires players to buy expensive "Victory Point" cards.

Figure 11: A typical *Dominion* card (left, © Rio Grande Games, used with permission) and *Dominion* gameplay session (right)

Dominion is a very strategic game, whose information-dense cards (e.g. Figure 11, left) can often be used in multiple different ways depending on the player's choice. As the set of cards available for purchase from the bank changes every game, players must put careful thought into planning their turns, examining not only the information content of cards, but also the sequence in which they are played. Players must also take care to maintain awareness of their opponent's actions, as a player's strategy might need to be altered to react to that of an opponent. Figure 11 illustrates a typical *Dominion* gameplay situation and a sample game card.

3.4.1 Rationale

All the card games observed required players to physically manipulate cards—that is, required players to manage piles of cards on the table, hold a set of cards in their hand, and move cards between the two—the games differed in the complexity of these actions. Thus, any of these games would support the study of cross-device object transfer. However, the complexity of these actions differed across games. Therefore choosing a game in which players were required to rely on the cross-device transfer method and transferred cards for a variety of reasons was determined to provide opportunities to elicit rich interaction data. Requiring players to apply transfer methods in many different ways also has benefits to the generalizability of the resulting data, as more individual use cases would be encapsulated in the larger task. Finally, since an aim of this to explore the cross-device transfer method techniques' effect on factors such as the level of effort required by participants, utilizing a task which demands a higher cognitive workload leaves fewer cognitive resources available for focusing on the interactions themselves. This situation will increase the likelihood that issues due to a technique's level of effort will be exposed.

As such, *Dominion* (which was arguably the most complex game observed) was an ideal candidate. In a simpler game like *President*, players followed a rigid turn order and the table served primarily as a storage location for a single discard pile. In contrast, in *Dominion,* players monitored and reacted to one another's turns while navigating an array of twenty or more different decks of cards on the table (Figure 11, right). *Dominion* players invariably spread their cards out in their personal areas, leveraging this external cognition strategy to enact and announce the progress of their turns, and providing a wide range of reasons why a player might desire to transfer objects between devices. These non-trivial uses of the digital table provide rich context in which to observe instances of cross-device object transfer. Finally, the game's competitive nature incentivizes players to keep certain information secret, an important consideration for studies that require participants to value privacy (Linderoth, 2011).

Permission for the use of the original *Dominion* rules and artwork in this research was graciously granted via email with by Rio Grande Games owner, Jay Tummelson.

3.5 Chapter Summary

This chapter outlined the design and performance of an observational investigation into play of traditional paper-based card games, having identified these as strong examples of real-world tabletop tasks which involve transfer of objects between private and shared spaces. Based on the study, a set of interaction themes were identified, and which were used to inform the design (Chapter 4) of the digital tabletop system examined in this thesis. Finally, the card game *Dominion* was selected as an appropriate experimental task for implementation in the digital tabletop system.

Chapter 4

System Design

The following chapter details the design of the digital tabletop computer system (Figure 12) developed as a test bed to support the investigation of object transfer techniques. The basic test bed is first described, followed by a description of each of the different transfer techniques that were implemented in the test bed, informed by the preliminary domain research described in Chapters 2 and 3.

Figure 12: The digital tabletop and tablet *Dominion* application

The system is composed of private and shared interaction surfaces. Each player's private device is designed to emulate the role of a hand of cards, providing display of private information, as well as support for reordering and organizing cards for play. The shared surface facilitates the rest of the gameplay, including storage of personal and shared cards, personal workspaces, and space to easily pass cards from one player to another.

The remainder of this chapter is organized as follows. First, a description of the system's hardware is provided. This is followed by a description of the two cross-device object transfer methods adapted for use in this research. Finally, an overview of implementation of the *Dominion* card game for play using this system is offered.

4.1 Hardware selection

The system was designed for use with a digital tabletop computer and a set of handheld tablet computers (one per player). As it was intended that the system emulate the direct manipulation of cards which would be familiar to players of the traditional paper-based version of *Dominion*, direct-touch interaction was selected rather than an alternative input form (such as that of a pen-based table). Details regarding the particular digital tabletop and tablet devices employed in the user study may be found in Chapter 5.

4.2 Adaptation of cross-device transfer methods

For the investigation of cross-device transfer methods, two techniques were adapted from existing transfer methods: "Adapted Pick-and-Drop" (based on Rekimoto's Pick and Drop (J. Rekimoto, 1997) described in Section 2.2.3) and "Bridges" (a method that has much in common with portals as described in Section 2.2.2).

4.2.1 Adapted Pick and Drop

Adapted Pick-and-Drop technique leverages players' familiarity with the manipulation of paper cards. In the implementation of this technique, three spaces that contain virtual cards are defined for each player, namely:

- The shared digital table, where shared and personal decks of cards can be manipulated,
- Their personal tablet computer, where a player's private hand of cards can be manipulated, and
- "Cards-in-Transit," an off-screen space where cards are stored after a player picks them up from one of the above spaces and before they drop them onto the other. This space is analogous to a player holding physical cards in the conventional game as they move cards between their hand of cards and the table (or vice versa).

Similar to the original Pick-and-Drop technique, transferring virtual objects in the Adapted Pick-and-Drop involves first selecting the object on the originating device (e.g. the tablet) to "pick" it up, and then selecting a location on the receiving device (e.g. the digital tabletop) to "drop" the object on that device (Figure 13).

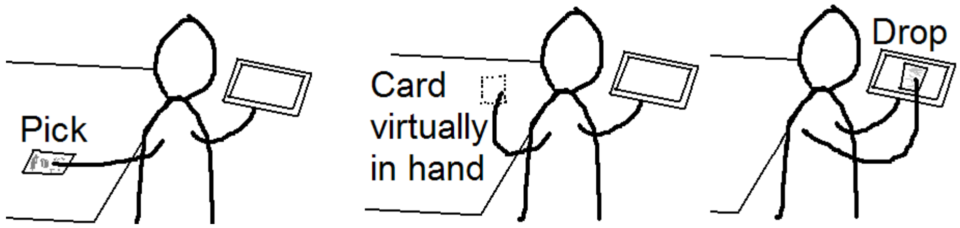

Figure 13: Example cross-device object transfer via Adapted Pick-and-Drop (Figure Copyright Guillaume Besacier, used with permission)

In this implementation, a picking action is initiated on the digital tabletop via a pie menu (see Figure 20), allowing one or more cards to be picked at a time. On the tablet computer, picking may be accomplished by dragging an object upwards, "off the top" of the tablet's screen, emulating the action performed when pulling a card from a fanned-out set of physical cards held in one hand. Once picked, cards remain in the off-screen "in-transit" space until a dropping action is performed.

To complete the transfer, a player touches down onto the tabletop computer or an empty region on the tablet. When dropped onto the tabletop, cards held in-transit are placed together in a stack (i.e. a deck), while cards dropped onto a tablet are added to the player's hand of cards.

4.2.1.1 User identification

The constraints of laser-light plane multi-touch tabletop environment required a number of adaptations to be made to reify the Pick-and-Drop concept. The primary constraint was the lack of user identification information available in the multi-touch tabletop platform. As *Dominion* is a multiplayer game, it was necessary to be able to accurately match the originating and receiving devices to support object transfer. For example, if Player 1 picked up a card from her tablet and then Player 2 also picked up a card from his tablet, it would be impossible for the tabletop system to determine which of these two cards should be transferred the next time a touch occurred on the tabletop. Thus, an alternative design solution was needed to address this limitation.

This was accomplished by explicitly dividing the digital tabletop area into territories. In front of each player is a personal space, a "player area". Within these spaces, it is assumed that all interaction is initiated by that territory's owner. These player areas are shaded in a different color for each player. By adding the additional assumption that each tablet is only ever used by one player, transfer between each player's tablet and player area may occur without any interference from other players. The remainder of table is a shared (or group) territory. In the most basic case, no attempt is made to associate touches in the shared space with a particular user, and as such no picking or dropping action into this space is permitted. However, this limitation would interfere with Pick-and-Drop's direct interaction metaphor (Nacenta, 2009). Thus, two independent "territory control" or turn-taking mechanisms were developed: token-based territory control and dynamic territory control.

When using the token-based control method, a moveable digital token is added to the tabletop surface. By moving this token into a player area, that player gains "control" of the table's shared territory (which changes colour to match that of the controlling player). While under that player's control, touches in the shared territory are ascribed to that player, permitting picking or dropping actions to be performed from the shared space, for example. To release control of the shared territory, the token may be moved back into the shared space or passed into another player's area.

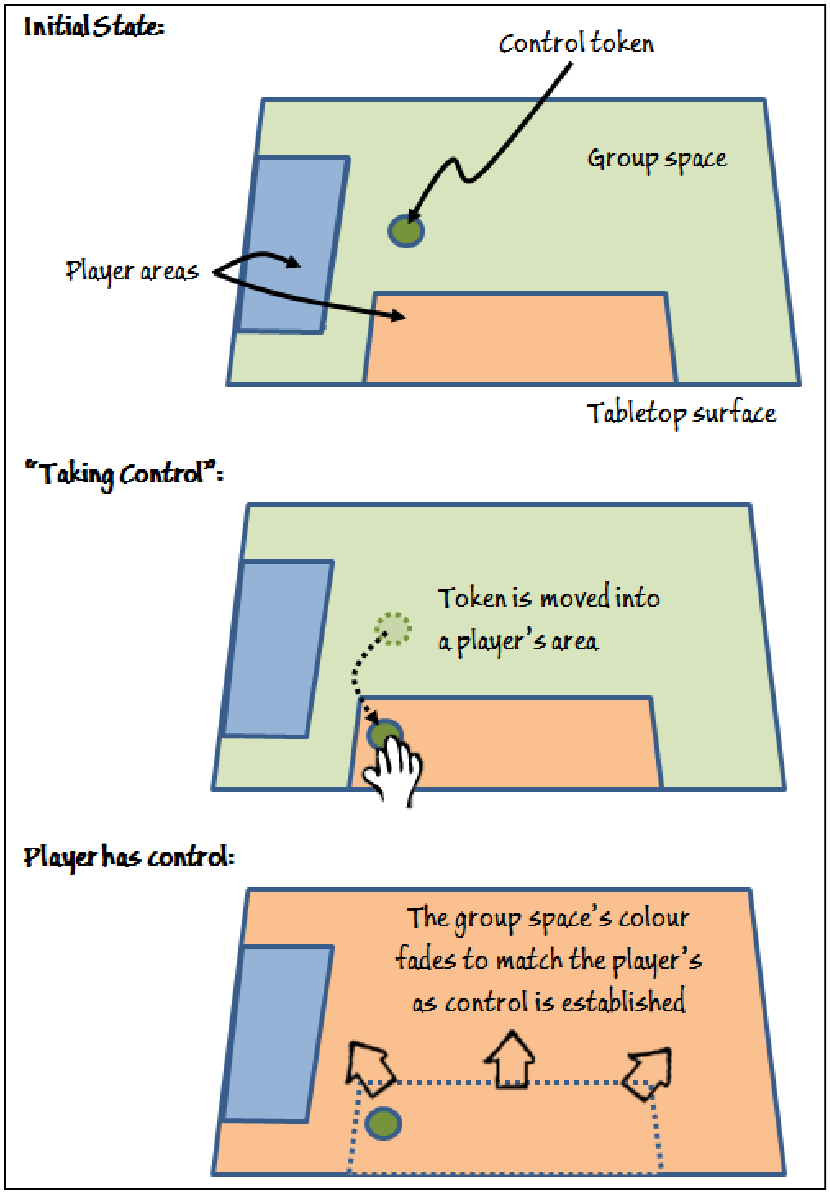

Figure 14: Storyboard: Token-based territory control

The dynamic control method functions similarly, but rather than using a token, it employs a different method to take and release control of the group space. With this interaction, whenever a player touches and maintains physical contact with their player area, control of the shared territory is assumed as well. (If multiple players make contact with their player area, control is held by the first one to take control until all touches on that player's area are released). While any touch held on the player area can be used to maintain control, this control method is specifically designed to support the following interaction. To take control, a player moves his tablet-holding hand forward, resting it in the play area (Figure 15). This leaves the other hand free to perform the transfer between the tablet's private space and the group space. At the same time, the visible movement of the player's body toward the shared space provides a social cue to other players that that player is claiming temporary control of the shared space.

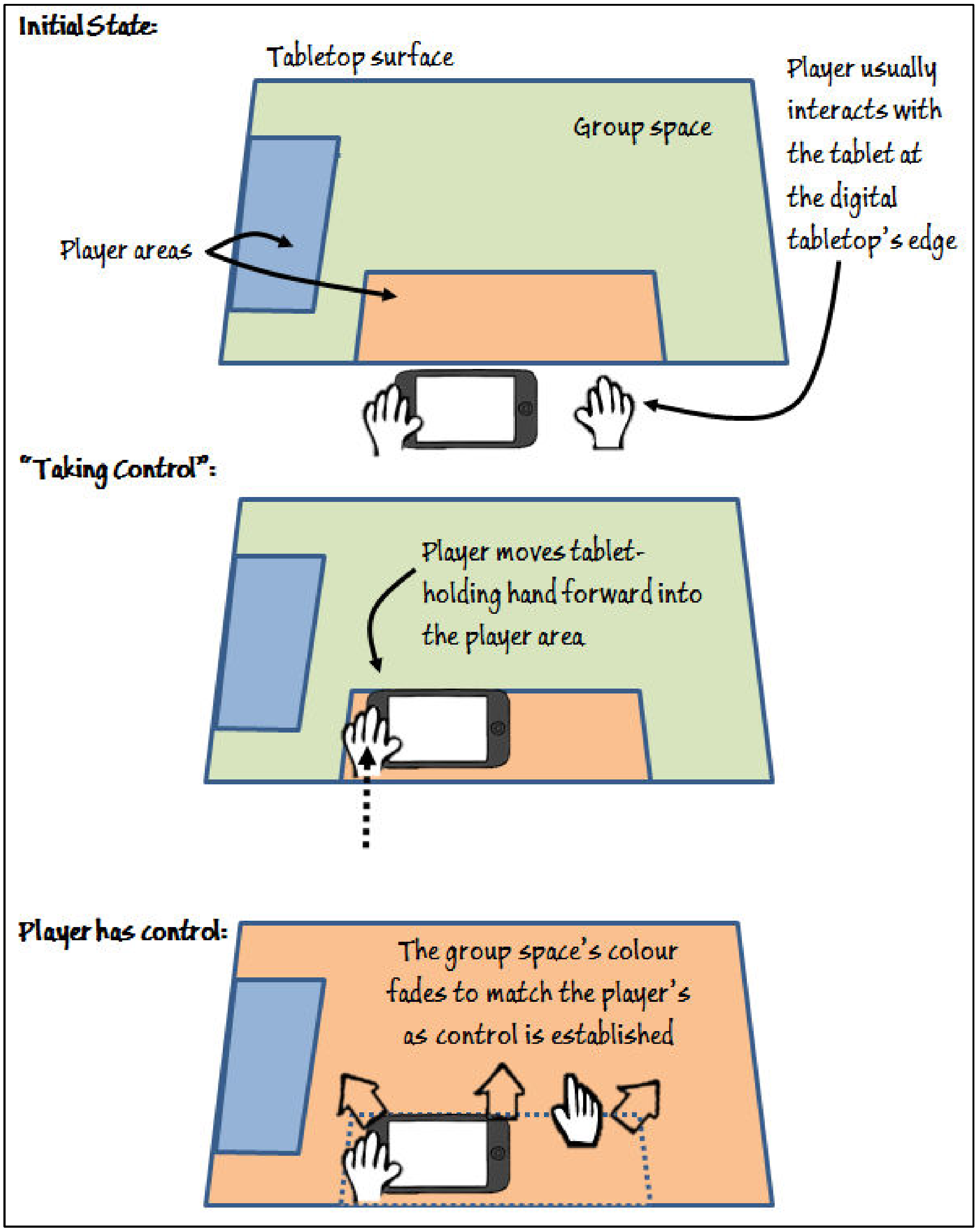

Figure 15: Storyboard: Dynamic territory control method

4.2.2 Bridges

Bridges is a planar object transfer technique which defines for each player three spaces that contain virtual cards:

- The shared digital table
- Their personal tablet, and
- Their personal "Bridge”, which is a matched pair of rectangular regions that facilitate card transfer between the above two spaces provided to each player and is located on their personal tablet and in their personal space on the table

The positions of the players’ Bridges are fixed: one at the bottom of each player’s area (along the edge of the table closest to that player), and one at the top of the player’s private device. The players’ Bridges are color-coded to match each player’s area.

When a card is dragged to either of these two Bridges, the top half of the card appears on the table-side Bridge, while the bottom half of the card appears on the tablet-side Bridge. The card can then be moved from either side of the Bridge onto the desired device by dragging the card fragment fully onto the target device.

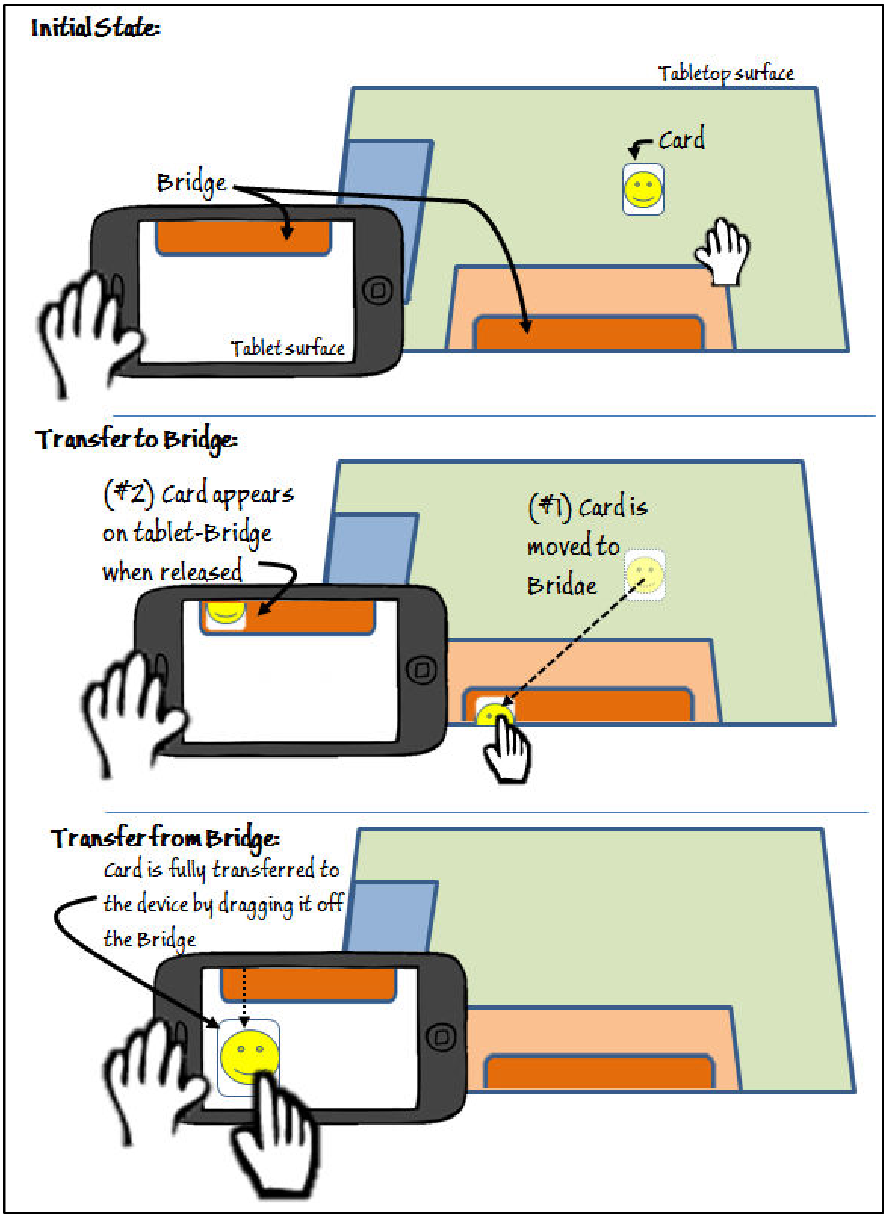

Figure 16: Storyboard: Cross-device object transfer via Bridges

To simplify manipulation of the small cards on the personal device's Bridge, cards on this device are always shown face-up. This design decision is supported by observations in the preliminary domain study (Chapter 3) that card game players never held both face-up and face-down cards in their hands simultaneously. In this way, a single card can have its top half displayed face-down on the table-side Bridge and its bottom half displayed face-up on the tablet-side Bridge. Cards transferred from the personal device to the table are always transferred face-up.

4.3 *Dominion* application design

The *Dominion* digital tabletop and tablet application (Figure 12) provides a useful context for the study of the two object transfer methods described above.

As in our choice of direct-touch interaction surfaces (Section 4.1), interaction in the *Dominion* system was designed to closely emulate the physical experience of playing a card game. One of the most significant effects of this was the decision to not implement any form of computer-assisted rule enforcement or anything more than very basic automation (e.g. shuffling of a deck, initial game setup). Instead, the system requires players to manually move digital cards across the table as they would in a physical card game. This decision was made to ensure that participants were free to pursue their own interpretation of *Dominion*'s rules (allowing, for example, house rules, "browsing actions", and the ability to take turns in parallel). Since players are free to shape the rules of physical *Dominion* to their liking, this ensures a more realistic use of *Dominion* as an experimental task. It is also recognized that *Dominion*'s cards contain more than just the information required for the player to take his turn; their form permits flexible arrangements to support external cognition or turn narration, and their movement across personal and shared spaces provides an important opportunity for other players to keep track of the game state. Understanding that reach is a common challenge in digital tabletop systems (e.g. (Bezerianos & Balakrishnan, 2005; Parker, Mandryk, & Inkpen, 2005; Pinelle et al., 2006; Chia Shen et al., 2006)), this implementation also enables players to assist another player to reach distant cards, as objects will respond to touch regardless of their "owner". Finally, by striving to design the *Dominion* implementation in a manner that emulates the physical card game experience, the design empowers the examination of generalizable interaction—the *Dominion* card images used in this game could easily be replaced with content for another game or task, just as the physical actions which support working with pieces of paper-based content are in many ways agnostic to the content of those pieces.

The software interface design of the digital tabletop system consists of two complementary applications: the digital tabletop display (developed using the C# programming language) and the tablet computer display (developed using the Java programming language).

4.3.1 Digital tabletop

The digital tabletop computer's user interface (Figure 17) includes four key components: cards, decks, menus, and territories.

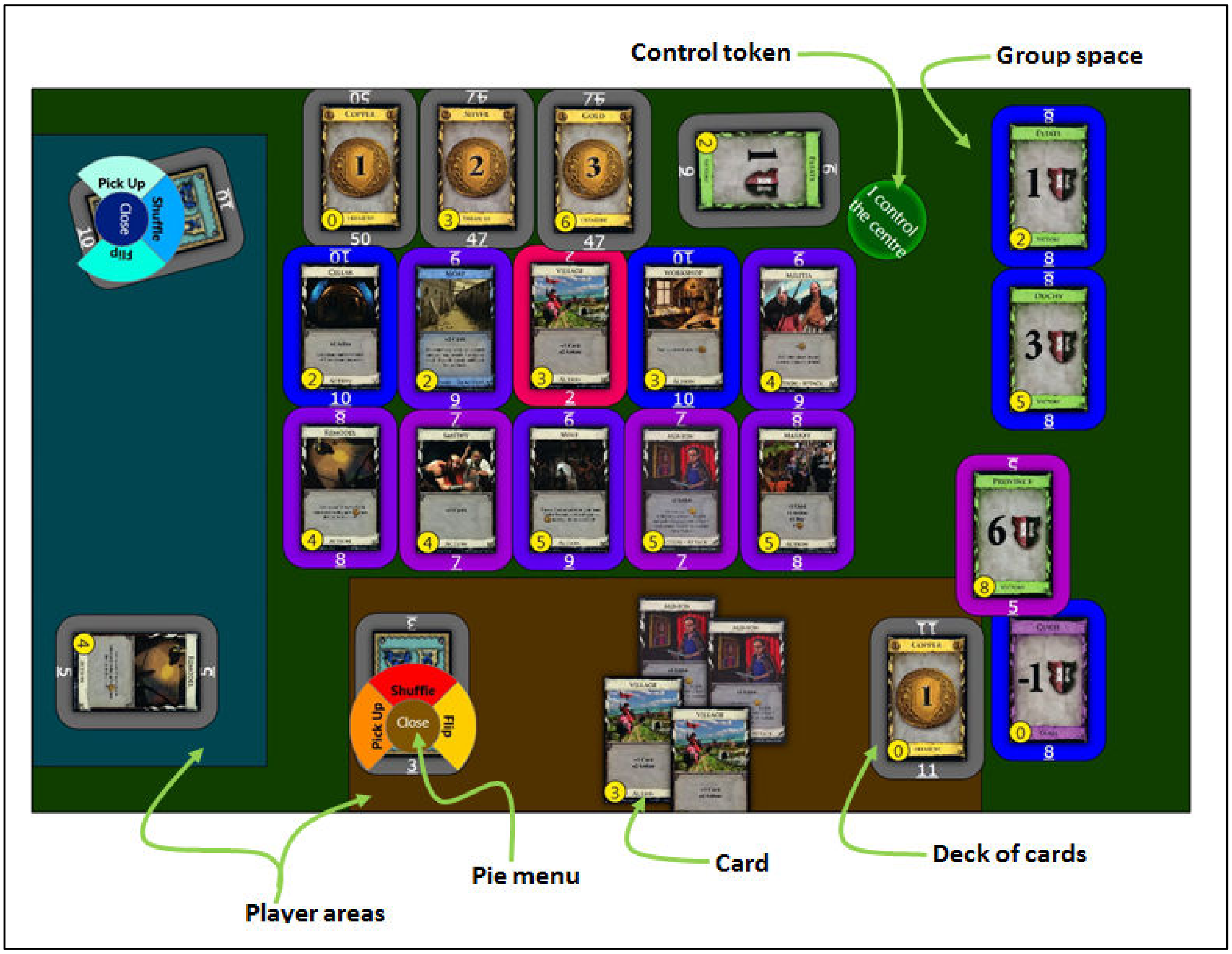

Figure 17: *Dominion* digital tabletop interface (Adapted Pick-and-Drop with token-based control condition shown)

4.3.1.1 Cards

The digital cards (e.g. Figure 18) in the system take the form of freely translatable, rotatable images, each displaying artwork identical to that of the cards in the physical *Dominion* game.

Figure 18: A group of four individual cards

The digital cards permit the following interactions:

- **Translation:** By touching the card at a single point, the card may be translated across the table.
- **Rotation:** If the card is touched at two points, the card may be rotated using either point as a centre of rotation.
- **Enlarge:** By using a two-finger spreading motion, a card may be enlarged to be more closely inspected. When released, the card "springs" back to its original size, briefly displaying a playful bouncing animation.
- **Flip:** Issuing the command through a contextual pie menu (Section 4.3.1.3), a card may be flipped in place. Like a traditional playing card, each of the digital cards has a front and a back image. (Whether a card is "face up" or "face down" is referred to in this thesis as its "facing".)
- **Pick and Drop:** When the Adapted Pick-and-Drop interaction is enabled, cards may be picked and dropped, as described in Section 4.2.1. For greater ease of use (Kruger, Carpendale, Scott, & Greenberg, 2004), cards automatically rotate to face the player actively controlling the space when dropped onto the table. If dropped onto a deck, cards instead rotate to match the deck's orientation.
- **Move to Bridge:** When the Bridges interaction is enabled, a player may place a card onto, or removed a card from, any of the Bridges on the table, as described in Section 4.2.2.

4.3.1.2 Decks

Much like their physical counterparts, a deck in the digital *Dominion* system is a stack of cards. Whenever a single card is released on top of another, a deck is created (Figure 19), identified by its large rounded border.

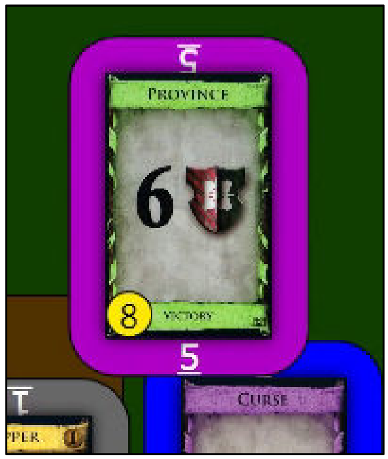

Figure 19: A deck five cards, with a "Province" card on top

Decks support the following interactions:

- **Add Card(s):** Whenever a card is released (or dropped, in the case of an Adapted Pick and Drop interaction) such that the point at which the player's finger lifts away from the card is atop a deck, the card is added to the top of the deck. This causes the card to "snap" into place on top of the deck, which responds with a brief (~0.2s) "bouncing" animation (i.e. the deck smoothly grows to 105% of its original size, before shrinking back to 100%) to provide confirmation of the interaction to the player. As a small aid to the player, when a single card is added onto a deck, it flips to match the facing of the top card in the deck. Since *Dominion* rules do not permit decks to contain cards of mixed facing, this small degree of automation saves players the effort of manually flipping cards when discarding (for example).

- **Remove Card:** To remove a card from a deck, the player simply touches the card displayed on the top of the deck and moves her finger. This causes the card to be released from the deck and translated to follow the path of the player's finger. Alternatively, in Adapted Pick and Drop conditions, the player may remove a card using the pie menu (Section 4.3.1.3). In either case, a "bouncing" animation provides visual confirmation of the event.

- **Translation and Rotation:** A deck may be translated and/or rotated in the same manner as a card. This is accomplished by touching its border with one or more fingers and performing the appropriate action.
- **Flip:** When a deck is flipped (in the same manner as a card), it emulates the behaviour of flipping a deck of physical cards. That is, its order of cards is reversed (i.e. the bottommost card becomes the top card, and so on), and the facing of every card is reversed as well.
- **Shuffle:** Since digital cards do not afford shuffling in the same manner as physical cards, a digital deck may be automatically shuffled using the pie menu (Section 4.3.1.3). Shuffling a deck randomizes the order of the cards, leaving their facings unchanged. The shuffle action is accompanied by visual confirmation in the form of a “wiggle” animation, in which the deck briefly (~0.5s) rotates back and forth +/- 15° around its midpoint.
- **Pick and Drop:** When the Adapted Pick-and-Drop interaction is enabled, individual cards may be picked from the top of the deck using the pie menu (Section 4.3.1.3). After one or more cards have been picked, tapping the deck causes all of that player’s picked cards to be dropped onto the top of the deck. Cards dropped in this manner rotate to align with the position deck. These dropped cards also flip to match the facing of the top card in the deck.

In addition to its role as a “handle” for interaction, a deck’s border also serves to communicate information about the deck’s contents to the player, with a design inspired by its physical counterpart. A physical deck of *Dominion* cards offers information about its contents in a couple of different ways. The height of the deck offers a gross, at-a-glance indication of the number of cards it contains. However, with some effort, a player can also fan through a deck to count the exact number of cards which it contains. Similarly, the digital *Dominion* decks provide a rough, at-a-glance estimate as well as higher-effort, exact count of the number of cards it contains. A deck’s border begins as a pure blue colour, but as cards are removed from the deck, this blue gradually shifts towards red. This technique provides a very easy to perceive, yet rough estimate of the deck’s progress towards exhaustion. For the *Dominion* game, as exhausting a deck is a significant event only for *some* decks (i.e. the “Action” and “Victory Point” cards stored in the group space), the colour-shifting visualization was only enabled for these decks, increasing the salience of this important information. Additionally, each deck’s border also displays the exact number of cards remaining on its top and bottom edge, providing a more exact, yet higher-effort method to determine the number of cards it contains.

4.3.1.3 Pie Menus

While simple rotation and translation actions on cards and decks are supported through direct interaction, more complex interactions upon these objects were supported via contextual pie menus (Callahan, Hopkins, Weiser, & Shneiderman, 1988). Each user can open one such menu at a time, and each menu contains one to three options. These options include "Flip" (for cards or decks), "Shuffle" (decks only), and in Adapted Pick and Drop conditions "Pick Up" (on cards or decks; See Section 4.2.1). A pie menu was selected to support this functionality for two reasons. Firstly, the particular digital tabletop available for use possessed inadequately sensitive touch recognition to reliably support a set of gesture-based interactions, such as a pinch-to-pick gesture (Jun Rekimoto, 2002; Tse et al., 2006). (Input resolution is a technical limitation which is not uncommon in direct touch systems (Benko, Morris, Brush, & Wilson, 2009; Chia Shen et al., 2006)). Secondly, the pie menu removed many of the discoverability and memorability challenges inherent in gesture-based interactions; a player only needs to be able to open the pie menu and select an option, rather than having to recall a set of unique interactions and their mappings to the intended result.

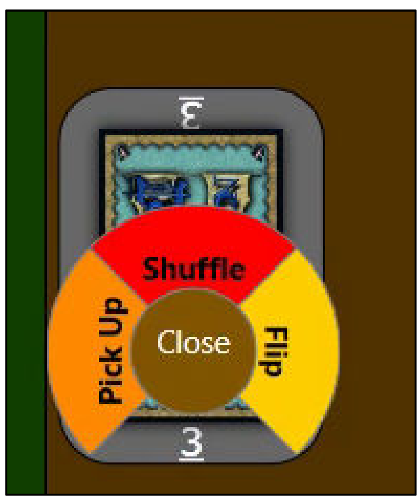

Figure 20: A pie menu opened on a deck

To open a pie menu, a player taps (defined as a touch down and touch up, with no translation in between) a card or deck. Each user has their own pie menu (colour-coded to match the colour of the player's player area, Section 4.3.1.4), and the pie menu always faces towards the edge of the table along which that player is seated. To reduce clutter, only one menu per player may be opened at a time; if the player opens a menu while one is already open, the first menu closes as the second opens.

4.3.1.4 Tabletop territories

To support user identification, the digital tabletop interface is explicitly divided into different spaces/territories.

Immediately in front of each player is that player's personal space, also called the player area. In this space, the system assumes that all touches are performed by the space's owner, facilitating user-specific interactions such as cross-device object transfer, automatic rotation of objects (e.g. pie menus facing their owner), and interaction logging. Although the system does not enforce this use, the space's size and position (modeled after the spaces spontaneously adopted by players of physical *Dominion*) provides a convenient space for players to store their draw and discard decks, as well as lay out their cards during a game turn to support external cognition. Each player area is shaded with a unique colour, matching the colour scheme of that player's contextual pie menu.

The remainder of the table is classified as group space. A group space functions in the same way as the personal spaces, with the exception that it typically does not recognize an owner. In consequence, user-specific interactions such as opening a menu are restricted in the group space, although all other interactions (e.g. translation, rotation, etc.) are permitted. To facilitate richer interaction in the group space, token-based or dynamic territory control methods (as described in Section 4.2.1.1) were enabled. When controlled by a player, the group space behaves in the same way as that player's area for the duration of the control—that is, user-specific interactions, such as those supported via the pie menu are enabled for that player. When control is released, the space returns to its default "uncontrolled" colour, closing any remaining pie menus which may have been left open in its area.

4.3.2 Tablet computer

The tablet computer interfaces serve as a private workspace for each player. The table computer interface can be divided into three regions: the hand of cards and scrolling area, the transfer area, and the preview area.

Figure 21: *Dominion* tablet interface (Bridges condition shown)

4.3.2.1 Hand of Cards

The digital "Hand of Cards" emulates a set of cards fanned out in a player's physical hand, where they may be rearranged or more closely inspected as the player plans his turn. After transferring cards to the tablet, the set of cards on the device are displayed in a row. Cards in this row may be freely reordered by touching the card and dragging and dropping it into another position in the row. When the number of cards in the hand becomes too large to be seen all at once within the display, a bar at the bottom of the device allows the player to scroll through the cards. This scroll-bar also provides a small view of the whole hand, so that the player can easily see how many cards they have in their hand.

4.3.2.2 Transfer Area

The thin region near the top of the device facilitates transfers between the tablet and tabletop computers. As described in Section 4.2.1, when Picking a card using the Adapted Pick and Drop technique or when moving a card to the Bridge in the Bridges technique, the player slides the card "off of the top" of the device. As the Samsung Galaxy Tab's bezel is not touch-sensitive, it is necessary to detect this motion *just before* the touch leaves the tablet's screen, in a dedicated "transfer area". When using the Bridges transfer method, the transfer area also displays the Bridge itself, including the bottom halves of any cards it contains.

4.3.2.3 Preview Area

The right-hand side of the tablet is a non-interactive space reserved for displaying card previews. This "preview area" displays a large (i.e. easily readable, being roughly the same size as a physical Dominion card) image of the card most recently touched by that player. The resolution of the digital tabletop computer's projected display is insufficient to allow easy reading of cards' fine text (a common difficulty in digital tabletop systems, eg. (Wigdor & Balakrishnan, 2005)), and unlike physical cards, digital cards do not afford lifting from the table's surface to read closely. This preview mechanism (as well as the pinch-to-zoom interaction) provided a simple workaround for this limitation.

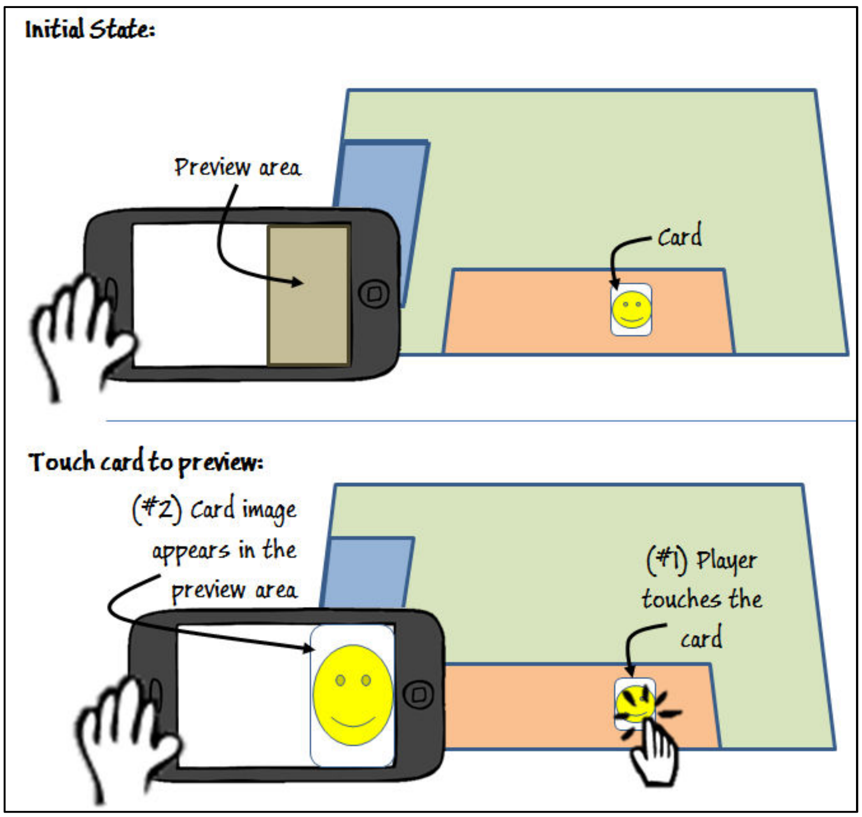

Figure 22: Storyboard: Card preview

4.4 Chapter summary

Drawing from the domain research of Chapters 2 and 3, two cross-device object transfer methods were adapted for us on a digital tabletop and tablet computer system. A digital tabletop and tablet implementation of Rio Grande Games' *Dominion* was developed to serve as a test bed for these object transfer methods. Chapter 5 outlines the study method used to investigate the use of the cross-device object transfer methods.

Chapter 5
Method

To explore the effectiveness of the Bridges and Adapted Pick and Drop transfer methods described in Chapter 4, a mixed-methods user study was conducted in a digital tabletop gaming context. This chapter describes the study methodology. First, the research design and focus are presented, followed by a description of the study conditions and participants. The experimental setting and hardware configuration is described. Finally, the study procedure is outlined.

5.1 Study Design

In order to leverage the benefits of both quantitative and qualitative data collection and analysis, a mixed-methods (Cresswell, 2008) user study methodology was adopted for this study. The study included quantitative (predominantly in the form of interaction logs and questionnaire responses) and qualitative (via video recording and analysis, as well as open-ended survey questions) measures. Inspired by themes in existing multidisplay groupware literature (Chapter 2), as well as by our previous gaming domain research (Chapter 3), the goal of the study was to examine the effectiveness of cross-display transfer mechanisms with particular focus on:

- **Awareness**: How well did each transfer method support the players' awareness during the task? This includes an understanding of changes in the state of the game, as well as a sense of an opponent's actions and strategy. Awareness during object transfer is important both for the player who performed the transfer action as well as for the other players.
- **Effort**: What level of effort did each transfer method require of the players? Did players feel that this level of effort was appropriate for their desired actions?
- **Enjoyment**: How satisfying or enjoyable was the transfer method to use? While arguably important in any context, this factor is particularly important in the recreational gaming domain. In particular, the transfer method should not *interfere* with the players' enjoyment of the overall gaming experience.

5.1.1 Study conditions

Using the cross-device transfer and turn-taking control methods described in Chapter 4, the study included the following three system three configurations as study conditions:

1. Adapted Pick and Drop transfer method using the Explicit control method
2. Adapted Pick and Drop transfer method using the Implicit control method
3. Bridges transfer method with no control method

A within-subjects design was used, where each group of players performed the study under each of three study conditions. As a first study of these methods, these conditions were selected in order to limit statistical complexity and to allow for common themes to be examined across a range of different interaction mechanisms, rather than employing a fully-permuted experiment design (e.g. a Latin square design) that would have been prohibitively time-consuming for comparing two object transfer mechanisms and three turn-taking mechanisms. Conditions 1 and 2 were included because turn-taking is required for our Adaptation Pick and Drop mechanism to function as-designed in shared spaces. In contrast, the Bridges transfer technique does not require any turn-taking mechanism in order to be fully functional, and so turn-taking was excluded from Condition 3. These conditions were counterbalanced to account for learning effects.

In addition to the three interaction conditions described above, three different sets of ten previously-selected *Dominion* kingdom cards (i.e. the cards which players may add to their decks) were used. This was necessary to maintain consistency with the way that players would typically play *Dominion*—players rarely, if ever, play twice in a row using the same set of kingdom cards. Kingdom card sets were chosen from Rio Grande Games' list of recommended configurations, although modifications to these sets were made to favor cards which encouraged players to interact with one another directly (e.g. cards which force the other player to discard, or cards which require players to swap a single face-down card with one another). Every group saw the same three sets of kingdom cards in the same order, in order to avoid interfering with the counterbalancing of the condition. Learning effects related to kingdom card sets were not anticipated, as all players had previous *Dominion* experience.

5.2 Participants

Participants were recruited in groups of two from the University of Waterloo. Participants were required to be aged 18 years or older and to have had previous experience with *Dominion* (see Appendix B for recruitment materials). Since the casual familiarity and camaraderie was observed as an important role in physical card games in the preliminary domain study (Chapter 3), it was important to recruit participants who would be similarly comfortable with one another. As such, participants were required to sign up with a friend as a group of two. After their initial response, participants were directed to self-select a session time using an online calendar. Fourteen groups of two participated in the study. Participants were aged 20-44, including 23 males and 5 females. This research was reviewed and received clearance from the University of Waterloo Office of Research Ethics. Study materials may be found in Appendix B.

5.3 Equipment and setting

The study was conducted in an access-controlled experimental laboratory in the Engineering Faculty at the University of Waterloo.

The study was performed using a laser light plane (LLP) digital tabletop computer[8] and a pair of 7-inch first-generation Samsung Galaxy Tab handheld tablet computers (one for each participant). The custom-built table was chosen as its large surface area (0.9m by 1.3m) more closely resembled the size of a traditional board gaming or card gable, than that provided by smaller commercial tables available for use at the time (e.g. SMART table[9], Microsoft Surface[10]). The table's 1280x800 pixel, rear-projected display resolution was provided by a single short-throw projector, mounted along one of the table's long edges. The tabletop computer used the Microsoft Windows 7 operating system, and touch recognition and image processing was performed using Community Core Vision[11] with a floor-mounted infrared camera. The Breeze for WPF 3.5[12] framework was used to translate Community Core Vision's TUIO touch data into object movement in the digital tabletop software.

The tablet computers were selected as they provided mobile, private surfaces for interaction that were large enough to provide a working area comparable to a card-player's familiar hand of cards, while at the same time being small and light enough to be comfortably held in one hand and manipulated with the other. Given tablet computers' recent surge in popularity as a consumer product, they also meet our criteria of being a readily available technology. Tablets communicated with the digital tabletop via a private wireless network, configured prior to the experimental sessions.

In each session, participants sat adjacent to one another, with one participant on a long edge of the table and the other on the short edge at the first player's left (Figure 23). Tablets were associated with players in a fixed order based on the sequence in which the *Dominion* application was launched on each tablet

[8] http://peauproductions.com/store/index.php?main_page=index&cPath=16
[9] http://smarttech.com/table
[10] http://www.microsoft.com/en-us/pixelsense/default.aspx
[11] http://ccv.nuigroup.com/
[12] http://code.google.com/p/breezemultitouch/

(i.e. the first tablet to launch the *Dominion* application was always associated with the player on the long edge of the table, while the second was always associated with the player on the short edge).

Figure 23: Photo demonstrating participants' seating

5.3.1 Data collection

Sessions were audio and video recorded. In order to ensure that all audible communication between participants was captured, each participant wore a headset-style microphone. Figure 23 shows the position of the video camera with respect to the rest of the system. This position was chosen as it provided a clear view of the tabletop screen as well as of at least one player's tablet display at all times. An open-source screen-recording program (CamStudio[13]) was also used to capture the tabletop computer's display during each game.

The tabletop software also included extensive interaction logging. Every object (e.g. cards, menus), region (e.g. player and shared areas), or logical grouping in the game (e.g. decks) was assigned a unique ID, allowing the movement through the system of each object to be tracked over time. Every touch was captured in an event log which included details such as time, touch location, and the user ID corresponding to the owner of the territory in which the touch occurred. Touches which effected a state change in the game (e.g. moving a card, adding or removing a card from a deck, opening a menu, or moving the turn-taking Token) were logged with additional relevant information, including which object(s) were involved, the object(s)' displacement, etc. Due to limitations in the network communication, rearrangement of cards on the tabletop computer's hand area was not logged; object transfer interactions were there only interactions on the tabletop computer which were logged. Finally,

[13] http://camstudio.org/

observational field notes were recorded by the researcher throughout the sessions, especially in the first few sessions (until fewer new behaviours were observed). The researcher observed from the back of the experimental room, some distance away from the digital tabletop (to allow participants to relax into their familiar game playing habits). Thus, the observational field notes were based primarily on participants' audible discussion and pleased or frustrated expressions.

5.4 Procedure

Upon arrival, participants were welcomed and then seated at the digital table. They were then asked to read an information letter detailing the goals and process of the study. They were then asked to complete a consent form and background questionnaire that gathered demographic and game-playing experience information (Appendix B). Following the review and completion of these forms, a brief demonstration and verbal explanation of the system was provided, including:

- guidelines for safe operation of the laser-light plane tabletop computer
- a demonstration of the tabletop game's interactive features such as card and deck movement, dragging and dropping objects onto one another, pinch-zoom on cards and triggering the card detail view on the tablet, and flipping cards and decks
- a demonstration of the cross-display transfer methods and turn-taking techniques to be used in the first condition, including moving objects to and from the tablet computer
- access to paper copies of the original *Dominion* rules (available on a nearby side table)

Once this demonstration was complete, screen and video recording was enabled, the software was restarted (to reset it to a fresh state), and participants were directed to begin their game. No instruction was offered with regard to how players should conform to certain game rules or practices. Instead, players were encouraged to play the game in whichever manner they were most comfortable.

Upon completion of the game (or in the cases where games exceeded one hour in length and thus were ended early), participants were asked to complete a questionnaire containing a series of Likert scale and short-answer questions that gathered their opinions on the game session they had just completed. This process was then repeated for the remaining two conditions, briefly demonstrating the relevant cross-display object transfer and turn-taking mechanisms prior to each game. Once the third game was complete, participants received debriefing letters, were given an opportunity for any general questions or comments about the study, and then thanked for their participation. Players were each remunerated $20 for their time.

5.5 Chapter summary

A mixed-methods observational study was conducted using the *Dominion* digital tabletop and tablet system to explore the use of two cross-device object transfer interactions Adapted Pick-and-Drop (with two different territory control methods) and Bridges, with particular emphasis on the themes of enjoyment, awareness, and level of effort. Each group of two participants played three games of *Dominion* (one in each of the three conditions). Computer logs, video and screen recordings, and researcher field notes were collected. The following chapter details the analysis and results of this effort.

Chapter 6
Results

During and after gameplay, participants were often quite vocal about their impressions of with regard to each condition's interaction design, and a comparison between the active condition and those that preceded it frequently served as a main topic of casual conversation among the players during their games. The preferences expressed during these discussions (and more formally, on the post-condition questionnaires), however, differed drastically between groups, and even between players. Consider the following contrasting comments, reported in the post-condition questionnaire results: Comparing the Bridge-supported conditions, one player commented that "having the [Bridge bar] partly on both screens was… very helpful," while another reported that "the [Bridge bar] being in two places was a little unwieldy." Comments pertaining to Pick and Drop were similarly contrasting. One player reported that that "[Pick and Drop] is a much better mechanic [than Bridge bars]," while another player commented that "[Pick and Drop] was NOT intuitive."

As this chapter will indicate, these contrasting opinions highlight a central theme in the results of this investigation: no one interaction method was best suited for all players at all times. Instead, the effectiveness of the interaction styles offered in each condition was highly player- and context-dependant.

This chapter is organized as follows: First, a quantitative analysis is offered, leveraging common measures of collaborative system performance. Then, a description of participants' use of the Adapted Pick-and-Drop territory control methods is provided. Finally, a qualitative analysis is offered, investigating the numerous interaction strategies which players applied in their use of the two object transfer interactions. Based on this analysis, a qualitative comparison of the Adapted Pick-and-Drop and Bridges methods is made.

6.1 Quantitative analysis

A standard approach to the study of collaborative systems includes taskwork and teamwork measures (J. R. Wallace et al., 2011), which are measures focused on the effort required to perform the task and the effort required to coordinate the group, respectively (Pinelle, Gutwin, & Greenberg, 2003).

Standard taskwork measures include time and error. With respect to the *Dominion* system, time measures (by condition) might include the length of time taken to transfer digital objects between surfaces, while errors might include instances in which sub-optimal strategic choices were made by players. However, in the case of this study, neither of these measures was appropriate. In the case of time, it was quickly identified that players routinely made use of the transfer mechanisms in ways that were not directly comparable, such as leaving cards in a half-transferred state on their Bridges as an organization strategy. In the case of error, *Dominion* is a task without a clear optimal solution against which to compare a player's actions. Furthermore, and as a recreational activity, it would be difficult to argue that a player must always *want* to pursue the optimal solution even if one were known.

In light of this, quantitative analyses which focused on teamwork measures were performed, including equity of participation (Marshall et al., 2008), and instances of parallel interaction. Finally, Likert-scale questionnaire data was also collected.

6.1.1 Equity of participation

An equity of participation ratio (defined as the difference between the total counts of each user's touches in a session, as a percentage of the total number of touches in that session) was calculated for each session. The intent of this was to reveal if a particular condition influenced one participant to interact more than another, as might be the case if an interaction technique was more effective for the participant on the long edge of the table than the one on the shorter edge, for example. A one-way analysis of variance (ANOVA) was performed on the equity of participation values across conditions. No significant difference was found ($F(2,39)=0.258$, $p=0.774$).

6.1.2 Parallel interaction

As participants develop competence with the tabletop system, they can more readily predict the outcome of a given interaction. It is believed that with this competence comes a level of comfort which encourages users to work in parallel—no longer fearing that the table will misinterpret input if two users work simultaneously. In this study, we measured instances of parallel (ie. near-simultaneous) interaction, defining these as instances in which a user touched the tabletop within 0.5 seconds of another user's touch. A one-way ANOVA was performed on the parallel interaction values across conditions. No significant difference was found ($F(2,39)=0.040$, $p=0.961$).

6.1.3 Participant feedback

Likert scale questionnaires were completed by participants immediately following each condition. These included questions targeting three themes inspired by Chapter 3's domain research: enjoyment, support for awareness, and level of effort. For each question, a one-way ANOVA was performed across conditions. Rather than treating each group member separately (and ignoring that each pair played the same game), a repeated measures design was used, in which each of a group's two members provided a measurement for a given question and condition. The scores' means (Table 1) indicate a modestly positive result across all questions (excepting "Level of Effort", which participants attributed in all conditions to issues with the digital table hardware's touch recognition). No significant differences was found across conditions for any question (See Table 1 for test metrics).

Table 1: Post-condition Likert questionnaire results (1 = "Strongly Disagree", 7 = "Strongly Agree)

Theme	Question	Pick-and-Drop Dynamic Control		Pick-and-Drop Token-based Control		Bridges		Repeated Measures ANOVA
		Mean (SD)		Mean (SD)		Mean (SD)		
Enjoyment	I had fun playing the game.	5.6	(1.4)	5.9	(1.0)	5.9	(0.9)	F(2,24) = 1.364, p = 0.275
Awareness	I was always aware of the other player's actions.	4.3	(1.6)	4.6	(1.9)	4.4	(1.8)	F(2,24) = 0.459, p = 0.637
	When the other player took action, I always understood their motivations for doing so.	5.4	(1.4)	5.4	(1.8)	5.4	(1.6)	F(2,24) = 0.021, p = 0.980
	When taking my turn, I was always aware of my play options.	6.1	(1.2)	6.3	(1.0)	6.3	(0.7)	F(2,24) = 0.393, p = 0.680
	I always understood how the game was progressing.	5.9	(1.2)	5.9	(1.4)	5.8	(1.4)	F(2,24) = 0.053, p = 0.949
Level of Effort	I felt that it took a lot of effort to play the game.	4.7	(1.4)	4.3	(1.7)	4.5	(1.8)	F(2,24) = 0.848, p = 0.441

6.2 Effectiveness of control methods

As was previously described, to facilitate user-specific Pick-and-Drop interactions in shared spaces, two methods were developed which allowed touches in these spaces to be paired with a particular user, one dynamic (inferred by user contact in their Player Area) and one token-based (managed by a token which was passed between users). In practice, however, groups found these control methods difficult to manage, opting instead to use interactions which required sharing control of the tabletop's group space.

6.2.1 Token-based control method

In the token-based control condition, the median number of times the token was used by a group to pass control of the shared play area was 2 (Minimum: 0, Maximum: 11), compared with an average[14] of 35

[14] Mean number of turns taken by the first three groups

turns taken during this condition. Figure 24 depicts the number of uses of the control token over time for the average game. Not only do players use the control token much less than would be expected if they were passing it back and forth between each turn, but even this slight use of the control token declined over time, presumably as players decided that its benefits did not outweigh its cost.

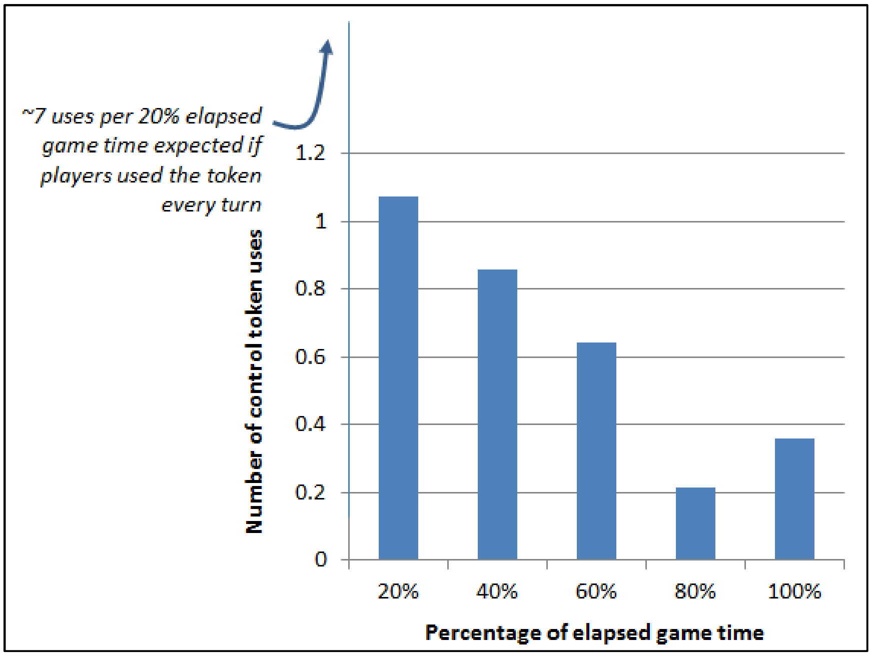

Figure 24: Histogram – Control token use during in each fifth of the game's duration

As the control token was so frequently forgotten in the times when it was used, players would often attempt to interact with spaces that were still controlled by their partner, inadvertently dropping cards that their partner had picked from their Player Area and requiring a pause in gameplay as players tried to determine what and where cards had been unexpectedly moved (Figure 25).

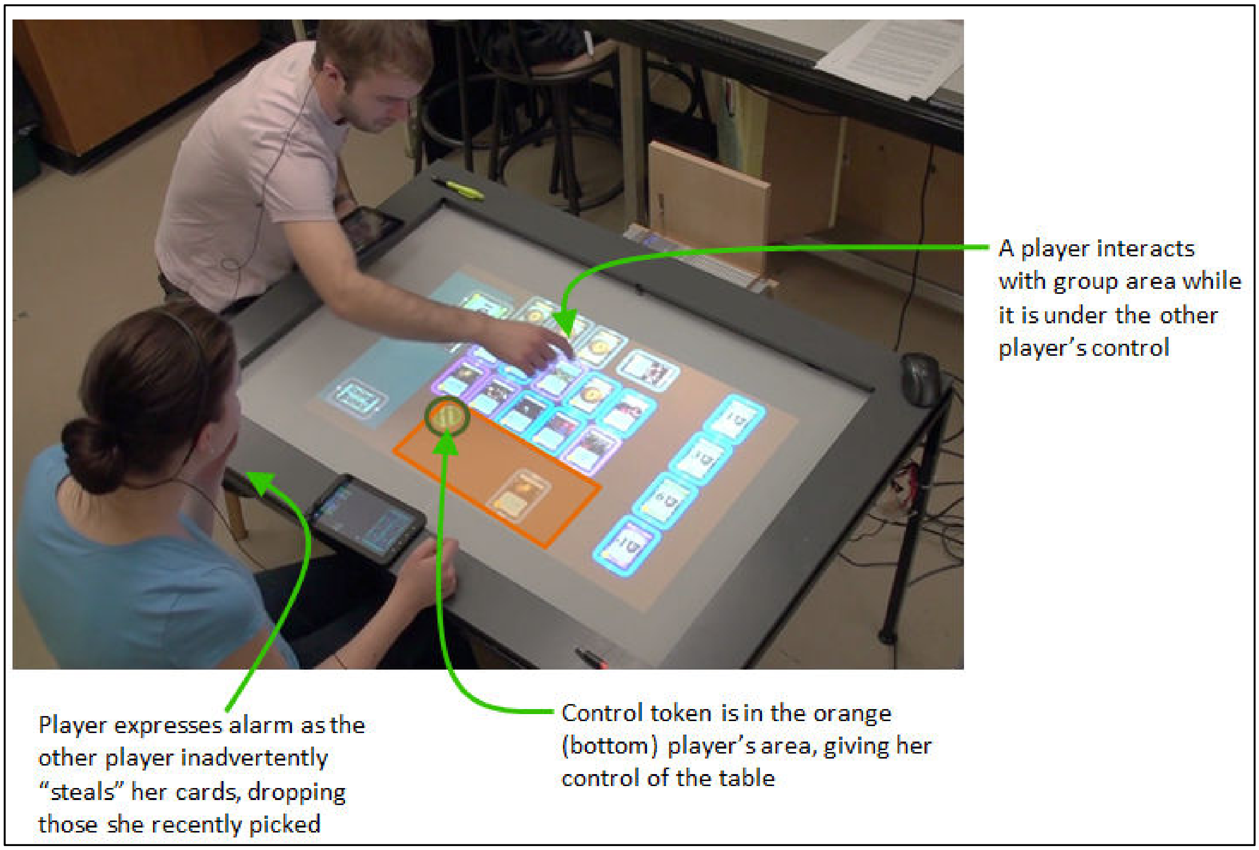

Figure 25: A player interacts with the group space while it is under his opponent's control, leading to confusion

6.2.2 Dynamic control method

The dynamic control method was similarly underutilized. Despite its inclusion in the pre-condition system demonstration, no players attempted to make use of intended method of activating the dynamic control method (i.e. leaning forward to rest the hand which holds the tablet in the Play Area, while interacting with the rest of the table using the dominant hand). While the reason for this was never explicitly stated by players, it may be attributable to a fear that loosely resting a hand in the Play Area might cause cards to be unintentionally repositioned.

Instead, some players attempted to make use of the dynamic control method using more subtle two-handed gestures—setting the tablet aside, placing one hand in the play area (to assume control of the shared space), and using the other hand to Pick or Drop as desired. However, this strategy suffered from two common problems. First, players would experience a frustrating "false-start", starting the pick portion of the Pick-and-Drop action before realizing that they had forgotten to first assume control of the shared space. Since touching the player area to assume control at that point would unintentionally drop the picked cards into the play area, the player would have to drop the cards back onto the tablet, and then assume control by touching the player area, and then re-pick the cards from the tablet before proceeding with the originally intended object transfer. Secondly, players would attempt Adapted Pick-and-Drop interactions in the shared space simultaneously, without monitoring the result. The dynamic control method assigns control on a first-come, first-served basis, meaning that in this case both players' interaction with the shared area would be attributed to only one of the two players. This might result in cards being dropped in the wrong location, and would leave the second player's cards un-dropped in-transit. This type of error often went undetected until players realized that cards were missing, creating confusion and mistrust in the system.

6.2.3 Control methods for "read only" interactions

Interestingly, while players in both control conditions tended to avoid the use of the control methods to support Pick and Drop interactions with cards, players did make frequent use of the control methods to support card browsing. (Recall that when a user touches a card in a space that he controls, a large-size image of that card is displayed on his tablet), most commonly in the dynamic control condition. Figure 26 shows a participant (top-left) performing a commonly-used card browsing strategy: setting her tablet down on the table's edge, she briefly touches her play area with one hand while taping the card which she desires to view with the other. Since she only maintains control of the table for less than two seconds, the likelihood of this action overlapping temporally with the other player's attempts to control the table are low. Furthermore, since this action does not meaningfully change the state of any of the cards in-play, the consequences of errors are low (eg. on occasions when both players attempt to apply this strategy at the same time). One of the two players will be forced to wait until the other player's control is released, but no cards are moved (and thus misplaced).

Figure 26: A participant (top-left) actively triggers the dynamic control method to preview a card

6.2.4 No-control method

Since neither control method was usefully adopted by participants in the two Pick-and-Drop conditions, these control methods effectively functioned similarly to the "No Control" configuration used by the Bridges condition. Thus, for the remainder of the analysis presented in this section we will differentiate conditions based on interaction style alone (i.e. Adapted Pick-and-Drop vs. Bridges).

6.3 Qualitative investigation of Adapted Pick-and-Drop vs. Bridges

The qualitative analysis followed an open coding method adapted from grounded theory (Cresswell, 2008). Beginning with a set of sensitizing themes—namely enjoyment, awareness, and effort—video recordings of the sessions were reviewed, building and refining a set of video codes. These codes identified events including:

- Physical interactions (e.g. a player transfers a stack of cards together, then spreads them out on the table)
- Communication (e.g. one player asks another to verbally recount their turn)

- Instances of evident confusion or frustration (e.g. a player asks another to explain his action, players misplace cards and need to pause play to locate them)

The first 9 hours of video were coded (spanning groups 1, 2, 4, and 5[15]), continuing until no new behaviours could be identified. Data from field notes (spanning all 14 groups) were used to supplement this exercise.

One of the primary themes observed in these data was that there was no one way in which a given transfer method enabled participants to perform the activities required by the game. Furthermore, the tone of each game appeared to be very different. Some players were very communicative, while some were nearly silent; some players took turns rapidly, some slowly; some players insisted that the game rules be rigorously observed, while others redefined the game's rules when it suited both players.

Figure 27: Two players share a single tablet while discussing its contents

[15] Group 3 omitted from this exercise due to technical issues

Figure 28: These participants opt to play "open-handed", revealing all their cards to one another

In order to investigate and understand these differences further, a set of interaction strategy diagrams were constructed, providing a means to document and compare the interaction strategies adopted by players during each phase of the task. This process and these diagrams will be described further below. To set the context for this effort, some additional task information is first provided about the *Dominion* game.

6.3.1 Organizing interaction strategies

A turn in *Dominion* is divided into four phases, described here as a set of actions to be performed:

Draw: The player moves a *group* of five cards from the *digital table to the tablet*. The cards' contents should be visible to the player, but not their partner. This is a fairly mechanical phase, with no strategic choice being offered.

Action: The player selects and moves a *sequence* of cards from the *tablet to the digital table*. Based on the content of these cards (some of which offer the player a choice of outcomes) and the order in which they are revealed, *additional cards may be moved between the digital table and tablet*. This phase of the turn is typically the longest and most mentally demanding, requiring the player to select the most advantageous sequence from among many possible options. During this phase, the opponent *monitors* the active player's revealed cards to inform their future strategy.

Buy: Calculating a score using all cards remaining on the tablet and those used during the previous phase, the player may move *one or more* cards from the *group space to their personal space on the digital table*. As before, the opposing player *monitors* the active player's actions.

Cleanup: All cards involved in the previous phases are moved ("discarded") to the player's discard pile, located in the player's personal area. Like the Draw phase, no choice is given to the player, although any cards which were drawn but not revealed may remain hidden as they are discarded.

For each of these phases in each of the transfer conditions, all unique strategies for performing the actions listed above were examined. Since each phase in *Dominion* must be completed before moving to the next, these phases provided a useful scaffold for identifying each interaction strategy employed by players.

6.3.2 Evaluating interaction strategies

Each of these interaction strategies has its own strengths and weaknesses. For example, in the Bridges condition, all players opted to fulfil the needs of the Draw phase in one of two ways:

1. The player individually moves five cards to their Bridge on the digital table, leaving the cards half-visible on each device. (Figure 29, left)
2. The player individually moves five cards to their Bridge on the digital table. The player then moves these five cards from the Bridge on the tablet to the larger Hand area on the tablet. (Figure 29, right)

Figure 29: A player's mobile device, as seen after each Bridges Draw method.

In this case, the first Draw method described above requires little physical effort (only one touch per card), while the second method is more work-intensive, requiring one touch per card on each device (thus two touches per card). However, while the first method leaves cards in a miniature, half-visible state on the tablet (often requiring expert knowledge in order to recognize and make use of them), the second method leaves cards in a large, easy-to-read state (making it much more usable to novice players).

For each interaction strategy in each phase of the game, a flow diagram, adapted from Holtzblatt and Beyer's Contextual Design (Beyer & Holtzblatt, 1997), was produced. Each flow model identifies the key *individuals* (as rounded rectangles), *places* (as rectangles), *responsibilities* (as annotations on individuals and places), *object or information flow* (as bordered or borderless rectangles on arrows, respectively), and *breakdowns* (annotated "lightning bolts") for a given interaction strategy. Figure 30 is one such model for the first Bridges Draw interaction strategy described above, and Figure 31 describes the second of the two Bridges Draw interaction strategies.

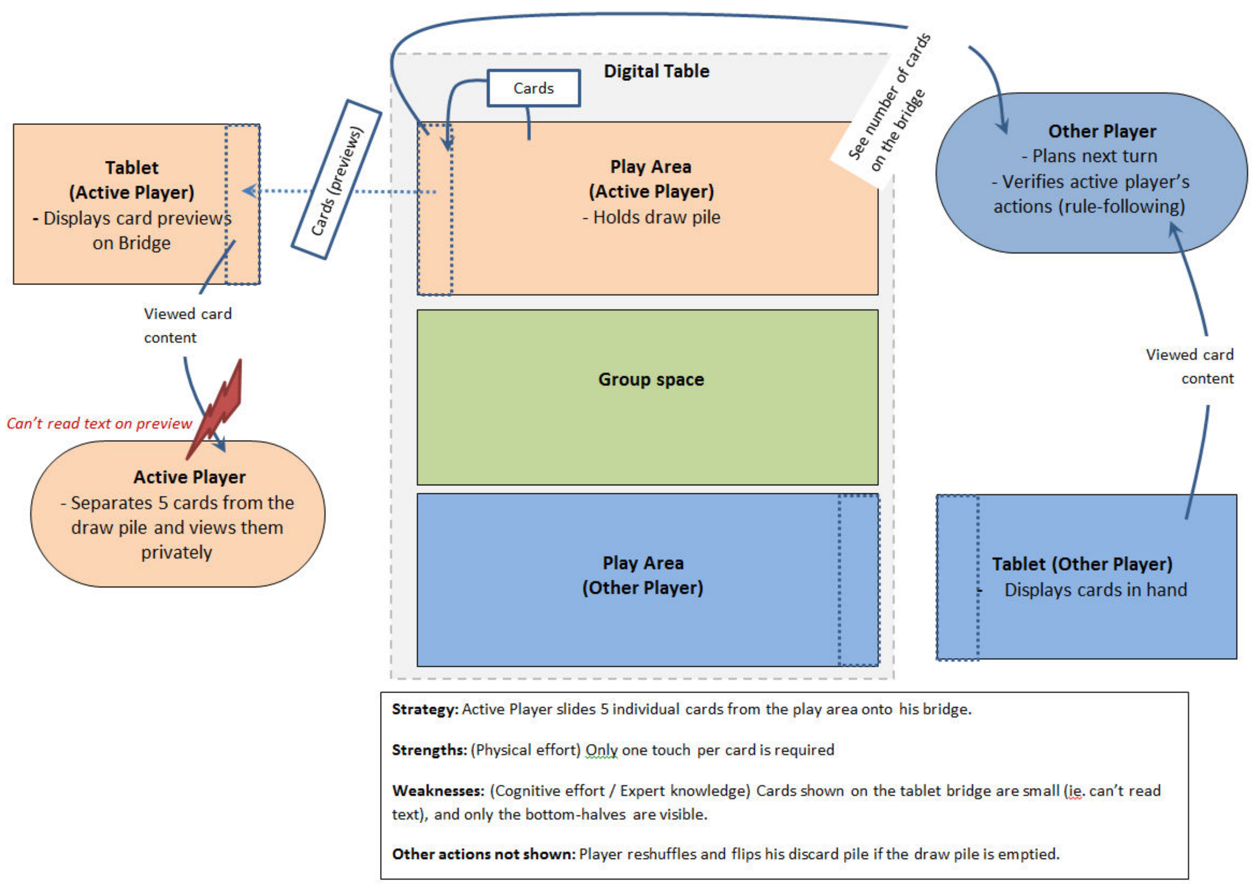

Figure 30: Interaction strategy diagram 1 (The player individually moves five cards to their Bridge on the digital table, leaving the cards half-visible on each device)

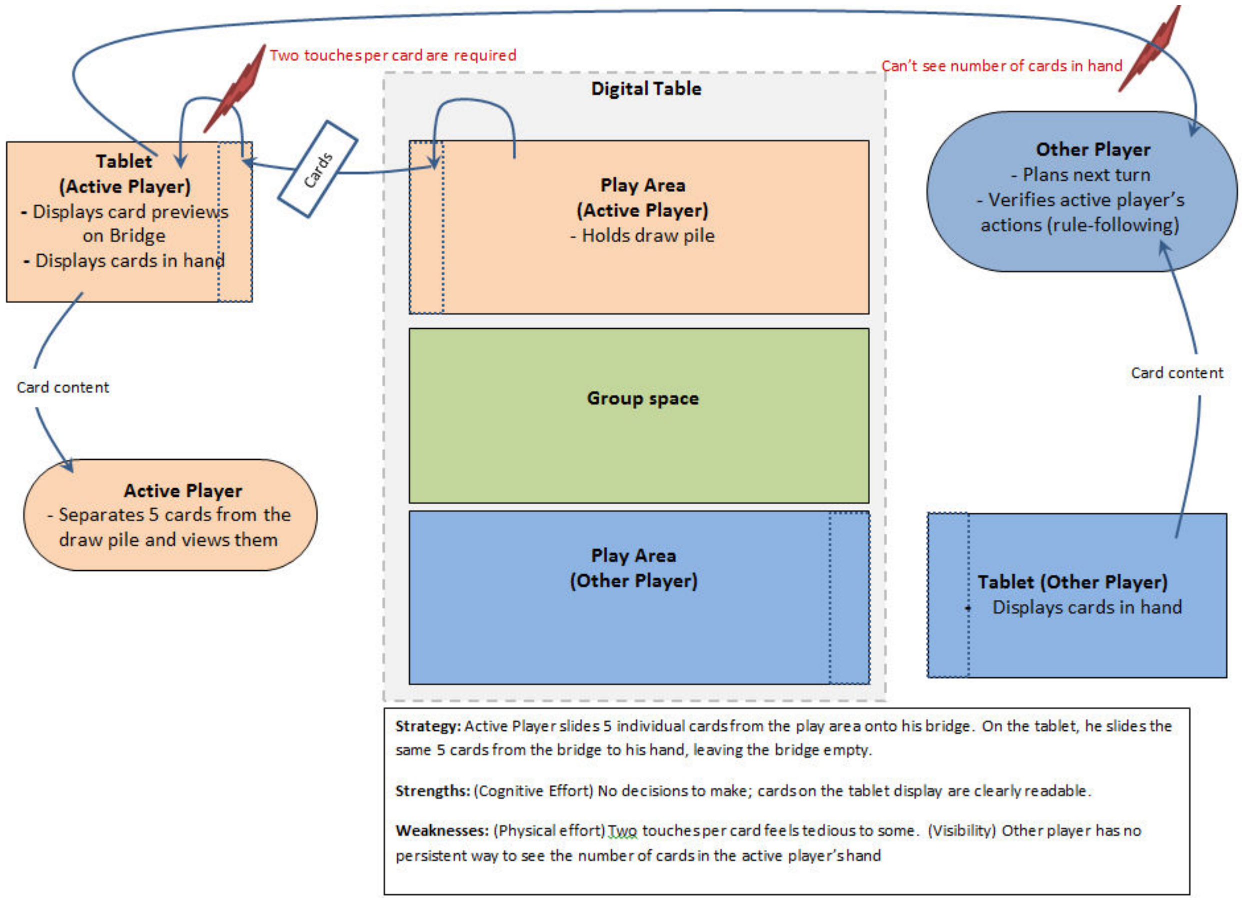

Figure 31: Interaction strategy diagram 2 (The player individually moves five cards to their Bridge on the digital table. The player then moves these five cards from the Bridge on the tablet to the larger Hand area on the tablet)

Thus, for each phase, an interaction strategy chosen by a player (including its strengths and weaknesses) can be easily compared to the other strategies which fulfill the needs of the same phase. As players were free to pursue interaction strategies that best aligned with their desires, we may examine the interaction strategies which they adopted in order to make inferences regarding players' priorities in the *Dominion* task.

The full set of interaction strategy diagrams produced may be found in Appendix C.

6.3.3 Interdependency of interaction strategies

Different interaction methods often left the system in slightly different end states, as illustrated in Figure 29, and these end states served to constrain the set of interaction methods available to the player for the next phase. For instance, in the same example, when planning which sequence of cards to choose in the

Action phase, some players who had left their cards on the Bridge leveraged the empty Hand space as an analysis workspace—placing subsets of cards from the Bridge side-by-side to compare in detail. Players who had moved all of their cards into the Hand space during the Draw phase, in contrast, often used their now-empty Bridge as a staging ground, moving cards to it one-by-one as they decided what sequence of cards to use.

The tendency for the set of available interaction strategies to be constrained by those employed during previous phases is an important consideration when comparing transfer mechanisms. This is because choosing a desirable interaction strategy early in a workflow (e.g. a turn in *Dominion)* might constrain the user to a set of less desirable strategies later in the workflow. In this way, it is important to consider interaction strategies not only in isolation, but also in relation to one another.

6.3.4 Summary of interaction strategies

In total, 28 key interaction strategies were identified, categorized by transfer method and game phase, and their strengths and opportunities for breakdown identified. Table 2 summarizes these interaction strategies.

Table 2: Summary of interaction strategies. Flow models for each (numbered as below) may be found in Appendix C.

	Draw	Action	Buy	Cleanup
Adapted Pick-and-Drop	**1.** Active player Picks 5 cards from the draw deck and touches the tablet to drop them into his hand.	**4.** Active player looks at the cards available in his hand, then chooses a series of one or more action cards to play, moving each to the table via pick and drop action.	**10.** Active player assesses the treasure cards on the tablet and the action cards on the table, calculates a treasure value, selects and moves purchase card(s) to player area.	**26**. Active player moves
			11. Active player picks treasure cards from the tablet and drops them into the play area.	
			12. Active player picks treasure cards from the tablet and drops them into the play area. Player then spreads out the group of cards.	
Bridges	**2.** Active Player slides 5 individual cards from the play area onto his bridge. On the tablet, he slides the same 5 cards from the bridge to his hand, leaving the bridge empty.	**5.** Active player looks at the cards available in his hand, then chooses a series of one or more action cards to play, sliding these to the bridge one by one.	**13.** Active player recalls the action cards played in the previous phase, and together with the treasure cards on the tablet, calculates a treasure value. He then chooses his purchase card(s).	**27**. Active player moves any unplayed cards on the tablet to the bridge. All cards on the bridge are then moved to the player's discard pile.
			14. Active player recalls the action cards played in the previous phase, and together with the treasure cards on the tablet (which he slides onto the bridge), calculates a treasure value. He then chooses his purchase card(s).	
		6. Active player looks at the cards available in his hand, then chooses a series of one or more action cards to play, sliding these to the bridge one by one. On the tabletop, the cards are moved from the bridge and lined up in a spatially-meaningfully way (dependent on player's preference and card text).	**15.** Active player assesses (or recalls) the action cards played in the previous phase, and together with the treasure cards on the tablet, calculates a treasure value. He then chooses his purchase card(s).	
			16. Active player assesses (or recalls) the action cards played in the previous phase, and together with the treasure cards on the tablet (which he slides from the tablet to the bridge), calculates a treasure value. He then chooses his purchase card(s).	
			17. Active player assesses (or recalls) the action cards played in the previous phase, and together with the treasure cards on the tablet (which he slides from tablet to bridge, and from bridge to table), calculates a treasure value. He then chooses his purchase card(s).	
	3. Active Player slides 5 individual cards from the play area onto his bridge	**7.** Active player looks at the cards available in his hand (via bridge), then chooses a series of one or more action cards to play, touching and releasing them on the tablet to cause them to flip face-up on the table. Active player then moves the cards from the bridge into the play area.	**18.** Active player looks at the bridge to see any available treasure cards and at the table to see previously-played action cards, calculates a treasure value, then selects and drags a purchase card to his play area.	**28**. Active player moves any unplayed cards from the bridge to the discard pile
			19. Active player moves all treasure cards to his hand on the tablet, and together with the previously-played action cards (left on the bridge) calculates a treasure value. Active player then selects and drags a purchase card to his play area.	
		8. Active player looks at the cards available in his hand (via previews on bridge), then chooses a series of one or more action cards to play, dragging each face-down from the tabletop bridge and flipping them over using the pie menu.	**20.** Active player moves all treasure cards to his hand on the tablet, and together with the previously-played action cards (left on the bridge) calculates a treasure value, and then moves the cards back to the bridge. Active player then selects and drags a purchase card to his play area.	
			21. Active player moves all treasure cards to his hand on the tablet, and together with the previously-played action cards (left on the bridge) calculates a treasure value, and then moves the cards back to the table play area via the bridge. Active player then selects and drags a purchase card to play area.	
		9. Active player looks at the cards available in his hand (via previews on bridge), then chooses a series of one or more action cards to play, touching and releasing them to cause the tablet to flip them face-up on the table.	**22.** Active player looks at the bridge to see any previously-played action cards or available treasure cards, calculates a treasure value, then selects and drags a purchase card to his play area.	
			23. Active player moves all treasure cards to his hand on the tablet, and together with the previously-played action cards (visible on the table) calculates a treasure value. Active player then selects and drags a purchase card to his play area.	
			24. Active player moves all treasure cards to his hand on the tablet, and together with the previously-played action cards (visible on the table) calculates a treasure value, and then moves them back to the bridge. Active player then selects and drags a purchase card to his play area.	
			25. Active player moves all treasure cards to his hand on the tablet, and together with the previously-played action cards (left on the bridge) calculates a treasure value, and then moves the cards back to the table play area via the bridge. Active player then selects and drags a purchase card to play area.	

6.3.5 Qualitative comparison of Adapted Pick and Drop vs Bridges

Having thus developed a scaffold to contextualize participants' behaviours and statements with regard to the objectives pursued by the player during the time at which the actions were observed, the interaction strategies facilitated by the two transfer methods could be more finely compared. By extension, the attributes of each transfer mechanism which players found helpful or problematic could also be better identified. These attributes can be summarized primarily on the following themes.

6.3.5.1 Cognitive effort

Players often described the Adapted Pick-and-Drop interaction as requiring more cognitive effort than Bridges. As one player reported in the post-condition questionnaire, "…not seeing cards that are [in my hand] while picking up confused me a couple of times," and another, "it took a while to get used to." In Adapted Pick-and-Drop, the burden of keeping track of how many cards had been picked was placed upon the user. This led to two areas of difficulty. First, users felt that they needed to take care to attend to each pick as it was initiated. If the pick animation was missed or occluded from view, then the user (especially in their first few interactions) would be uncertain of how many cards had been picked. Second, after a card or group of cards had been picked, if the user became distracted (e.g. by conversation with their partner) then he sometimes forgot that the system had been placed into this mode. Then, touching the digital table or tablet, the sudden appearance of dropped cards could be surprising.

In contrast, the Bridges transfer mechanism required very little thought to understand its operation. By design, the Bridges method has no modes; it can only function in one way, and it never hides from the user the state of any object involved in the transfer. Since players were required to physically move each card onto the Bridge (compared to Adapted Pick-and-Drop's button-initiated pick), the transfer felt far more explicit; players were never unsure if an attempted transfer was successful or how many cards had been moved. As a result, participants frequently commented that Bridges was the "easier", "more natural" and "more intuitive" of the two transfer mechanisms. Bridges made it "easier to keep track of cards", and its simplicity was, as one player declared, "beautiful".

6.3.5.2 Physical effort

While it was the more difficult of the two transfer mechanisms, Pick-and-Drop also seemed the fastest. When interacting with the tablet and Player Area, Pick-and-Drop allowed users to move cards from their initial locations directly to their intended destination. Bridges, alternatively, required that all cards travel across the table to pass through the Bridge, an artificial bottleneck. When managing many cards, this “extra step” imposed by Bridges was seen by players as an increasingly tedious obstacle. As one player commented after the Bridges condition, “Not having the ability to drop a bunch of [cards from my hand] at an area added so much more effort. The [Bridge] was super annoying. There is no reason for cards to go from hand to play [like that] – it just added more [touches] to the game.”

It should be noted, however, that not all players agreed that the speed offered by Adapted Pick-and-Drop produced an advantage for their play of *Dominion*. The retail *Dominion* cards’ paper format imposes restrictions on the speed at which they can be physically manipulated, and Bridge’s interaction was slowed by the bottleneck described above. In the absence of these limitations which may impose a more deliberate, thoughtful pace, one participant reported “a strong tendency to move forward without thinking”.

6.3.5.3 Flexibility

In a task like *Dominion,* objects are transferred between devices for a variety of reasons: cards might be moved to the digital table to be discarded, to be displayed to an opponent, to be arranged with others as a mechanism for supporting external cognition, to be hidden away discreetly, and others. In each of these actions, the intended end state of the card is a little bit different. The card may be face-up or face-down, close to one player or the other, or on top of a deck or separate. One of Adapted Pick-and-Drop’s key advantages is its ability to leverage a touch’s context: factors such as the location of the touch or the number and state of the cards already present that that location. In our implementation of *Dominion*, we leveraged this contextual information to determine whether to place a card face-up or face-down—a level of control which the Bridges condition’s simple design could not offer, being unable to judge the player’s intent for the cards at the time of the transfer. Many players commented upon this—appreciating that Adapted Pick-and-Drop offered “a lot of flexibility with regard to how cards are played.” In another player’s words, “with [Adapted Pick-and-Drop], it is possible to play in exactly the same manner as with cards, and so it is more true to the game rules than any other computer implementation [that I’ve seen].”

While not as flexible in the terms outlined above, many players did find ways to repurpose Bridges’ rigid design in other ways. Put another way: rather than the transfer mechanism adapting to the intents of the user, many users chose to adapt their play style to the capabilities of the transfer mechanism. One common way in which this was accomplished was previously illustrated in Figure 8. Rather than fully transferring a set of cards from the digital table to the tablet during the Draw phase, players chose to leave their cards on the Bridge, displaying only a small preview on the tablet. Effectively, the Bridge became an additional container, with the cards it contained (those left in this "half-transferred" state) remaining readily available for use on either the tablet or the digital table, as suited the user's needs.

6.3.5.4 Privacy and secrecy

It was mentioned previously that Bridges is less context-aware than is Adapted Pick-and-Drop, and as a result (and in order to keep the tablet interface simple), Bridges applies a default behaviour: all objects transferred between the tablet and the digital table arrive face-up. The consequence of this is that the content of *every* card moved from a player's tablet to the digital table could be seen by an observant opponent (a circumstance that is often—though not always—the case in the physical version of *Dominion*). Additionally, whereas Adapted Pick-and-Drop interactions can be initiated and completed from almost anywhere on the play surfaces, transfers using Bridges are confined to the areas immediately in front of each player. As a result, it is far more obvious to a player in the Bridges condition whenever their opponent is transferring objects between devices than to the same player in an Adapted Pick-and-Drop condition; the player need only notice *where* their opponent is interacting rather than *what* he is doing at that location.

Stemming from these two factors, players frequently commented on a feeling that Bridges offered them far more awareness of their opponents' actions while Adapted Pick-and-Drop interactions seemed more private, although reactions to these feelings were mixed. Many players valued this disclosure, one commenting that "[Bridges] allowed you to show what you were doing much more easily", or that "not being able to see what my opponent was doing [in the Adapted Pick-and-Drop condition] was unnerving." Conversely, some of the more competitive players were annoyed by Bridges' openness, going so far as to leave cards half-transferred and face-down on their Bridge (to avoid revealing them when transferring them back from tablet to digital table), using only the small preview of the card on their tablet to plan their turn.

6.4 Chapter Summary

A mixed-methods observational study was performed, examining groups' play of the Dominion tabletop and tablet system in each of three object transfer conditions: Adapted Pick-and-Drop with the dynamic territory control method, Adapted Pick-and-Drop with the token-based territory control method, and Bridges with no territory control method. No significant differences were detected among the quantitative measures used. Leveraging a work modelling technique adapted from Contextual Design, subsequent qualitative analyses examined the many varying interaction strategies which players developed and adopted depending on their personal interpretation of the *Dominion* game. Based on this analysis, a qualitative comparison between Adapted Pick-and-Drop and Bridges was offered along dimensions such as physical and cognitive effort, flexibility, and privacy/secrecy.

Chapter 7
Discussion

The following section moves beyond a direct comparison of Pick-and-Drop and Bridges, offering lessons-learned and principles for the design and research of future cross-device transfer mechanisms. It begins with a discussion of the users' role in defining the objectives in a task like the game of *Dominion.* Following this, design considerations for the design of future cross-device transfer methods and territory control methods are offered. A reflection on experimental design for gaming domain research is offered as well. Finally, limitations of the research are discussed.

7.1 Players (not just the task) define interaction requirements

By applying an understanding of the rules of *Dominion* and the differences between our implementations of Pick-and-Drop and Bridges as outlined above, one might think that one of them could readily be identified as the more suitable interaction technique for digital tabletop *Dominion* task. This is far from the reality, however. In fact, while the majority of participants voiced a preference between the two transfer mechanisms (20 out of 28), these preferences were divided fairly evenly between the two (8 for Adapted Pick-and-Drop and 12 for Bridges).

As a recreational game, players of *Dominion* seek to maximize their enjoyment of the activity, but what offers this enjoyment is different between groups or individuals, and even an individual's preferences can change from one moment to the next. Competitive groups might rigidly follow the rules, demanding secrecy or disclosure (e.g. by explicitly fanning out cards as proof of a legal action) where each is required, while more casual groups may permit more disclosure (e.g. by playing "open-hand" with all cards face-up on the table), sacrificing strategic advantage for comfort and ease. Advanced players, easily recognizing cards by their artwork alone, can take turns rapidly, moving large volumes of cards quickly with minimal additional effort put into communication (e.g. by "narrating" their turns to keep their partner informed of its progress) with similarly-experienced partners. If one player is clearly winning a round, players may begin speeding up their play to move on to the next round. Within a single round, a player can transition from meticulously informing their partner of their every action to taking their turn almost in parallel with their partner, communicating nothing verbally, as the pace and intensity of the game increases.

Dominion, like many tasks within the gaming domain and beyond, is a task whose goal is defined not only by those who authored its rules but also by those who perform it. The different interaction strategies employed by participants in our study were not simply different routes leading to the same goal, such as different approaches to solving a mathematical problem, but rather, each group felt free to reinterpret the rules of *Dominion* and the use of the tabletop system in slightly different ways in pursuit of their own continuously renegotiated definition of "a good game"—whether competitive or casual, exciting or relaxing. The challenge for designers of systems which support such tasks, then, is to provide interaction techniques which offer this degree of flexibility.

7.2 Lessons-learned for territory control mechanisms

As discussed earlier, groups did not make effective use of the dynamic or token-based territory control methods, with many players opting not to use these at all. A key reason for this lack of adoption may be that the control methods' use was, in practice, something that required a shift of attention from the desired outcome of an interaction (e.g. moving cards) to a technological construct (e.g. changing territory control). (Recall Figure 1, which depicted conceptual importance of allowing a player to focus on the *result* rather than the *process*). While the dynamic control method was designed to leverage the act of leaning forward into the player area to signal (both socially and programmatically) the player's intent to interact in the group space, in practice this interaction did not appear to be natural to (or desired by) the players. Instead, the players in this condition had to be explicitly "turned on" by setting down the tablet, touching the player area with one hand, and then performing the desired interaction with the other hand. Similarly, the token-based control method could have leveraged the natural turn-taking that occurs as part of the task, but players did not feel that passing the token back and forth between turns was important. As a result, both of these control methods effectively required that, in order to pick or drop objects in the group space, an additional, seemingly arbitrary action needed to be added *before* the pick or drop was initiated. As reported in Section 6.2, players frequently forgot to perform this action; the resulting failure of the pick or drop surprised or frustrated them, and then further attempts to perform pick and drop interactions in the group space were abandoned.

The lesson taken from this experience is that a territory control interaction should not require the user to disrupt the direct path between intent and action. As an example drawn from the *Dominion* system, if the player desires to pick a card from a shared space, the *first step* in the process must be one which the player readily associates with picking the card—touching the card, opening its menu, etc. Control could be inferred from the interaction (e.g. if a player initiates a Pick from a tablet, the system automatically assigns control of the group space to the player in player to receive the drop), or it might be determined after the fact (e.g. when the interaction cannot be programmatically associated with a player, the player could intervene to resolve the ambiguity, such as by menu option), or else the player must already have control of the required space through some other means.

Interestingly, there was one instance when territory control (specifically, the dynamic control method, which assigned control whenever a player was in contact with her player area) was consistently effective. Players frequently and positively commented on the ability to use dynamic control to trigger card previews on their tablet. It is believed that the success of dynamic control for this purpose, in contrast to its use for Pick and Drop as described above, can be attributed to three factors. First, the act of "previewing" a card (i.e. touching a card on one surface to cause it to be temporarily duplicated on another) is digital interaction that is not strongly analogous, at least mechanically, to a familiar physical interaction. Players, then, might see the need to claim control over the shared space as a reasonable first step in this newly-learned activity, rather than an arbitrary addition to a well-established interaction. Second, the duration of the control was minimal. Players tended to claim control just long enough to tap a card to trigger the preview, and this limited the opportunity for multiple players' attempts to take control to conflict. Finally, even when conflicts did occur, the consequences were minimal. Since no objects were transferred during preview actions (i.e. the game state was not changed), there was little disruption caused by one player, for example, touching the group space while it was under another player's control. These finding suggest that territory control methods may be best applied to new interactions not having clear physical analogs, when the duration of control is minimal, and when consequences of error are low (such as when the interaction causes no objects to be moved). An opportunity exists to explore this further in future research.

7.3 Design considerations for cross-device transfer

In the comparison of Adapted Pick-and-Drop and Bridges in the previous chapter, the data analyses showed that players' behaviour and comments were divided between these techniques in four key areas. To design a more widely-accepted transfer mechanism, the following four design considerations are offered.

7.3.1 Feedback is essential

While many participants liked the power of the Pick-and-Drop interaction, none liked that it caused cards to disappear from view when picked. Bridges' design, in contrast, showed players exactly where each card was at all times. The design principle that we draw from this experience is clear: during transfer—objects should be visible (at least to their owner) at *every* stage in the process.

7.3.2 Leverage context

Whenever possible, leverage context around the transfer interaction to define the resulting location, orientation, or other properties of the transferred object(s). This context might include the transferring touch or gesture's absolute location, its location relative to existing objects, and properties of those objects (such as their orientation or content). For example, in the *Dominion* system, cards dropped onto a deck determined their facing based on that of the top card in the deck. This removed the need to tediously flip cards when performing common actions, as well as eliminating the undesirable possibility of mixing cards of differing facing within the same deck. By leveraging context, a transfer interaction can be made to appropriately predict its initiator's intent, reducing or eliminating the number of actions required to adjust the transferred object(s) upon their arrival.

7.3.3 Appropriate disclosure during object transfer

Both the physical performance of a transfer action (i.e. where and how one moves their body to induce digital objects to move between displays) and the representation of the transferred object(s) before, during, and after the transfer communicate information to other users of the system. Disclosure from either or both of these sources may be desirable (e.g. providing cues to increase others' awareness of how a task is progressing, such as a *Dominion* player transferring several cards from a Bridge at the end of his turn) or it may be undesirable (e.g. revealing private information to an opponent, such as a Bridge revealing the content of all cards transferred). The design of the transfer action should restrict disclosure to a level appropriate to the design of the task, but should remain flexible enough that users may be more communicative if desired.

7.4 Reflections on system and experimental design for gaming domain research

7.4.1 Digitally emulating a physical task

While it was not explicitly a criterion for success for our study of cross-device transfer methods, it was satisfying to see strong commonalities between player behaviours in the study and the volitional behaviours practiced by participants in the initial observational research presented in Chapter 3. These behaviours, which include turn narration, browsing actions, players taking turns in parallel, and various forms of "undo-ing" actions, serve as indicators that the digital tabletop interpretation of *Dominion* was able to support realistic gameplay sessions (in their many varieties). Furthermore, in enabling players to pursue their preferred styles of *Dominion* gameplay, the qualitative analyses were greatly enhanced, allowing a comparison of the Adapted Pick-and-Drop and Bridge transfer methods along the dimensions which were seen to be most important to the players—the ultimate users of the system and the transfer mechanisms which support it.

There were some features of the system design which fell short of capturing the breadth of interactions which the physical *Dominion*'s cards support. The most common comment in this respect was that the system supported only very precise interactions with cards. Gross or macro-gestures (such as using one's open hand to sweep a large number of objects to the side, clearing a workspace) were not supported. While a physical deck of cards could be easily spread or fanned out to search for a specific card, our tabletop implementation required players to remove cards from a deck one-by-one in order to search for a card it contained. Finally, there is little support in the system for partial-overlapping of cards—when in a deck, cards can only be stacked perfectly atop one another, while physical cards more readily supports grouping related cards by partially overlapping each other.

Finally, while the flexibility offered by a "physical" interpretation of the *Dominion* game (e.g. as opposed to a rule-enforced "video game" interpretation) was advantageous to this research, it is important to note that this does not mean that an ideal digital tabletop conversion of the game would exactly emulate the interactions supported by the physical game. Rather, digital tabletops and tablets provide opportunities to expand upon the flexibility of physical objects. Five participants in our study commented that they felt the play area to be restrictively small in area. Opportunity exists to explore relaxing such spatial constrains in this domain by introducing resizable or scalable containers, as have been explored in previous digital tabletop computing literature (Scott et al., 2003).

7.4.2 Experimental measures

As discussed in Chapter 6, many of the quantitative measures applied in the study were insufficiently sensitive to detect significant differences between conditions. In the course of performing the study, it was observed that many domain-specific factors influenced participants' responses, in addition to condition. For example, enjoyment was complicated with personal preference for the set of cards which was used in the game, whether the players were evenly-matched in performance, and how effectively the players were able to interact with the tabletop hardware. Further studies may actually benefit from using novice *Dominion* players who would not have these established biases. Furthermore, one's awareness of an opponent's actions is influenced not just by the actions that are observed, but by their understanding of how an opponent might form a strategy based on the available play options. Since players' and groups' play objectives can be so different in this domain, future studies may further benefit by the addition of a post-experiment questionnaire and interview, at which time information about users' specific preferences and goals could be elicited.

7.5 Limitations of the user study

As in any research of this kind, the system development and execution of the study imposed certain limitations, most notably in the effectiveness of the digital tabletop's touch recognition and the method used to pair the tablet and tabletop computers.

7.5.1 Tabletop touch recognition

The laser light plane (LLP) digital tabletop computer used in this study introduced a number of interaction challenges related to the sensitivity of its touch recognition.

First, at the extreme edges of the table closest to each of the 8 cardinal and intercardinal directions (i.e. the positions of the table's infrared lasers), touch response was intermittent. This caused, in some cases, cards dragged near these edges to be unexpectedly dropped or have their pie menu opened unintentionally.

Second, the light plane across the table's surface sometimes detected false touches (in addition to the actual point of contact with the table), when other parts of the hand being held close to the table were also detected (as far as ~ 1 cm away in some cases). For some players, this created unexpected touches which resulted in unexpected game actions, detracting from the enjoyment of the experience.

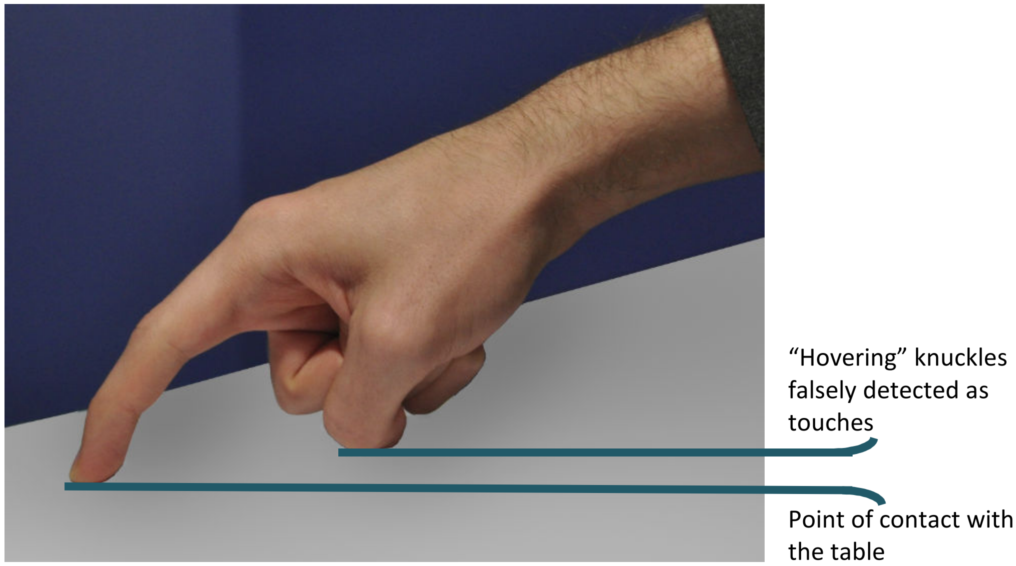

Figure 32: Parts of hand near the surface of the table are sometimes falsely detected as touches

7.5.2 Device pairing

The study focused specifically on the user interaction required to transfer objects between devices, but it is important to consider the larger technical context in which these actions are performed. The tablet computers in the system were pre-configured to be persistently paired (i.e. associated for the purposes of cross-device interaction) with the digital tabletop computer (allowing the players to focus on the object transfer, rather than connecting the devices). However there are tasks and contexts for which this assumption is not always appropriate. For example, consider the context in which a public walk-up-and-use display requires a user to transfer only a single object between the two devices; in this case, the method of device-pairing might more strongly influence which is the best interaction to transfer objects between the two displays. These alternative usage situations warrant further study to better understand the most appropriate cross-device transfer methods.

7.6 Limitations of studying cross-device transfer in the gaming domain

In applying a gaming domain task to the study of cross-device object transfer, it is valuable to consider the ways in which the task choice shapes the results and influences the study's generalizability to other domains.

7.6.1 Competition and other *Dominion* game rules

Dominion's rules encourage groups to structure their activities according to certain guidelines. For example, interaction in *Dominion* is structured around an explicit turn order (although as has been said previously, this order was not rigidly imposed), which tends to de-incentivise (though not eliminate) parallel work. Additionally, the *Dominion* implementation supported two players in direct competition, which naturally had implications regarding factors such as privacy. Cooperative tasks or collaborative tasks in which private information is stored exclusively on a personal device (rather than stacked in face-down piles on the shared surface) may have different privacy requirements of a cross-device transfer method. Finally, in *Dominion* the majority of a player's taskwork takes place in his or her personal area. All players need access to the resources and storage areas located in the group space, but most of the active management of objects (e.g. moving, manipulating, spatially arranging) occurs immediately in front of the player. Figure 33 illustrates this, marking with a line (coloured by player; white if the player could not be determined) every translation action which was applied to a card.

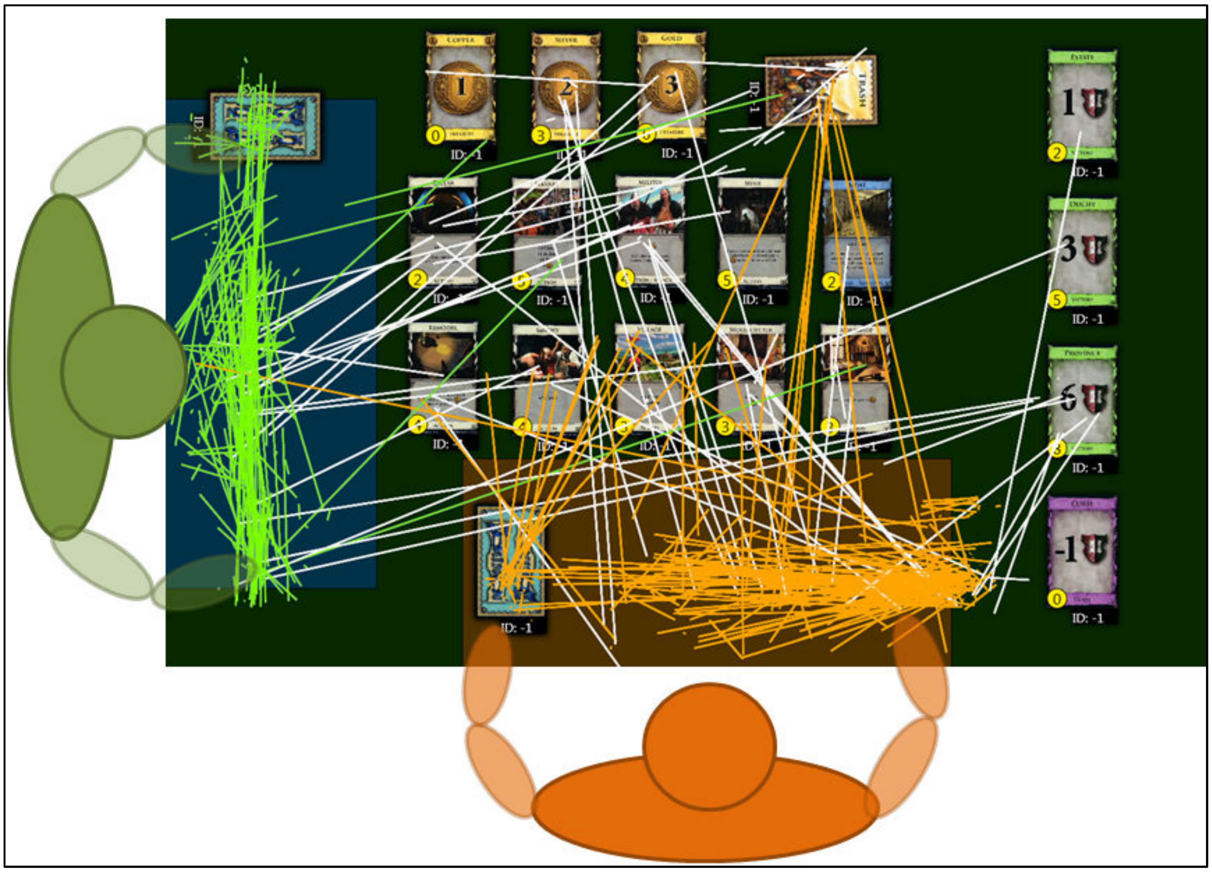

Figure 33: Activity plot (Group 1, Adapted Pick-and-Drop with dynamic control). Lines (coloured by user, where possible) represent card displacement.

Further investigation may be needed to corroborate this thesis' findings for tasks which are strongly cooperative, and which emphasize users working with the same objects simultaneously in a shared group space.

7.6.2 Interactive content within a digital object

Like a physical playing card, the digital cards used in our study used static images. While the interpretation or choice of a card's meaning could be changed by participants, the system did not support modification of its content or interacting with subcomponents within the card's boundary extents (e.g. buttons, text entry, etc). If designing a system that involves cross-device object transfer when the objects themselves support this type of rich interactivity, there would exist another layer of complexity not examined in this study: how to best support interacting with an object as a container, while also supporting how to support interacting with content contained within that object. This interface design situation requires further study to better understand its interaction needs.

7.6.3 Fixed number and location of users

In *Dominion*, as in many tabletop games, players remain in a fixed seating arrangement throughout the task. The digital tabletop implementation of *Dominion* reflected this, constraining players' seats and play areas to fixed positions. Opportunity then exists to explore these cross-device transfer mechanisms without this limitation—with a task design in which users can move dynamically around the table, or by changing their seating order, or even supporting a variable number of participants, as they join or withdraw from the task-in-process.

7.7 Chapter Summary

This chapter discussed broader implications of this research, moving beyond a direct comparison of Adapted Pick-and-Drop and Bridges transfer techniques. As observed during the *Dominion* gameplay sessions, it is seen that tasks like recreational games are often subject to reinterpretation by their players, and it is important for system designers to consider this when developing interaction techniques that must support not only use of the system as-designed but as it might be seen by the many different types of users that it supports. Design considerations for cross-device transfer include providing continuous feedback, leveraging context to add meaning to an interaction, and facilitating an appropriate level of information disclosure during object transfer. Other discussion included lessons-learned for tabletop territory control methods, experimental design in gaming domain research, and limitations of the research presented.

Chapter 8
Conclusions

Digital tabletop computers offer the opportunity to bring computational strength and networked data access to the rich face-to-face context provided by the ubiquitous physical table. However, privacy on this single shared surface is limited. To remedy this, personal interaction surfaces (such as tablet computers) can be coupled with the digital tabletop, yet these in turn require the introduction of powerful, intuitive interactions to support digital object transfer between devices. While cross-device object transfer interactions have been a fairly frequent topic of literature in the collocated groupware domain in the past 10 years, much of this literature focuses on the system design or controlled experimental analysis of the interaction. This thesis was motivated by a desire to adapt these existing object transfer interactions for use in a realistic task using commonly-available technology, and to perform an exploratory observational study of the result.

8.1 Research objectives and summary

Chapter 1 outlined this work's four research objectives, namely: to examine existing methods for bridging private and shared interaction surfaces, to examine the context in which object transfer occurs in realistic physical tasks, to design and develop a system to explore object transfer between private and shared interaction surfaces for a collocated task, and to examine the designed system interactions' effectiveness in supporting a realistic task.

The first objectives was fulfilled by performing a literature review, examining considerations in digital tabletop application design, methods for cross-device object transfer, privacy in collocated systems, and prior art in the domain of digital tabletop games (Chapter 2). This literature review revealed an unaddressed need for the study of object transfer using real-world task and commonly-available equipment. To fulfill the second objective, a small observational investigation of card game play using traditional physical media was conducted (Chapter 3). This informed the design of cross-device transfer methods in the subsequent research, ensuring that the methods could support not only the interactions specified by the rules of the task, but also those which might be desired or expected by its users. To satisfy the third objective, a digital tabletop and tablet implementation of Rio Grande Games' *Dominion* was designed and developed (Chapter 4), informed by the activities performed during the first two objectives, and able to support two different adaptations of existing cross-device transfer interactions. Finally, the fourth objective was satisfied by conducting an observational study of *Dominion* players using the digital tabletop application multiple times: once for each of the transfer methods.

As a result of these activities, the following contributions were made:

- **Introduced and examined two implementations of cross-device object transfer methods, Adapted Pick-and-Drop and Bridges.** Qualitative results of our observational study indicate that, of the two methods, Adapted Pick-and-Drop was more powerful, less physically demanding, and better supported privacy, while Bridges was far easier to understand, and better promoted awareness of players' actions.

- **Methodology for analyzing interaction techniques in user-directed tasks.** As the *Dominion* task was designed in such a way as to give users freedom to shape it according to their interests (e.g. competitive or casual gameplay, flexible rule enforcement, etc.), the effectiveness of traditional measures of taskwork was diminished. Instead, a qualitative analytical approach was devised, identifying and comparing each interaction strategy which players pursued using the tools provided by each experimental condition.

- **Considerations for the design of cross-device transfer methods.** These considerations include: understanding the way in which users are empowered to redefine a task's interaction requirements, providing constant visual feedback during object transfer, leveraging spatial and informational context to make object transfer more powerful, and designing for appropriate disclosure through the visibility of body movement and object content during object transfer.

- **Recommendations for the design of digital tabletop turn-taking "control" methods.** For interactive surfaces which are unable to automatically differentiate its users to support user-specific interaction in shared territories, territory control methods may be used. However, invoking a territory control method must not disrupt the user's path between intent and action. Territory control may also be best applied in situations where the digital interaction has no clear physical analog (and so is a newly-learned interaction rather than one with which the user has previous experience). Occurrences of errors in territory control can be reduced by ensuring that territory control need be maintained only for a brief period of time, and the impact of these errors can also be lessened by employing it only where the interaction causes no state change (e.g. no relocation of digital objects) in the system.

8.2 Future work

This research suggests a number of opportunities for further investigation.

Firstly, it was identified that the dynamic and token-based territory control methods employed in this study were not effectively adopted by players to support object transfer. Alternative territory control methods might be explored in the future, particularly those in which control may be automatically inferred by a player's previous actions (and thus requiring no explicit action to activate), or else may be resolved after-the-fact if an ambiguous interaction is ever performed (e.g. by prompting the user for identification in an unobtrusive way).

Second, an important goal of the study was to explore cross-device object transfer as applied to a realistic case study, in this case a task in the gaming domain. There remains an opportunity to further investigate the generalizability of the results offered by this work by leveraging the same object transfer methods in tasks from different domains, such as collaborative decision- or sense-making tasks. Additionally, since the *Dominion* task closely emulated a task with a familiar physical analog (the physical version of the *Dominion* card game), it would be informative to apply the same transfer interactions to a task without a direct physical analog (e.g. data visualization or interaction with digital video clips).

Finally, the study results revealed that a significant challenge in the use of the Adapted Pick-and-Drop interaction was its cognitive complexity in the absence of persistent visual feedback. Further research might expand upon the design of Adapted Pick-and-Drop by providing this feedback. While placing on the table an indicator of the cards currently picked by the user would begin to alleviate this issue, the general availability of inexpensive vision hardware such as the Microsoft Kinect[16] provide an opportunity for a higher-fidelity solution. By using a vision sensor to track arm movement above the table, automatic user differentiation might be added to the digital tabletop system. Furthermore, a visualization which shows a user's hand holding the off-screen virtual cards might be added (McClelland, Besacier, & Scott, 2012).

[16] http://www.microsoft.com/en-us/kinectforwindows/

Figure 34: Mocked-up design concept of an Adapted Pick and Drop arm shadow. The arm representation follows the movement of the user's arm until the hand's contents are dropped

This visualization, inspired by arm shadows used previously in mixed-presence groupware applications (Coldefy & Louis-dit-Picard, 2007; Wilson & Robbins, 2007), offers an exciting opportunity to explore the Adapted Pick and Drop interaction further, potentially reducing cognitive effort and providing the user with a stronger sense of embodiment in the digital space (Pinelle, D., Gutwin, C., Nacenta, 2008; Tang et al., 2004).

Permissions

Phil McClelland <phil.mcclelland@uwaterloo.ca> Mon, Jan 9, 2012 at 12:57 PM
To: riogames@aol.com

Mr. Tummelson,

My name is Phil McClelland, a Systems Design Engineering graduate student at the University of Waterloo. In my research, I investigate ways to effectively leverage technology to support face-to-face collaboration, and in this pursuit, I've thoroughly enjoyed using boardgames as case studies. As an example, past projects have included adapting GMT Games' *Pax Romana* and Z-Man Games' *Pandemic* for play on a digital tabletop computer in order to lessen the learning curve or explore the effects of automation on collaboration, respectively.

I'm writing to request your consent to use *Dominion* in the next phase of my thesis research. In the work, I would port *Dominion* to one of our digital tabletop computer systems, and run a small user study at our lab, inviting players to play the game and observing their interactions with each other and with the tabletop computer.

It is very important to me to respect Rio Grande Games' property. I would like to make clear that this is strictly academic, non-commercial research. If you are interested in supporting us by permitting us to use original *Dominion* artwork, none of these materials would be transferred, copied, or otherwise redistributed beyond our lab, nor would they be sold or otherwise commercialized. The only exception to this would be, if you consent, the publication of photos of the project in my thesis or other non-commercial academic publication. Furthermore, we would explicitly specify to all participants that our study is not affiliated with Rio Grande Games.

If you have any questions about this or related work please do not hesitate to ask. Additionally, this project is being overseen by my thesis supervisor Dr. Stacey Scott (Assistant Professor, Systems Design Engineering and Associate Director, University of Waterloo Games Institute) and committee member Dr. Neil Randall (Director, University of Waterloo Games Institute). They may be contacted at stacey.scott@uwaterloo.ca and nrandall@uwaterloo.ca, respectively.

Information concerning our work with Z-Man Games' *Pandemic* can be seen at: http://www.nsercsurfnet.org/pmwiki.php?n=SurfNet.ScottGrahamDigitalTabletopBoardGaming

Thanks very much for your time,

Phil McClelland

riogames@aol.com <riogames@aol.com> Mon, Jan 9, 2012 at 1:05 PM
To: phil.mcclelland@uwaterloo.ca

Hi Phil,

That all sounds fine to me - thanks for your interest.

Jay M Tummelson
Rio Grande Games
PO Box 1033
Placitas, NM 87043

Phil McClelland <phil.mcclelland@gmail.com> Sun, Nov 18, 2012 at 7:01 PM
To: Guillaume Besacier <guillaume.besacier@uwaterloo.ca>

Hi Guillaume,

I'm if you'd consent for me to use your stick-figure diagrams from our CHI paper in my thesis.

Cheers,
Phil

Guillaume Besacier <guillaume.besacier@uwaterloo.ca> Mon, Nov 19, 2012 at 12:15 AM
To: Phil McClelland <phil.mcclelland@gmail.com>

Hi Phil,

Sure, no problem.

Guillaume

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Appendix A
Study Material, Preliminary Domain Research (Chapter 3)

University of Waterloo

Information Sheet for Participants

Title of Project: An Observational Study of Communication and Coordination Processes during Board and Video Game Play

Student Investigator: Phillip McClelland

University of Waterloo, Department of Systems Design Engineering

519-884-4567 Ext. 36813

Faculty Supervisors: Prof. Stacey Scott

University of Waterloo, Department of Systems Design Engineering

519-884-4567 Ext. 32236

Prof. Catherine Burns

University of Waterloo, Department of Systems Design Engineering

519-884-4567 Ext. 33903

Summary of the Project:

The overall goal of our research is to understand how the medium over which a group of people play a game influences their communication and coordination practices. While interactions between a single user and computer have been studied for decades, interactions within groups are somewhat more difficult to study; as the number of users increases, the interactions between group members becomes increasingly complex. Understanding of communication process and efficiency in these environments through the observation of real groups of participants playing board and video game can help researchers understand how to study groups working together on a shared task. The information gathered in this study will be used to guide the future study of digital tabletop systems that support natural collaborative behavior.

Procedure:

Your participation in this study will involve playing a board and/or video game with a group, followed by a brief group interview. A description of each activity follows.

You will be asked to:

- Complete a short background questionnaire (approx. time 5 min)
- Play at least one round of each of a board and a video game as a group (approx game time 45 min each)
- Participate in a short, semi-structured group interview (approx. 15 min)
- Be video recorded while playing the game

The session will take approximately 2-5 hours, depending on participants' interest.

During the session, a researcher will observe and take notes regarding your interactions with the activity resources, as well as your interactions with other participants in the team sessions. You will also be video recorded and any task materials produced during the session will remain with the researcher. You may decline to answer any questions, if you wish. You may withdraw your participation in the study at any time without penalty.

Confidentiality and Anonymity:

All information you provide is considered completely confidential. Your name will not appear in any thesis or report resulting from this study, however, with your permission anonymous quotations may be used. In these cases participants will be referred to as Participant 1, Participant 2, … (or P1, P2, …) or collectively as a group (group A, B, …). Data collected during this study will be retained in a locked office and only researchers associated with this project will have access.

You will be explicitly asked for consent for the release of photo/video/audio data captured during the study for the purpose of reporting the study's findings. If consent is granted, these data will be used only for scientific (inclusion in conference presentations, conference or journal papers), thesis and/or teaching purposes. You will not be identified by name.

All questionnaires and recordings will be kept indefinitely in a secure cabinet in a locked University of Waterloo room. Electronic data will be kept indefinitely and stored on a password protected computer and/or copied to CD.

Remuneration for your Participation:

As a participant in this study, you will not receive any monetary compensation. We anticipate that the study will take approximately 2-5 hours, depending on participant skill level and interest.

Risks and Benefits:

There are no known or anticipated risks to participation. There are no direct benefits to you, however the results of this research may contribute to the knowledge base of Human Systems Engineering research and also may lead to the development of better user interfaces.

I would like to assure you that this study has been reviewed and received ethics clearance through the Office of Research Ethics at the University of Waterloo. However, the final decision about participation is yours. If you have any comments or concerns resulting from your participation in this study, please contact Dr. Susan Sykes at this office at 519-888-4567 Ext. 36005, or by email at ssykes@uwaterloo.ca.

Thank you for your assistance in this project.

UNIVERSITY OF WATERLOO

INFORMED CONSENT BY SUBJECTS TO PARTICIPATE IN A RESEARCH EXPERIMENT

Project: An Observational Study of Communication and Coordination Processes during Board and Video Game Play

I have read the information presented in the information letter about a study being conducted by Prof. Stacey Scott and Phil McClelland of the Department of Systems Design Engineering at the University of Waterloo. I have had the opportunity to ask any questions related to this study, to receive satisfactory answers to my questions, and any additional details I wanted.

Sometimes a certain image and/or segment of video clearly shows a particular feature or detail that would be helpful in teaching or when presenting the study results at a scientific presentation or in a publication.

I agree to allow video and/or digital images in which I appear to be used in teaching, scientific presentations and/or publications with the understanding that I will not be identified by name.

I also agree to allow excerpts from the conversations from this study to be included in teaching, scientific presentations and/or publications, with the understanding that any quotations will be anonymous.

I am aware that I may withdraw my consent for any of the above statements or withdraw my study participation at any time without penalty by advising the researcher.

This project has been reviewed by, and received ethics clearance through, the Office of Research Ethics at the University of Waterloo. I was informed that if I have any comments or concerns resulting from my participation in this study, I may contact the Director, Office of Research Ethics at 519-888-4567 ext. 36005

	Please Circle One		**Please Initial**
With full knowledge of all foregoing, I agree, of my own free will, to participate in this study.	YES	NO	_______
I agree to be video recorded, photographed, and audio recorded.	YES	NO	_______
I agree to let my conversation during the study be directly quoted, anonymously, in presentation of research results.	YES	NO	_______
I agree to let the video recordings/digital images/audio recordings be used for presentation of research results.	YES	NO	_______
I agree to let my actions during the study be recorded via computer logging software.	YES	NO	_______

Participant Name: __________________________ (Please print)

Participant Signature: __________________________ Date __________________________

Witness Name: __________________________ (Please print)

Witness Signature: __________________________ Date __________________________

UNIVERSITY OF WATERLOO

An Observational Study of Communication and Coordination Processes during Board and Video Game Play

Dear Participant,

I would like to thank you for your participation in this study. As a reminder, the purpose of this study is to establish a basic understanding of communication and coordination processes in board and video games through the observation of real groups of participants playing these types of games. The information gathered from the recorded video and interview questions in this study will be used to guide the study of interactive tabletop software that supports natural collaborative behavior.

Please remember that all information you provide will be considered completely confidential. Should an image and/or video recording of you taken in this study be used in a publication or presentation resulting from this study, you will not be identified by name. Once all the data is collected and analyzed for this project, I plan on sharing this information with the research community through seminars, conferences, presentations, and journal articles. If you are interested in receiving more information contact me at either the phone number or email address listed at the bottom of the page. If you would like a summary of the results, please let me know now by providing me with your email address. When the study is completed, I will send it to you.

As with all University of Waterloo projects involving human participants, this project was reviewed and received ethics clearance through, the Office of Research Ethics at the University of Waterloo. Should you have any comments or concerns resulting from your participation in this study, please contact Dr. Susan Sykes in the Office of Research Ethics at 519-888-4567, Ext. 36005.

If you have any questions about participation in this study, please feel free to ask the researchers. If you have additional questions at a later date, please contact my thesis supervisor Dr. Stacey Scott at (519) 888-4567 ext. 32236 or by email at s9scott@uwaterloo.ca.

Phil McClelland
University of Waterloo
Department of Systems Design Engineering

519-888-4567 x36813
pjmcclel@uwaterloo.ca
If you are interested in learning more about the topic, please see:

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Appendix B

Study Material, Cross-device Object Transfer Study (Chapter 4)

LETTER OF INFORMATION

Tabletop Card Games Study

You are invited to participate in a research project directed by Phil McClelland, Dr. Guillaume Besacier, and Dr. Stacey Scott (Faculty Supervisor) conducted at the University of Waterloo Collaborative Systems Lab in the Systems Design Engineering Department. We will read through this letter of information with you, describe our experimental procedures in detail, and answer any questions you may have. The research is being funded by NSERC Surfnet Strategic Network.

This study aims to explore gameplay facilitated by digital tabletop and tablet computers. You will be playing the Dominion card game with 1 other participant. Following the study, the researcher will explain the details to you of what aspects of the user interface were specifically tested. The study will last up to 180 minutes (three games).

Prior to the session, you will be asked to complete a questionnaire, including demographic and background information. While playing the game, you will be video recorded, and other data about how you use the interface will be recorded. You will play the game three times, each with a different setup. Following each play of the game, you will be asked to fill in a questionnaire giving your opinions on the game and setup under study. You will be provided with a copy of the official rules of the game you are playing, which you may refer to at any time. If you experience difficulties during the study and cannot proceed, advise the researcher who may briefly help you.

You will be given a $20 honorarium for your participation.

Your participation is voluntary. You may decline to answer any questions if you wish. If you wish to withdraw from participation at any time, please advise the researcher. Any data collected up to the point of withdrawal will be destroyed. Should you choose to withdraw, you will still receive the honorarium for your participation ($10 for the first hour or $20 for any time thereafter).

While you may not benefit directly from this study, results from this study will inform the development of future tablet and tabletop interfaces.

All information provided is considered completely confidential. Your name will not appear in any publication resulting from this study; however, with your permission anonymous quotations from the conversation may be used. In these cases participants will be referred to as Participant 1, Participant 2, … (or P1, P2, …) Data collected during this study will be retained indefinitely in a locked cabinet or on password protected desktop computers in the Collaborative Systems Laboratory at the University of Waterloo.

You will be asked to explicitly consent to the use of video and audio data captured during the study for the purpose of reporting the study's findings. If and only if consent is granted, this data will be used only for the purposes associated with teaching, scientific presentations, publications, and/or sharing with other researchers. Participants will not be identified by name.

We would like to assure you that this study has been reviewed and received ethics clearance through the Office of Research Ethics at University of Waterloo. However, the final decision about participation is yours. Should you have any ethical comments or concerns resulting from you participation in this study, please contact the Director, University of Waterloo Office of Research Ethics (519-888-4567 ext. 36005).

Please retain a copy of the letter of information and consent form. If you have any questions, concerns or comments about this research, please contact any of the research team: Phil McClelland (pjmcclel@uwaterloo.ca) or Guillaume Besacier (Guillaume.Besacier@uwaterloo.ca).

INFORMED CONSENT BY SUBJECTS TO PARTICIPATE IN A RESEARCH STUDY

Project Title: Tabletop Card Games Study

I have read the information presented in the information letter about a study being conducted by Phil McClelland, Dr. Guillaume Besacier, and Dr. Stacey Scott (Faculty Supervisor) at the University of Waterloo. I understand that I will be participating in a research project in tabletop gaming, and that I will be engaging in a study and the procedures and risks are described in the attached letter of information. I have had the opportunity to ask any questions related to this study, to receive satisfactory answers to my questions, and any additional details I wanted.

Sometimes a certain image and/or segment of video recording clearly shows a particular feature or detail that would be helpful in teaching or when presenting the study results at a scientific presentation or in a publication.

I am aware that I may allow video and/or digital images in which I appear to be used in teaching, scientific presentations, publications, and/or data sharing with other researchers with the understanding that I will not be identified by name. I am aware that I may allow excerpts from the conversational data from this study to be included in teaching, scientific presentations and/or publications, with the understanding that any quotations will be anonymous.

I am aware that my participation is voluntary and that I may withdraw my consent for any of the above statements or withdraw my study participation at any time without penalty by advising the researcher.

This project has been reviewed and received ethics clearance through the Office of Research Ethics at University of Waterloo. I was informed that if I have any comments or concerns resulting from my participation in this study, I may contact Phil McClelland (phil.mcclelland@uwaterloo.ca) and Guillaume Besacier (guillaume.besacier@uwaterloo.ca), and that if I have any ethical comments or concerns about the study I may contact the Director, University of Waterloo Office of Research Ethics (519-888-4567 ext. 36005).

	Please Circle One		**Please Initial Your Choice**
With full knowledge of all foregoing, I agree, of my own free will, to participate in this study.	**YES**	**NO**	____
I agree to be video and audio recorded	**YES**	**NO**	____
I agree to let my conversation during the study be directly quoted, anonymously, in presentation of the research results	**YES**	**NO**	____
I agree to let the video recordings, digital images, or audio recordings be used for presentation of the research results	**YES**	**NO**	____

Participant Name: ____ (Please print)

Participant Signature: ____

Date: ____

Background Questionnaire Subject ID:____________

Project Title: Tabletop Card Games Study

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

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

Female Male

2. What is your age? _____

3. What is your occupation? __________________________________

If student, what degree/program are you in? ___________________________________

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

Left hand Right hand

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

Never	Rarely	Sometimes	Often	Very Often
1	2	3	4	5

6. Which card games have you played most often?

____

____

____

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

Never	Rarely	Sometimes	Often	Very Often
1	2	3	4	5

8. Which video games have you played most often?

9. On a scale of 1-5, please indicate how often you have played the game **Dominion** in the following formats:

   a) Traditional, card game format:

Never	Rarely	Sometimes	Often	Very Often
1	2	3	4	5

   b) Computerized / video game format:

Never	Rarely	Sometimes	Often	Very Often
1	2	3	4	5

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

Never	Rarely	Sometimes	Often	Very Often
1	2	3	4	5

11. How well do you know the other player?

Never Met				Very Well
1	2	3	4	5

Project Title: Tabletop Card Games Study

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

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

	Strongly Disagree 1	**2**	**3**	**Neutral 4**	**5**	**6**	**Strongly Agree 7**
I had fun playing the game.	1	2	3	4	5	6	7
I was always aware of the other player's actions.	1	2	3	4	5	6	7
When the other player took action, I always understood his/her motivations for doing so.	1	2	3	4	5	6	7
When taking my turn, I was always aware of my play options.	1	2	3	4	5	6	7
I always understood how the game was progressing.	1	2	3	4	5	6	7
I felt that it took a lot of effort to play the game.	1	2	3	4	5	6	7

1. What aspects of the system assisted the game play?

2. What aspects of the system hinder the game play?

University of Waterloo
Research Participant's Acknowledgement of
Receipt of Remuneration
and
Self-Declared Income

Section A: To be completed by Principal Investigator or designate

Principal/Faculty Investigator's Name: Dr. Guillaume Besacier, Dr. Stacey Scott

Student Investigator(s)'s Name: Phil McClelland

Department: Systems Design Engineering

Study Title: Tabletop Card Games Study

Section B: To be completed by research participant

In appreciation of my involvement as a research participant in the above study,
I acknowledge that I have received $ __________ from the University of Waterloo.

I further acknowledge that:

- this amount received from the University of Waterloo is taxable;
- that it is my responsibility to report the amount received for income tax purposes; and
- the University of Waterloo will not issue a tax receipt for the amount received.

Participant's Name: ______________________________

Participant's Signature: ______________________________

Date: ______________________________

Witness' Name ______________________________

Witness' Signature: ______________________________

Date: ______________________________

POST-EXPERIMENT DEBRIEFING
Tabletop Card Games Study

Phil McClelland
MASc Student
Systems Design Engineering
University of Waterloo

Thank you for your participation in this study. Now that you have completed your tasks, the researcher will answer any questions you raised during the performance of the tasks, and any additional questions you have on the process used and the purpose of the study.

Multitouch digital tabletop computers provide a compelling platform to support group interaction with shared digital artifacts. However, these systems are less suitable for supporting private information. One solution, then, is to enable users to use private tablet computers in conjunction with the shared digital tabletop. In order to facilitate this, the system must allow users to effectively move digital objects between the private and shared surfaces. In this study, you experienced different methods in which this bridging might be accomplished, including the use of 'portals' which allow cards to be pushed from one device onto another or 'pick and drop' interactions which allow you to drop cards directly onto specified points on the table. By comparing these conditions, we will gain insight into how such bridging methods influence factors such as group interaction and performance. In turn, this will enable us to develop more effective bridging mechanisms in the future.

Please remember that all information you provide will be considered completely confidential, expect where consent has been granted for an image and/or video recording to be used anonymously in the context of teaching, scientific presentations, publications, and/or data sharing with other researchers.

If you have any questions, concerns, or comments about this research, please contact Dr. Guillaume Besacier (guillaume.besacier@uwaterloo.ca) or Phil McClelland (phil.mcclelland@uwaterloo.ca).

If you have any ethical comments or concerns about this study, please contact:

Director, University of Waterloo Office of Research Ethics
519-888-4567 ext. 36005

Further information on this and related work is available at the Collaborative Systems Lab website, http://csl.uwaterloo.ca.

Tabletop Games - Participants Needed

Participants are needed for a study being carried out by the Collaborative Systems Lab, Department of Systems Design Engineering, at the University of Waterloo. **The study explores game play using digital tabletop and tablet computers**. The study consists of one session of three games of *Dominion* (please allow up to 3h). Results may contribute to the development of novel interaction techniques for systems which use tabletops and tablets. Participants will be asked to complete a background questionnaire. Sessions will be video recorded.

Participants must:

- Be aged 18 and older
- Have some experience playing ***Dominion***, by Rio Grande Games
- Sign up in groups of 2.

You will be given a **$20** honorarium for your participation.

If you are interested in being a participant in this study, please contact Phil McClelland by email at phil.mcclelland@uwaterloo.ca

Thanks for your attention!

This project was reviewed and received ethics clearance through the Office of Research Ethics.
Study Ends: May 28, 2012

Tabletop Game Study
Contact: Phil McClelland
phil.mcclelland@uwaterloo.ca

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Tabletop Game Study
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Recruitment Email

Participate in a Research Study

We are seeking participants for an observational study of groups playing Rio Grande Games' *Dominion* using digital tabletop computer media and android tablets. Participants, in groups of 2, will play different digital tabletop versions of *Dominion*. Participants will also complete a background questionnaire and be video recorded while playing the game.

The study takes place in one session of three games (please allow up to 3h). Participants must be aged 18 or older and have some previous experience with Rio Grande Games' *Dominion*. Participants will each receive $20 remuneration for their participation. Participants are asked to sign up in groups of 2.

The study will be held between May 8 and May 28, 2012.

Please contact Phil McClelland at phil.mcclelland@uwaterloo.ca if you are interested.

This project was reviewed and received ethics clearance through the Office of Research Ethics.

Appendix C

Interaction Strategy Flow Models

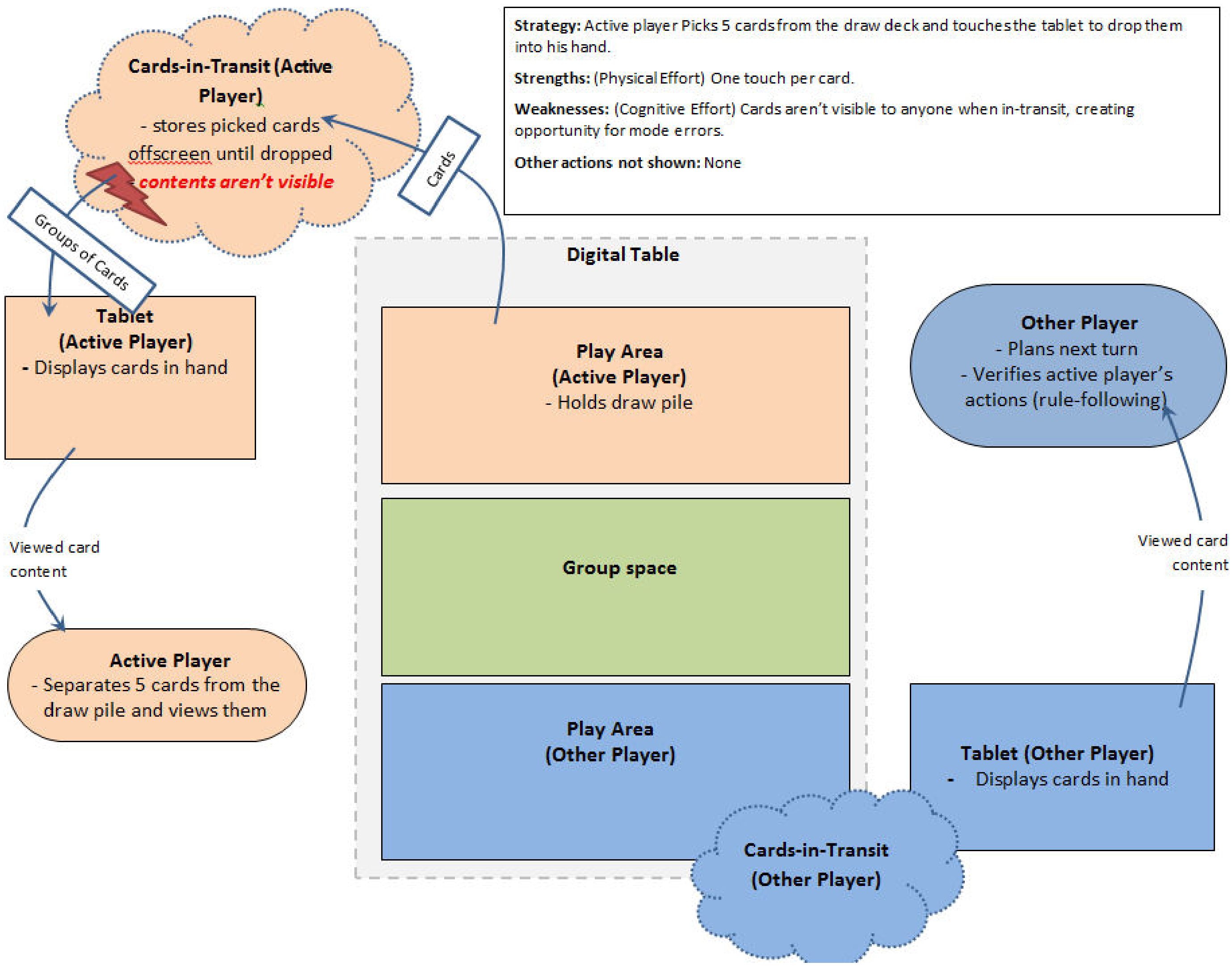
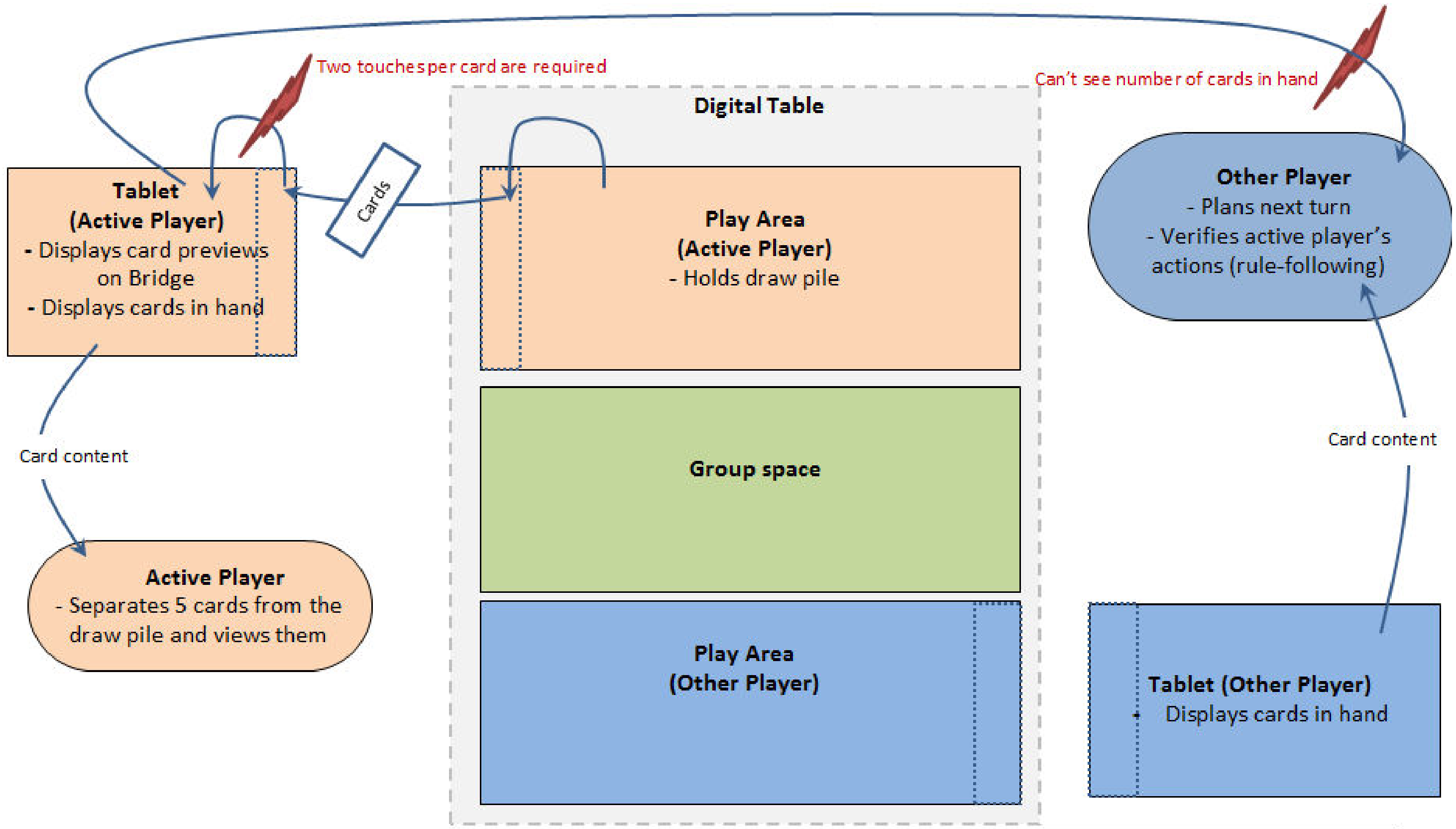


Figure 35: Interaction Strategy Flow Model #1

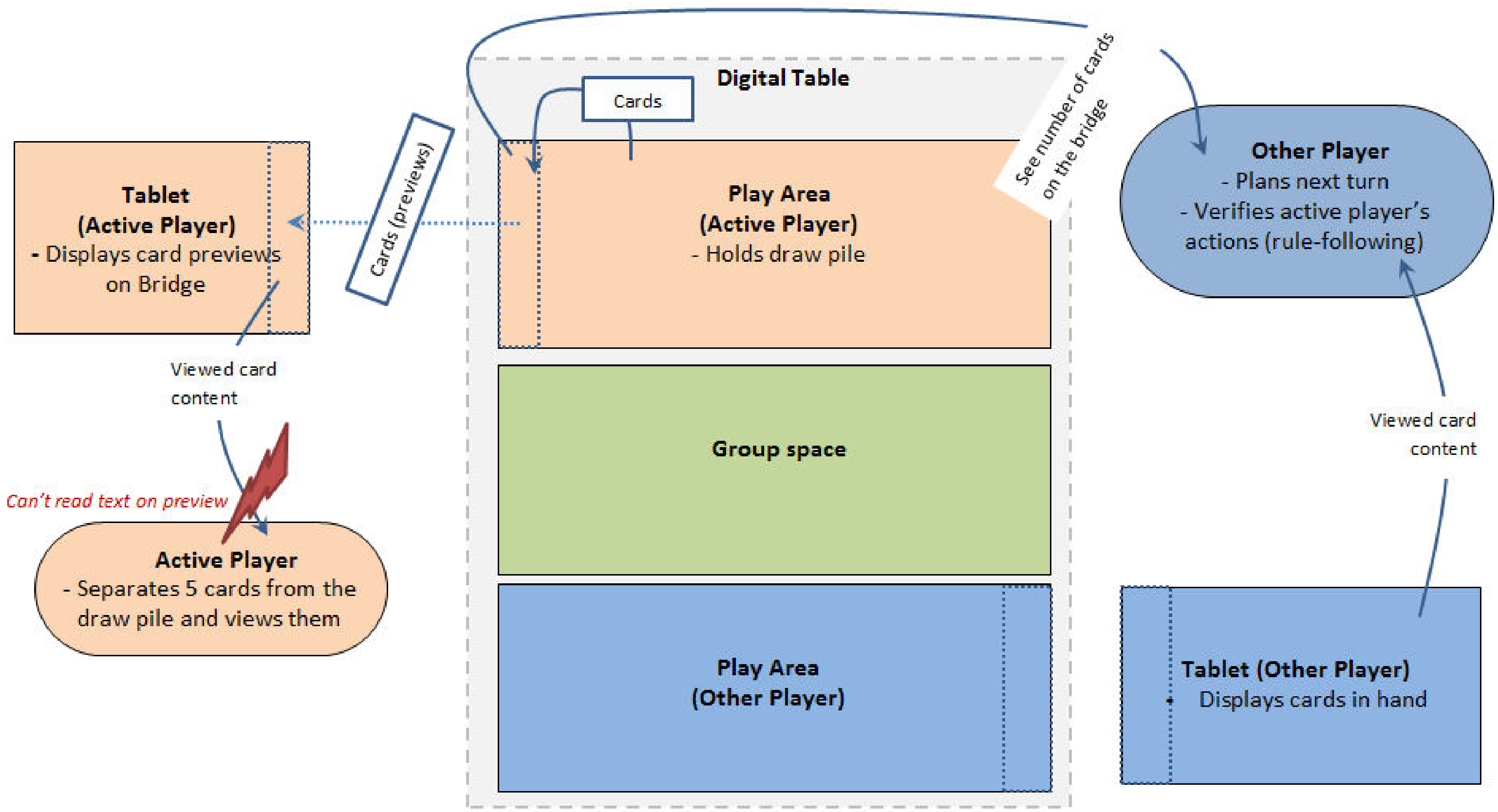


Strategy: Active Player slides 5 individual cards from the play area onto his bridge. On the tablet, he slides the same 5 cards from the bridge to his hand, leaving the bridge empty.

Strengths: (Cognitive Effort) No decisions to make; cards on the tablet display are clearly readable.

Weaknesses: (Physical effort) Two touches per card feels tedious to some. (Visibility) Other player has no persistent way to see the number of cards in the active player's hand

Figure 36: Interaction Strategy Flow Model #2



Strategy: Active Player slides 5 individual cards from the play area onto his bridge.

Strengths: (Physical effort) Only one touch per card is required

Weaknesses: (Cognitive effort / Expert knowledge) Cards shown on the tablet bridge are small (ie. can't read text), and only the bottom-halves are visible.

Other actions not shown: Player reshuffles and flips his discard pile if the draw pile is emptied.

Figure 37: Interaction Strategy Flow Model #3

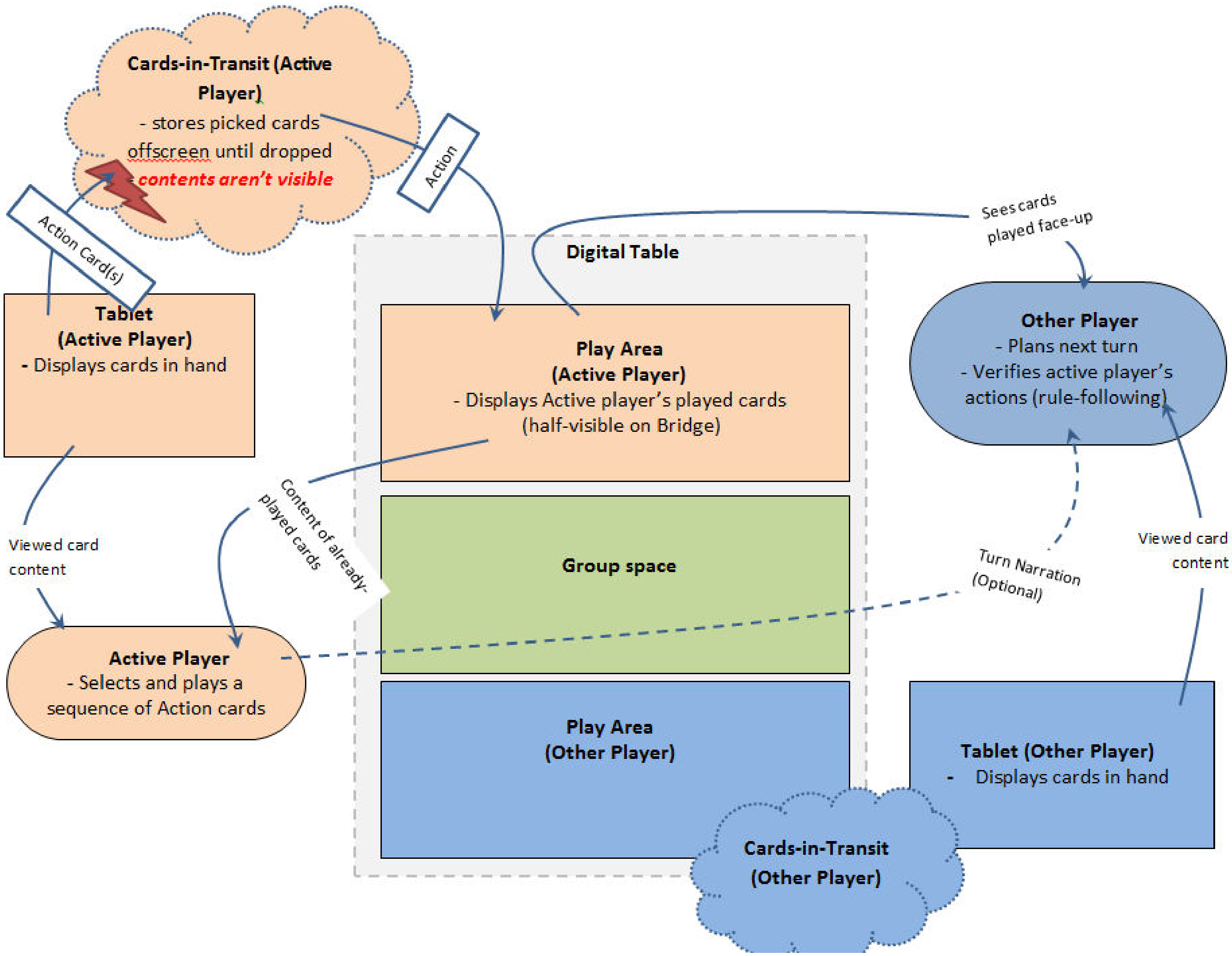
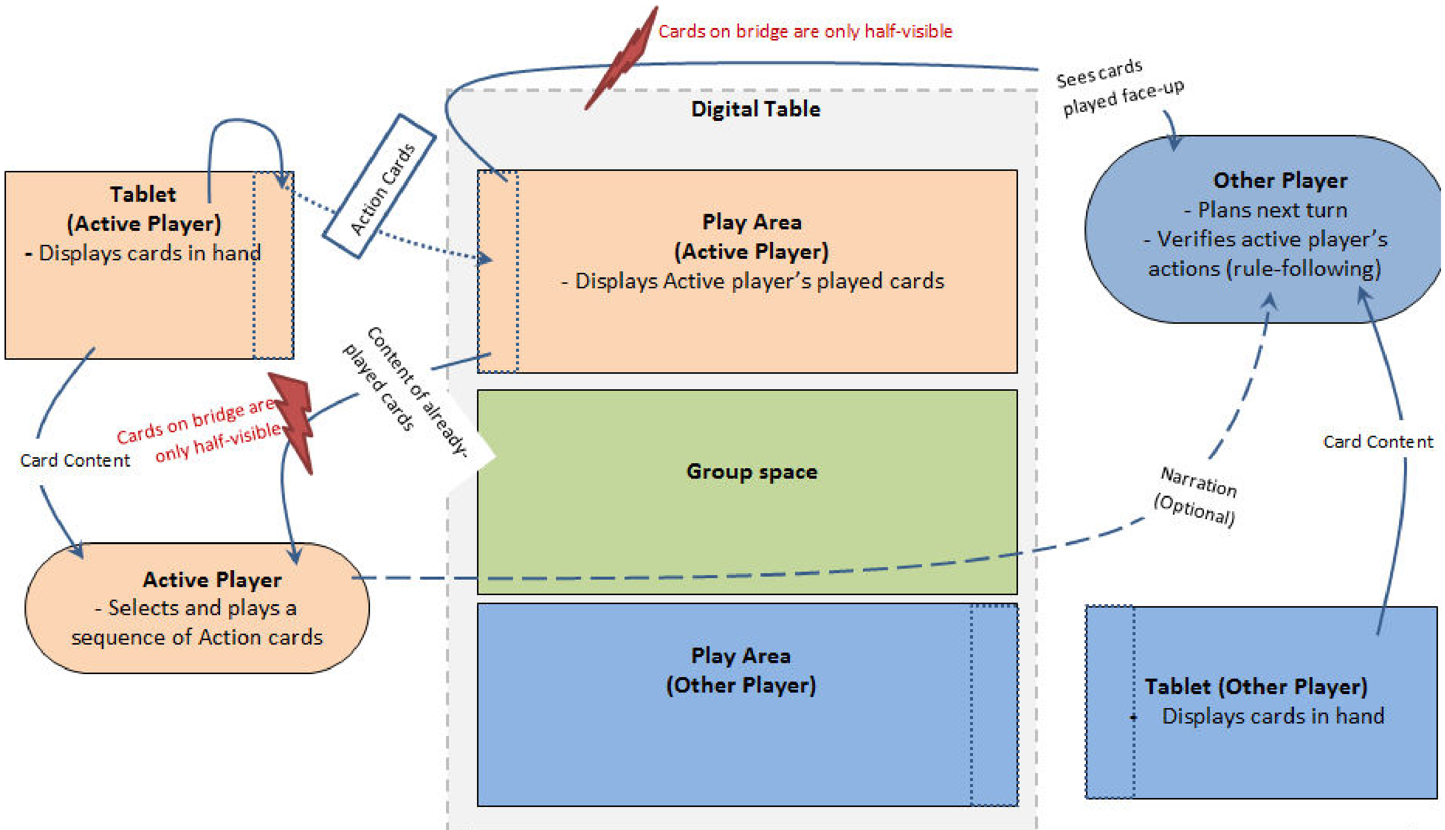


Figure 38: Interaction Strategy Flow Model #4



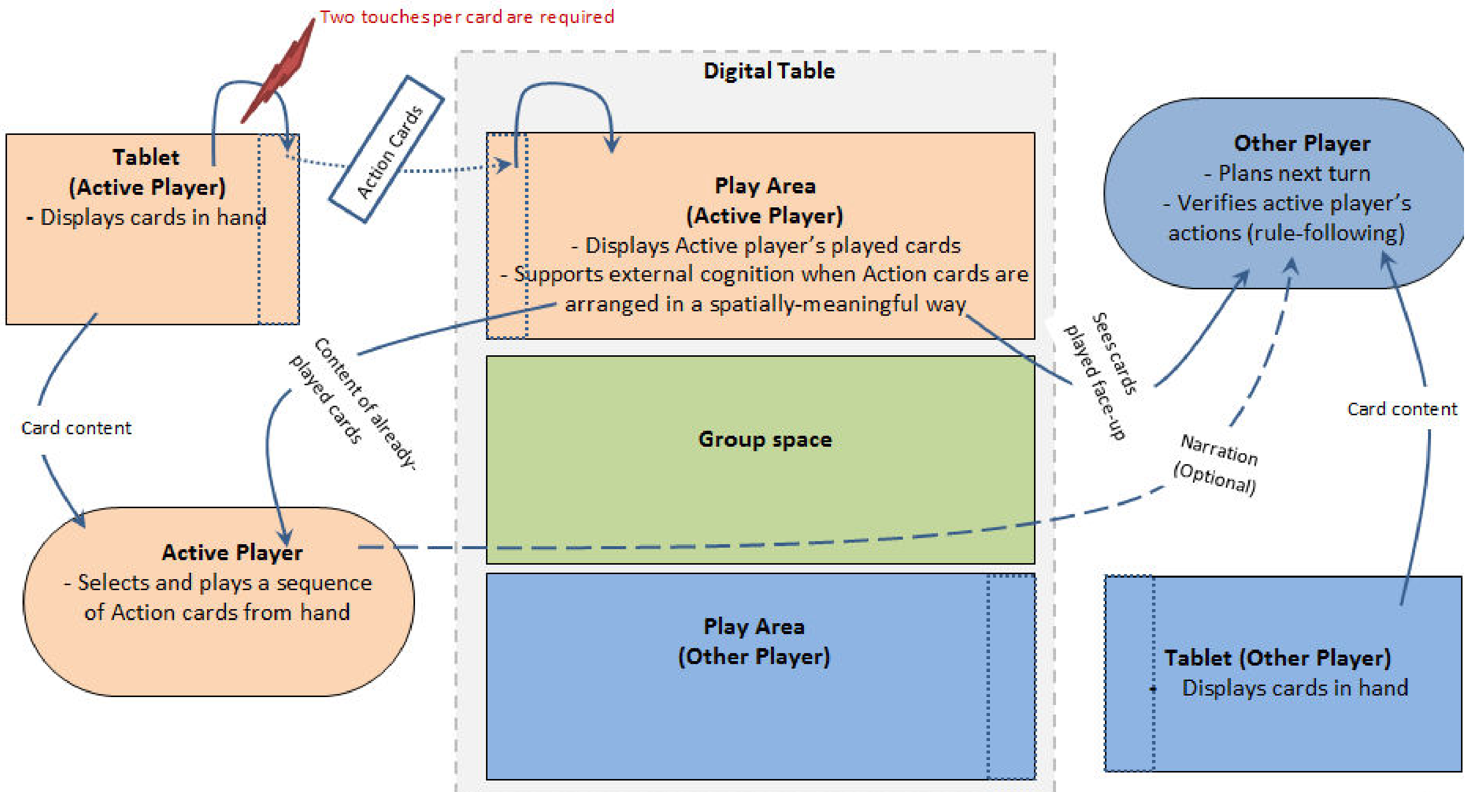
Strategy: Active player looks at the cards available in his hand, then chooses a series of one or more action cards to play, sliding these to the bridge one by one.

Strengths: (Physical Effort) Only one touch per card. Player can focus eyes on the tablet alone.

Weaknesses: (Cognitive effort) Played action cards are left on the bridge rather than being spread out in the play area to support external cognition. (Visibility) Cards on bridge are only half-visible to the Other Player.

Other actions not shown: Action cards instructions vary widely, and may include other effects like taking cards from the group space or forcing the Other Player to discard.

Figure 39: Interaction Strategy Flow Model #5



Strategy: Active player looks at the cards available in his hand, then chooses a series of one or more action cards to play, sliding these to the bridge one by one. On the tabletop, the cards are moved from the bridge and lined up in a spatially-meaningfully way (dependent on player's preference and card text).

Strengths: (Cognitive Effort) Cards are clearly visible at all times and can be arranged to support external cognition. (Visibility) Other Player can see all necessary parts of the Active Player's actions.

Weaknesses: (Physical Effort) Two touches per card are required.

Other actions not shown: Action cards instructions vary widely, and may include other effects like taking cards from the group space or forcing the Other Player to discard.

Figure 40: Interaction Strategy Flow Model #6

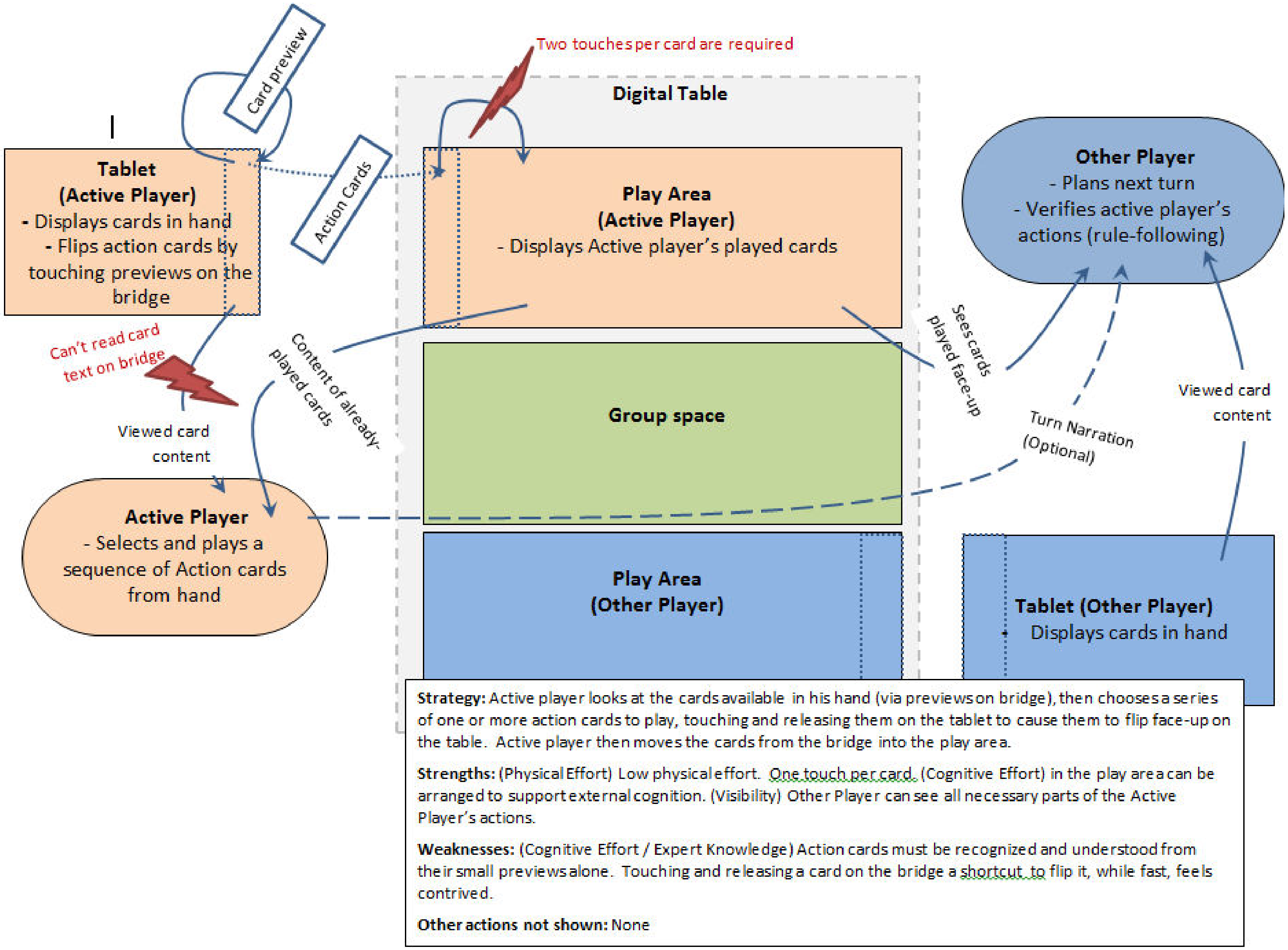
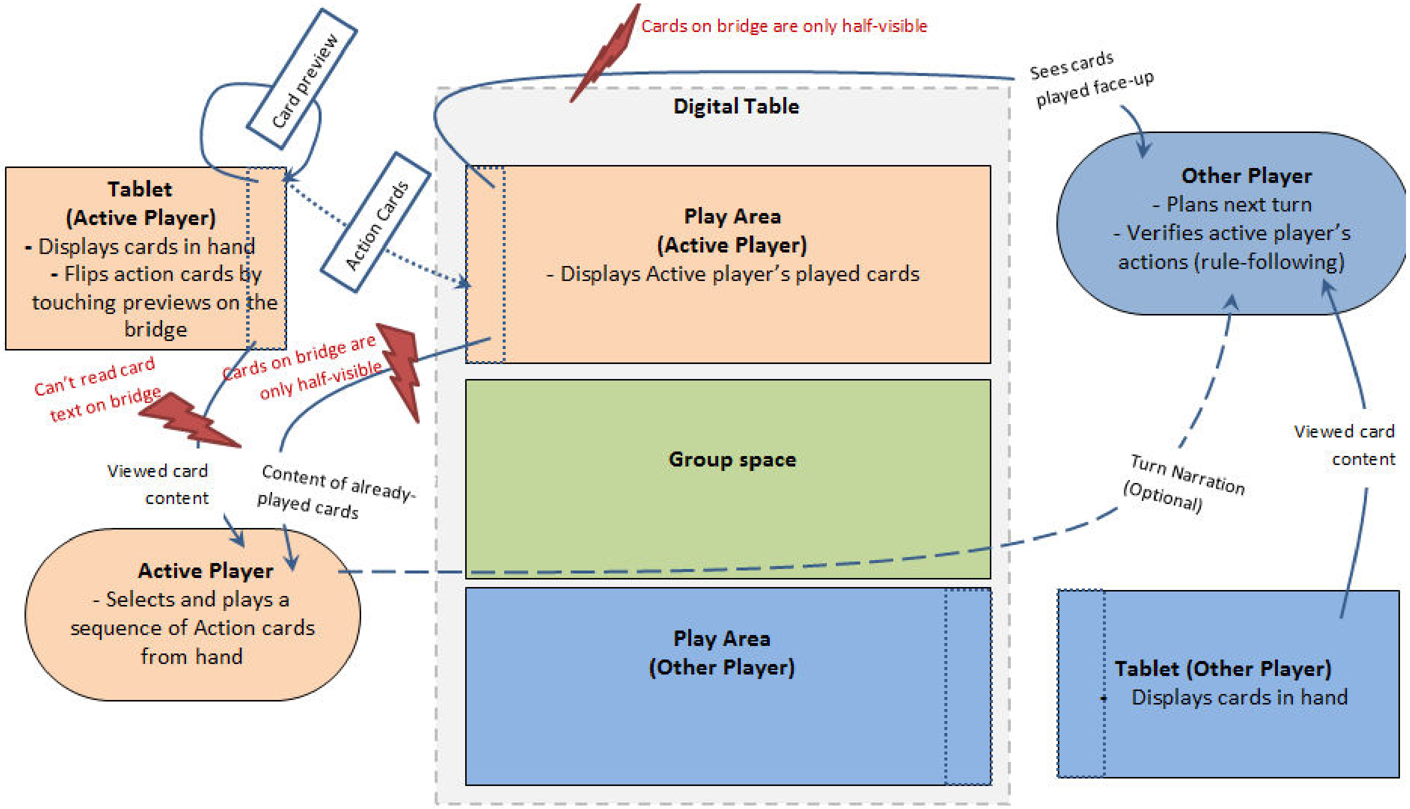


Figure 41: Interaction Strategy Flow Model #7



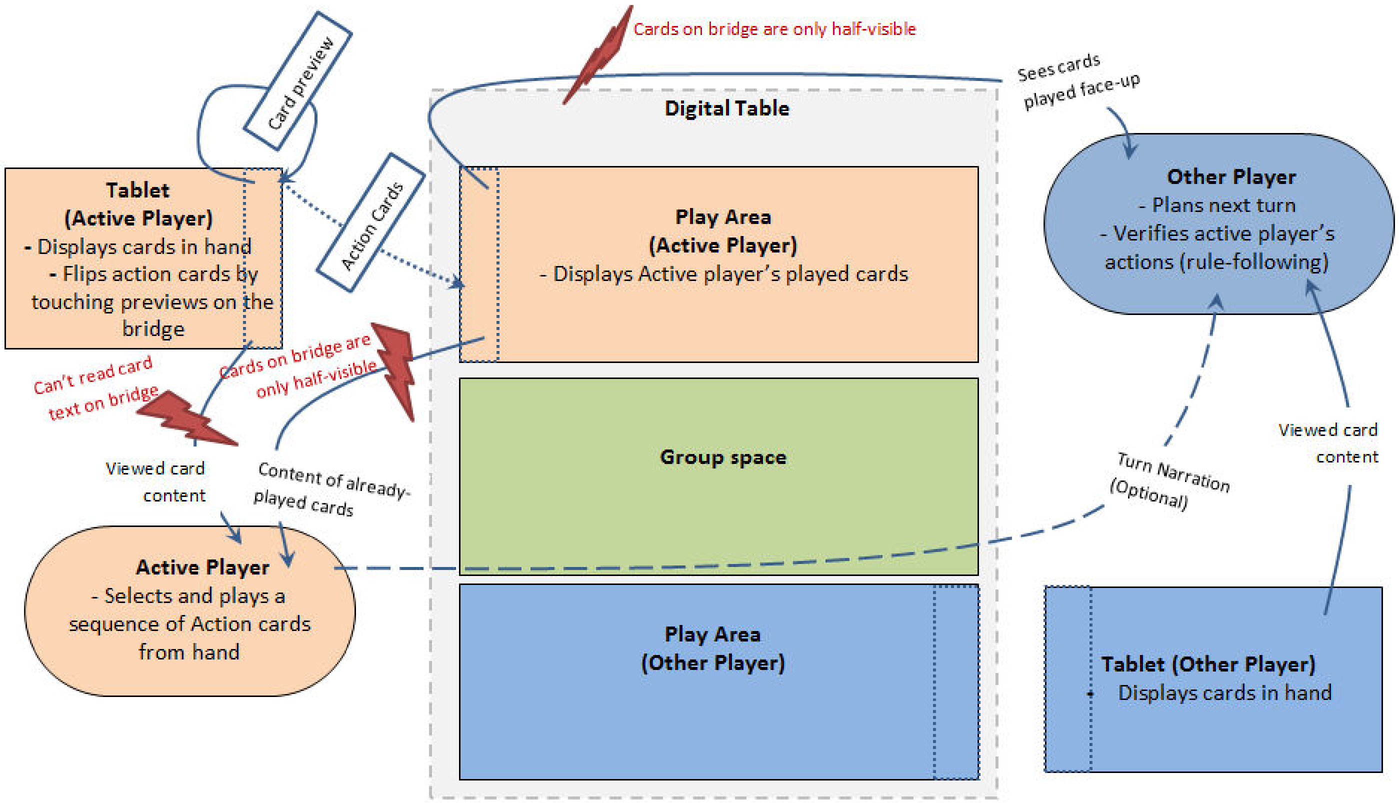
Strategy: Active player looks at the cards available in his hand (via previews on bridge), then chooses a series of one or more action cards to play, touching and releasing them to cause the tablet to flip them face-up on the table.

Strengths: (Physical Effort) Low physical effort. One touch per card.

Weaknesses: (Cognitive Effort / Expert Knowledge) Action cards must be recognized and understood from their small previews alone. Touching and releasing a card on the bridge a shortcut to flip it, while fast, feels contrived. (Visibility) Other player can only see the top halves of the Active Player's used cards.

Other actions not shown: None

Figure 42: Interaction Strategy Flow Model #8



Strategy: Active player looks at the cards available in his hand (via previews on bridge), then chooses a series of one or more action cards to play, touching and releasing them to cause the tablet to flip them face-up on the table.

Strengths: (Physical Effort) Low physical effort. One touch per card.

Weaknesses: (Cognitive Effort / Expert Knowledge) Action cards must be recognized and understood from their small previews alone. Touching and releasing a card on the bridge a shortcut to flip it, while fast, feels contrived. (Visibility) Other player can only see the top halves of the Active Player's used cards.

Other actions not shown: None

Figure 43: Interaction Strategy Flow Model #9

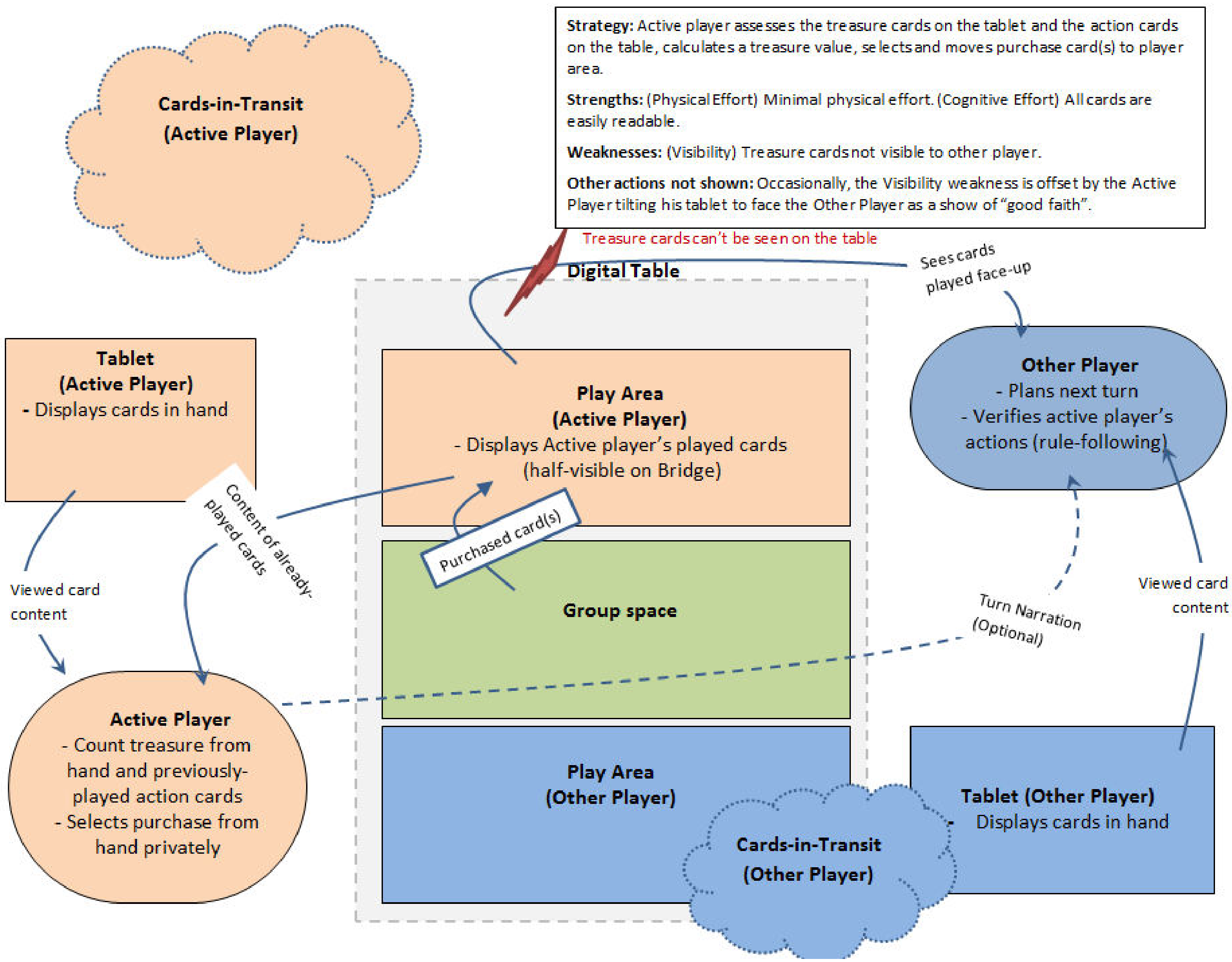


Figure 44: Interaction Strategy Flow Model #10

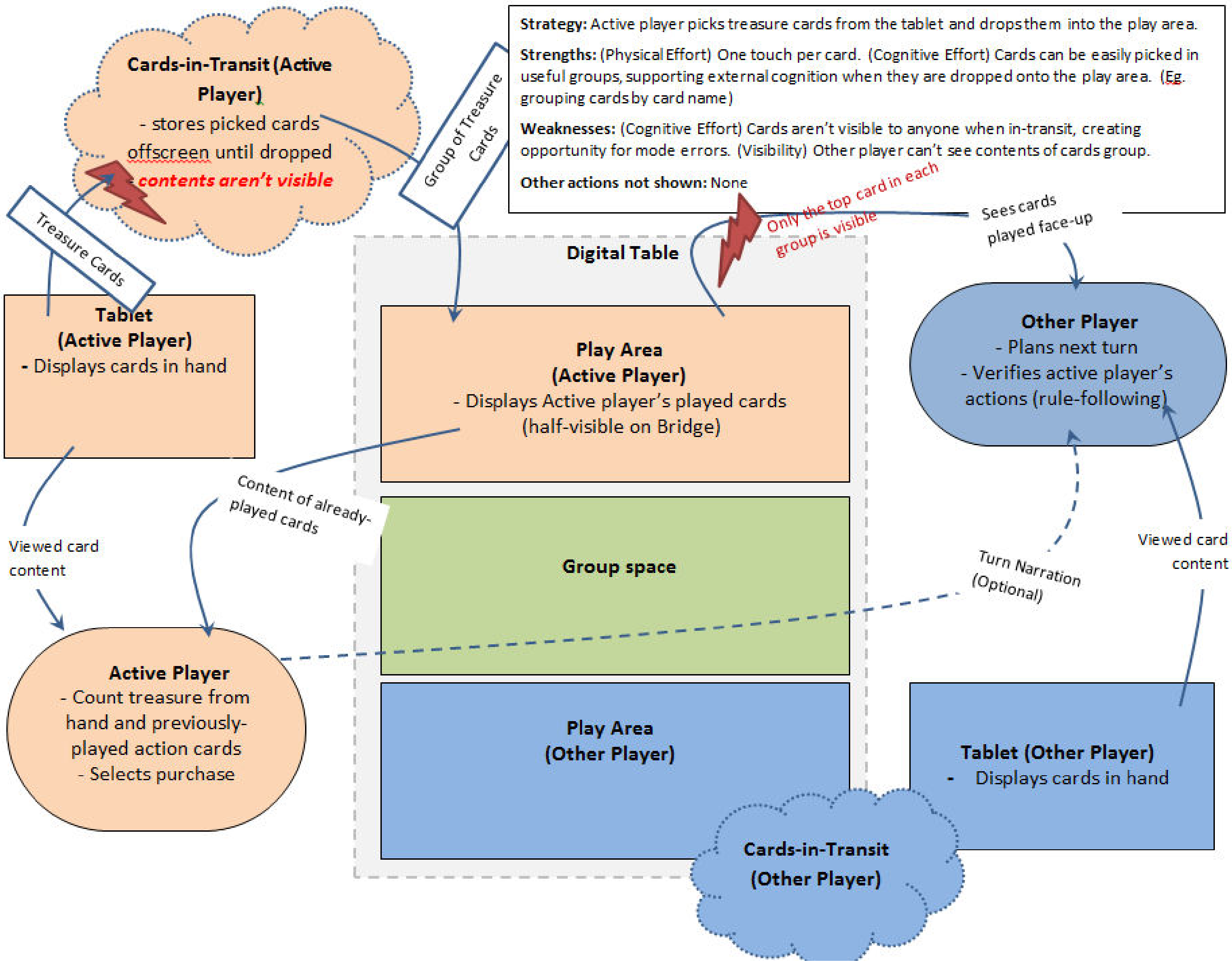


Figure 45: Interaction Strategy Flow Model #11

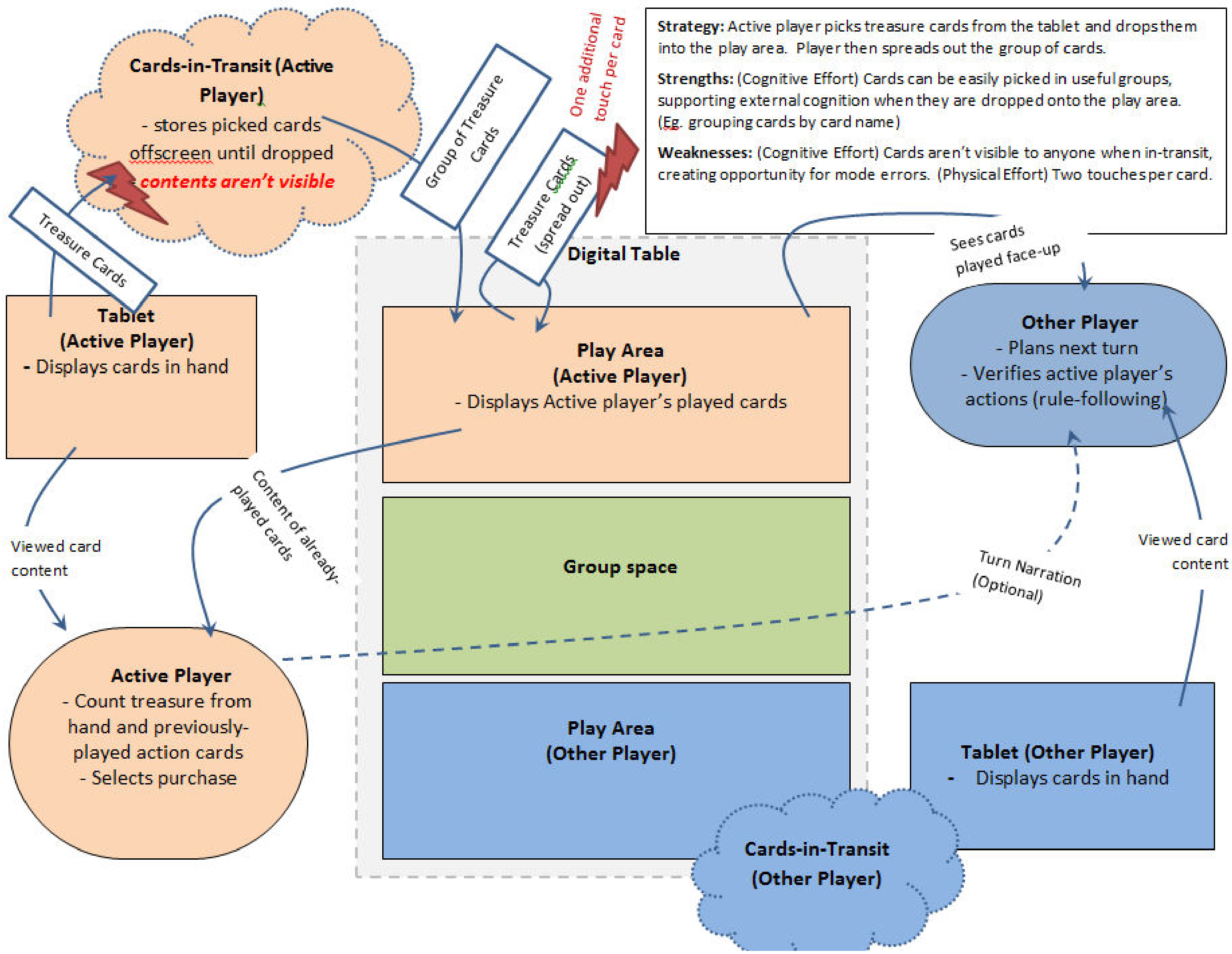
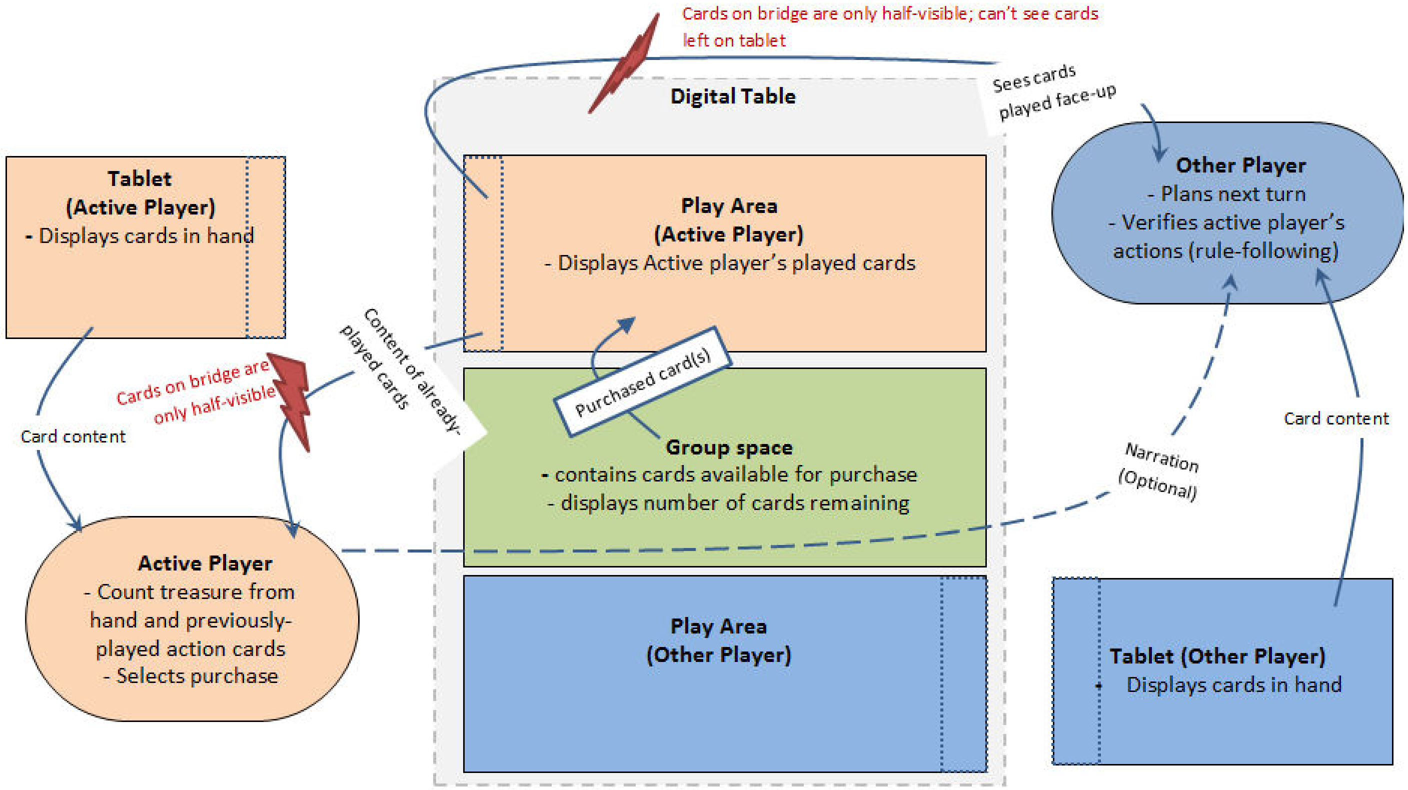


Figure 46: Interaction Strategy Flow Model #12



Strategy: Active player recalls the action cards played in the previous phase, and together with the treasure cards on the tablet, calculates a treasure value. He then chooses his purchase card(s).

Strengths: (Physical Effort) Minimal physical effort. No touches required beyond moving the purchased card.

Weaknesses: (Cognitive Effort) Actions from previous phase must be remembered, since cards on bridge are half-hidden. (Visibility) Other player can [half] see only a subset of the Active Player's used cards.

Other actions not shown: Occasionally, the Visibility weakness is offset by the Active Player tilting his tablet to face the Other Player as a show of "good faith".

Figure 47: Interaction Strategy Flow Model #13

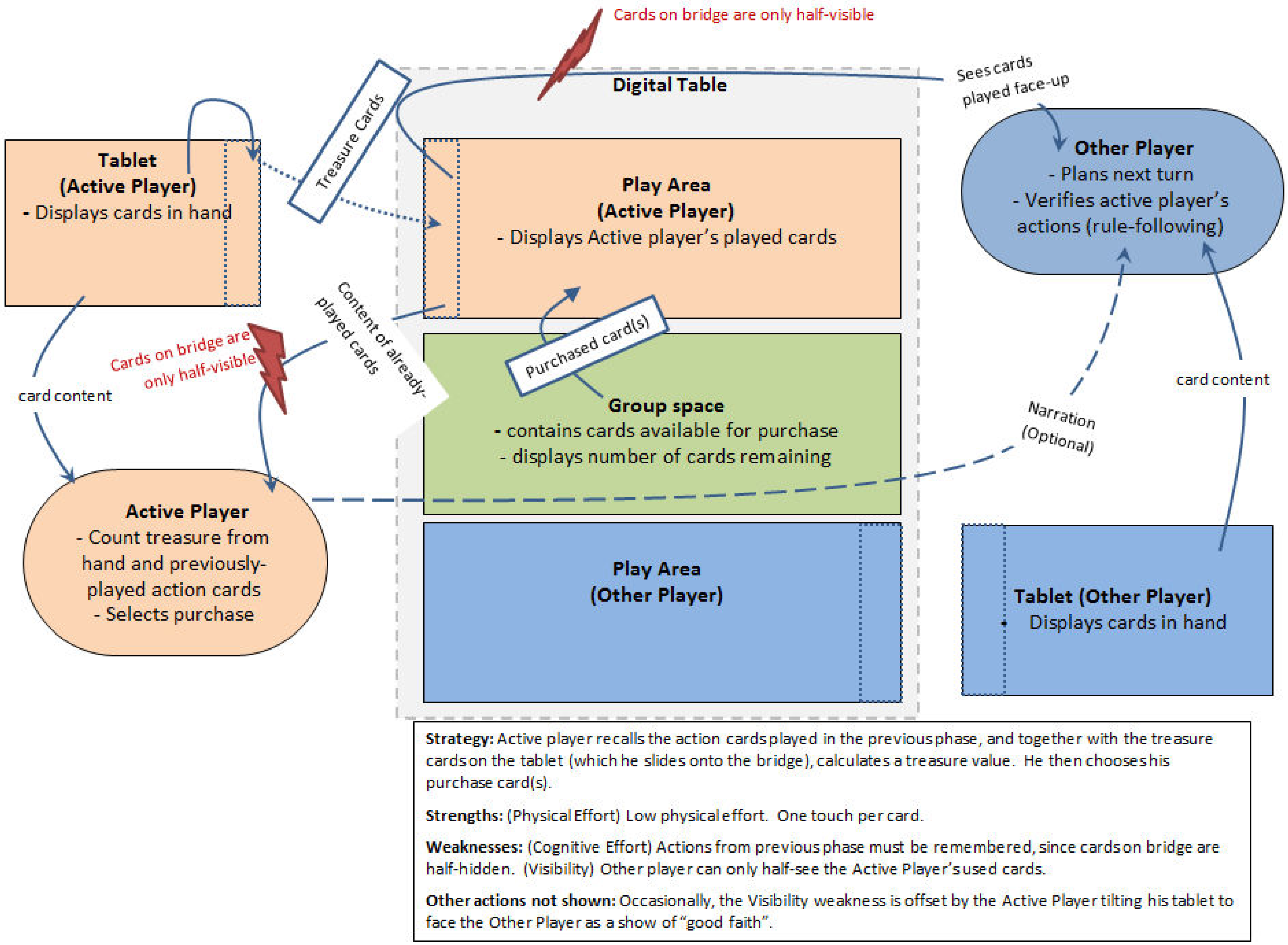
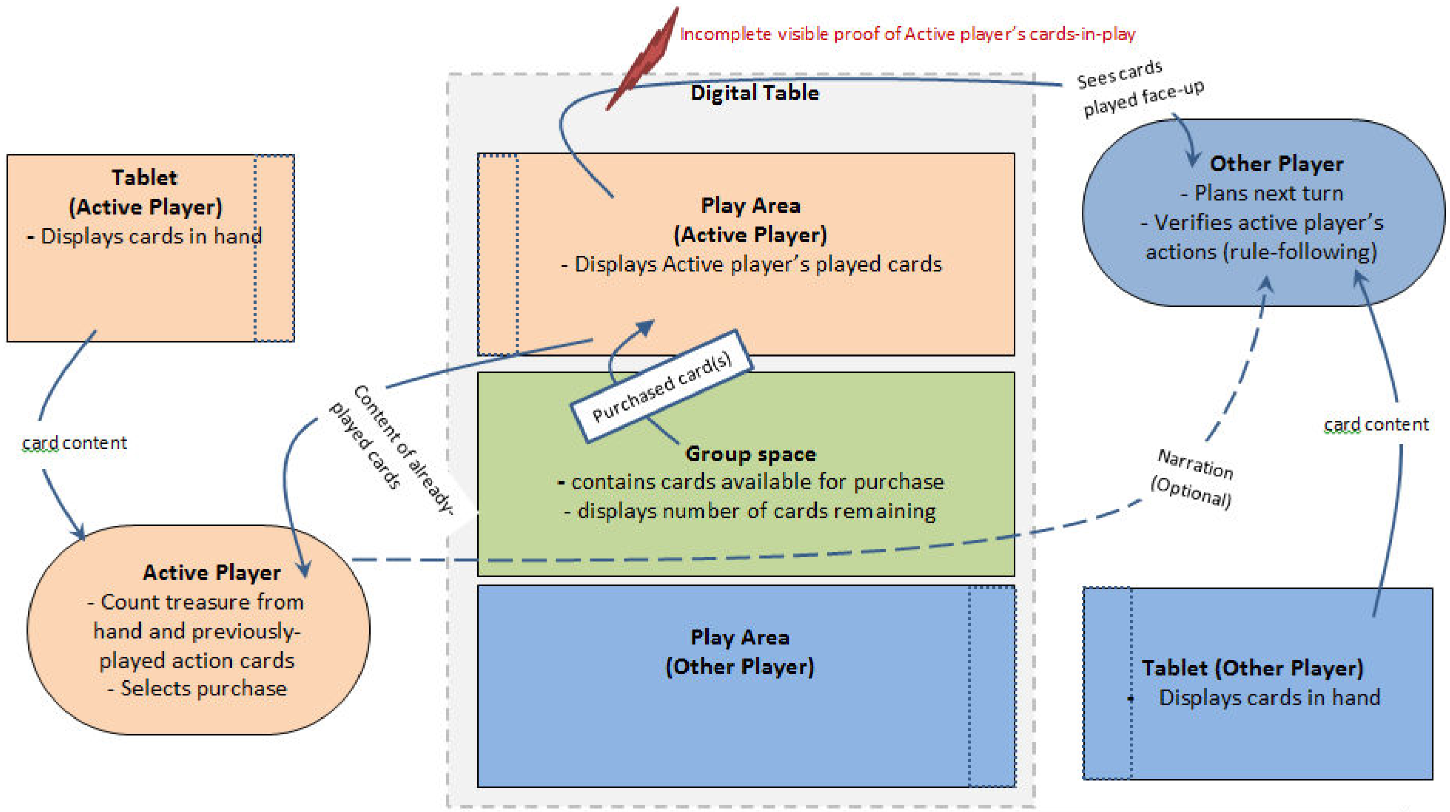


Figure 48: Interaction Strategy Flow Model #14



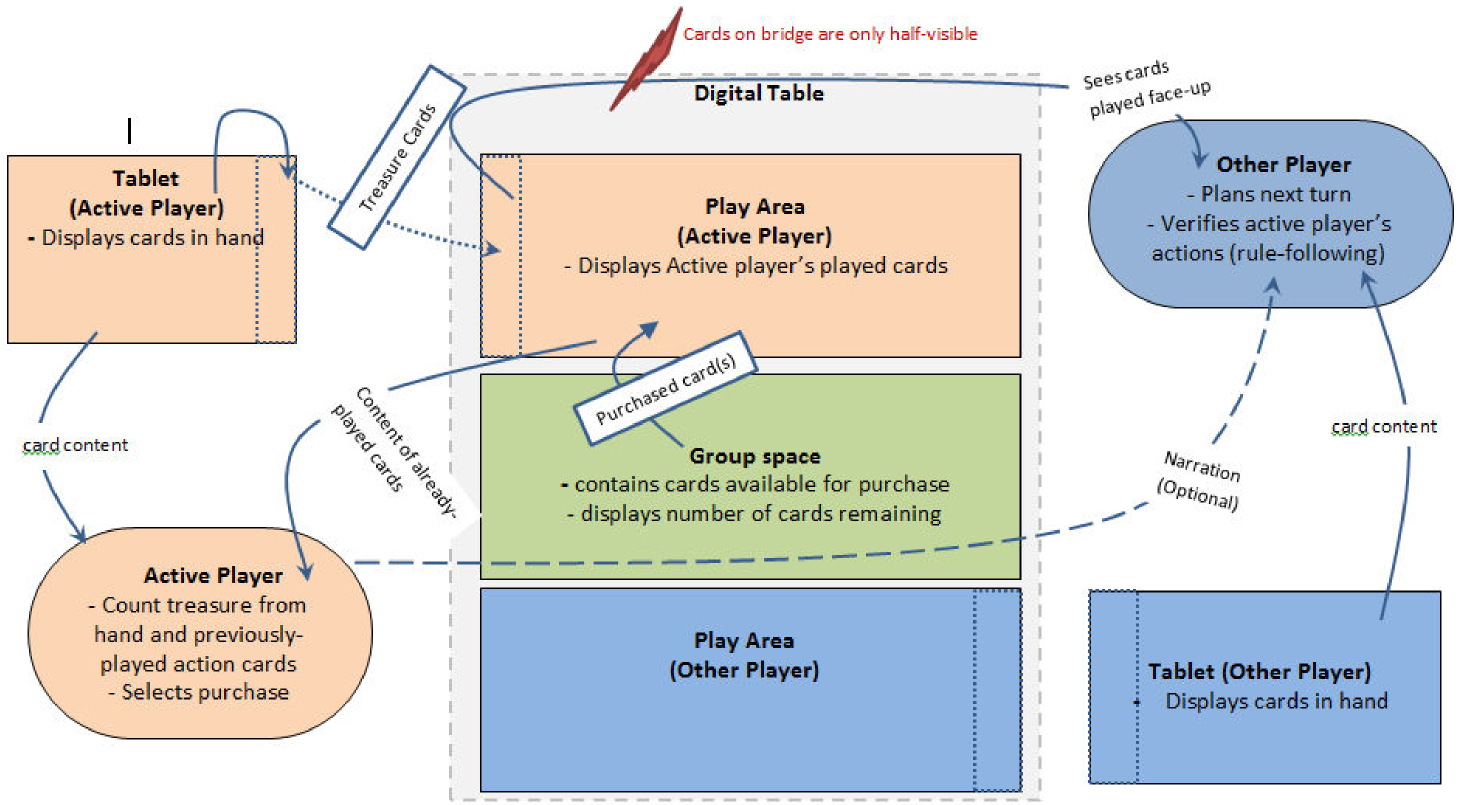
Strategy: Active player assesses (or recalls) the action cards played in the previous phase, and together with the treasure cards on the tablet, calculates a treasure value. He then chooses his purchase card(s).

Strengths: (Physical Effort) Minimal physical effort. No touches required beyond moving the purchased card.

Weaknesses: (Visibility) Other player can see only a subset of the Active Player's used cards.

Other actions not shown: Occasionally, the Visibility weakness is offset by the Active Player tilting his tablet to face the Other Player as a show of "good faith".

Figure 49: Interaction Strategy Flow Model #15



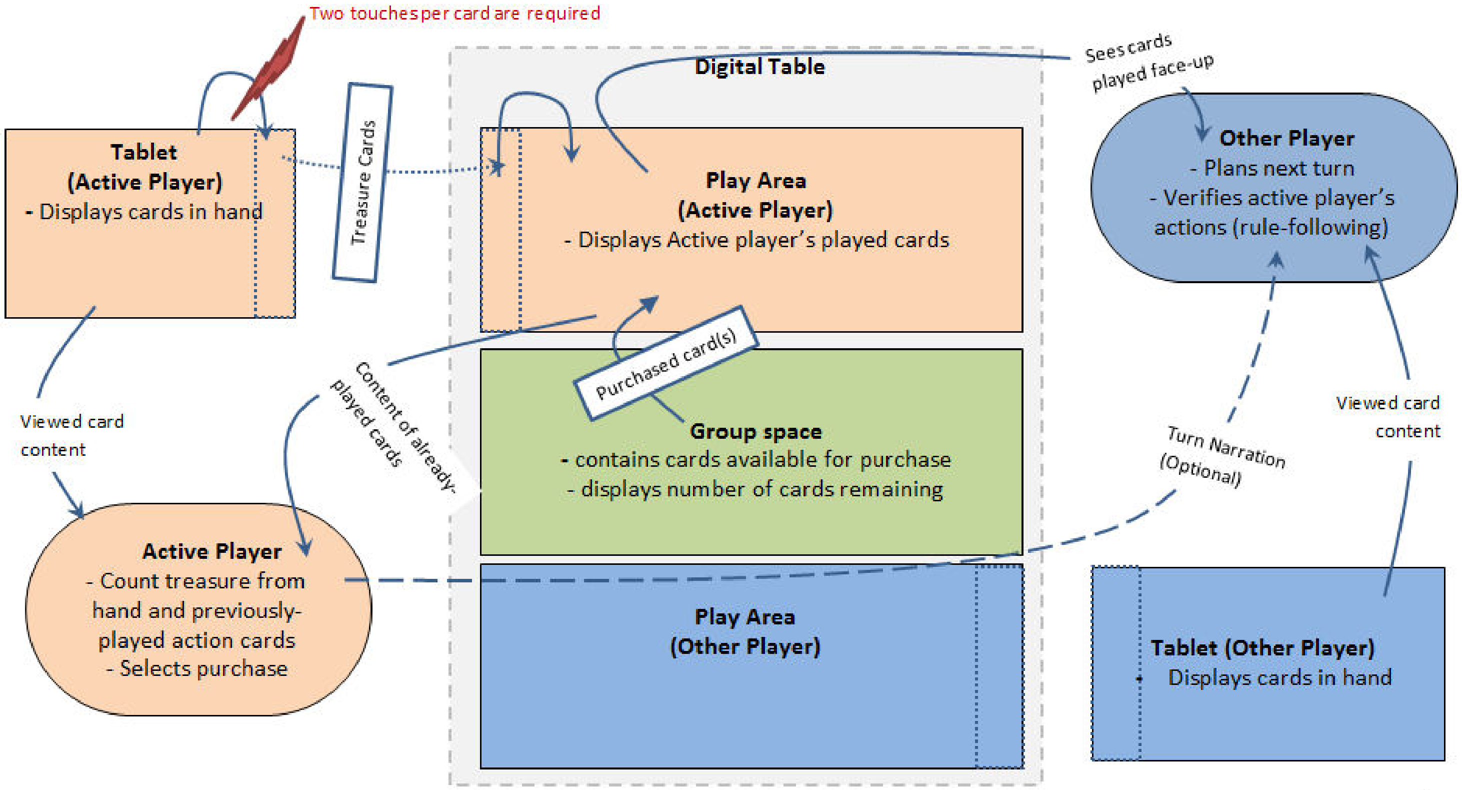
Strategy: Active player assesses (or recalls) the action cards played in the previous phase, and together with the treasure cards on the tablet (which he slides from the tablet to the bridge), calculates a treasure value. He then chooses his purchase card(s).

Strengths: (Physical Effort) Only one touch per card.

Weaknesses: (Visibility) Minor: Treasure cards are only half visible.

Other actions not shown:

Figure 50: Interaction Strategy Flow Model #16



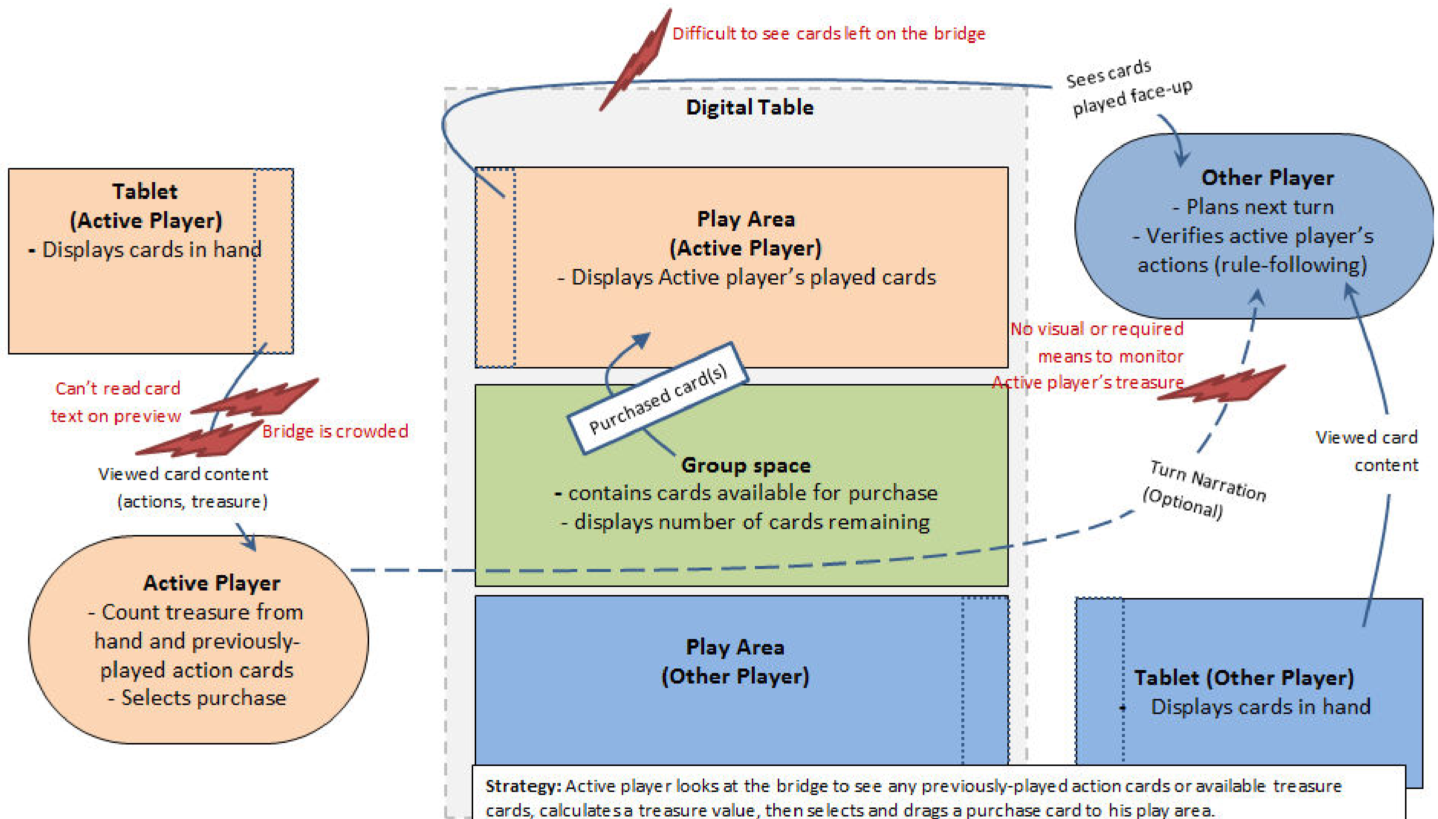
Strategy: Active player assesses (or recalls) the action cards played in the previous phase, and together with the treasure cards on the tablet (which he slides from tablet to bridge, and from bridge to table), calculates a treasure value. He then chooses his purchase card(s).

Strengths: (Cognitive Effort) Cards are clearly visible at all times and can be arranged to support external cognition.

Weaknesses: (Physical Effort) Two touches per card are required.

Other actions not shown:

Figure 51: Interaction Strategy Flow Model #17



Strategy: Active player looks at the bridge to see any previously-played action cards or available treasure cards, calculates a treasure value, then selects and drags a purchase card to his play area.

Strengths: (Physical effort) Minimal physical effort. No touches required beyond moving the purchased card.

Weaknesses: (Cognitive Effort) Actions from previous phase must be remembered, since cards on bridge are half-hidden, treasure cards are difficult to see on the bridge. No opportunity to move or group cards means little support for external cognition. (Visibility) Other player can [half] see only a subset of the Active Player's used cards.

Other actions not shown: Occasionally, the Visibility weakness is offset by the Active Player tilting his tablet to face the Other Player as a show of "good faith".

Figure 52: Interaction Strategy Flow Model #18

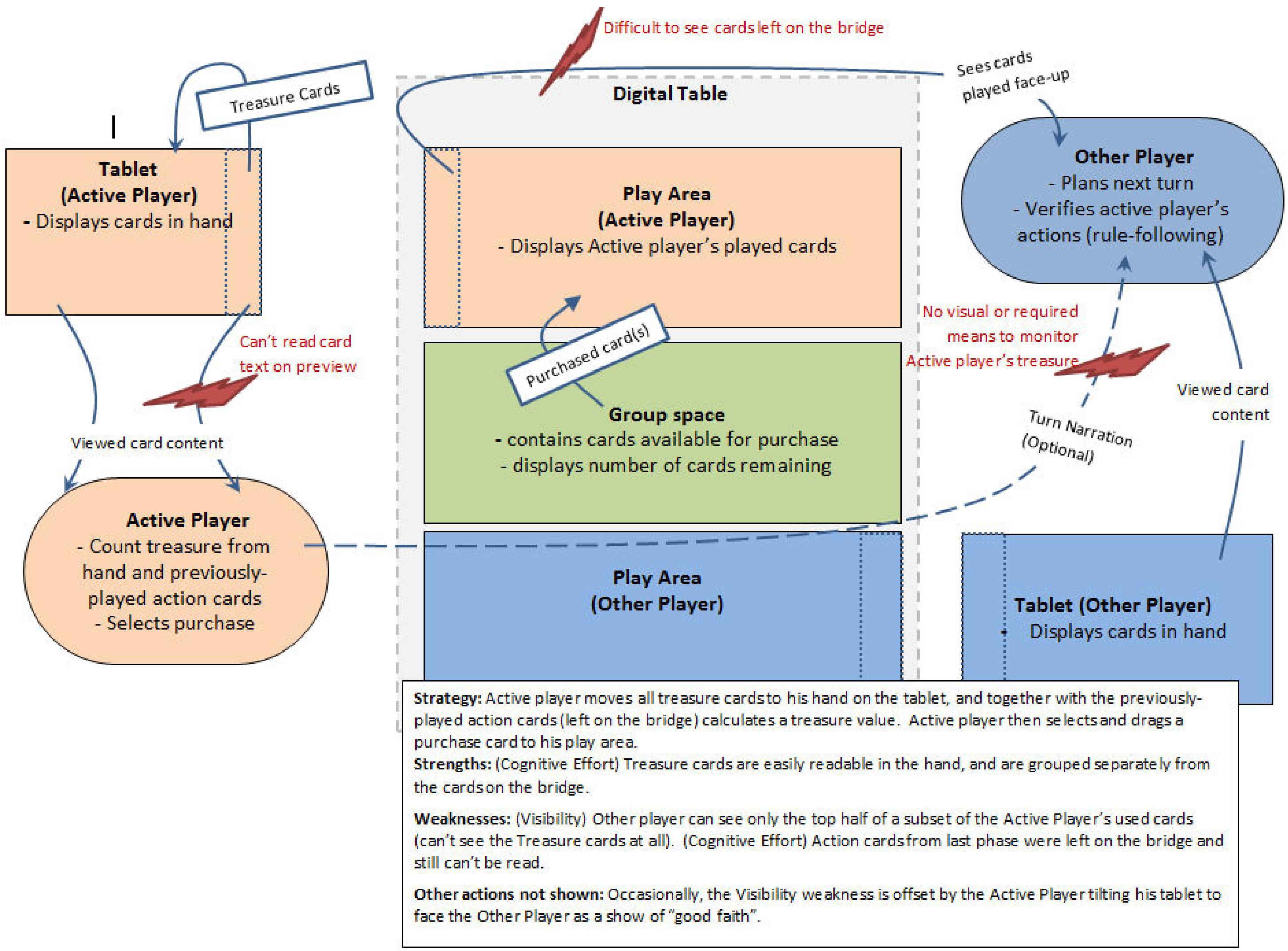


Figure 53: Interaction Strategy Flow Model #19

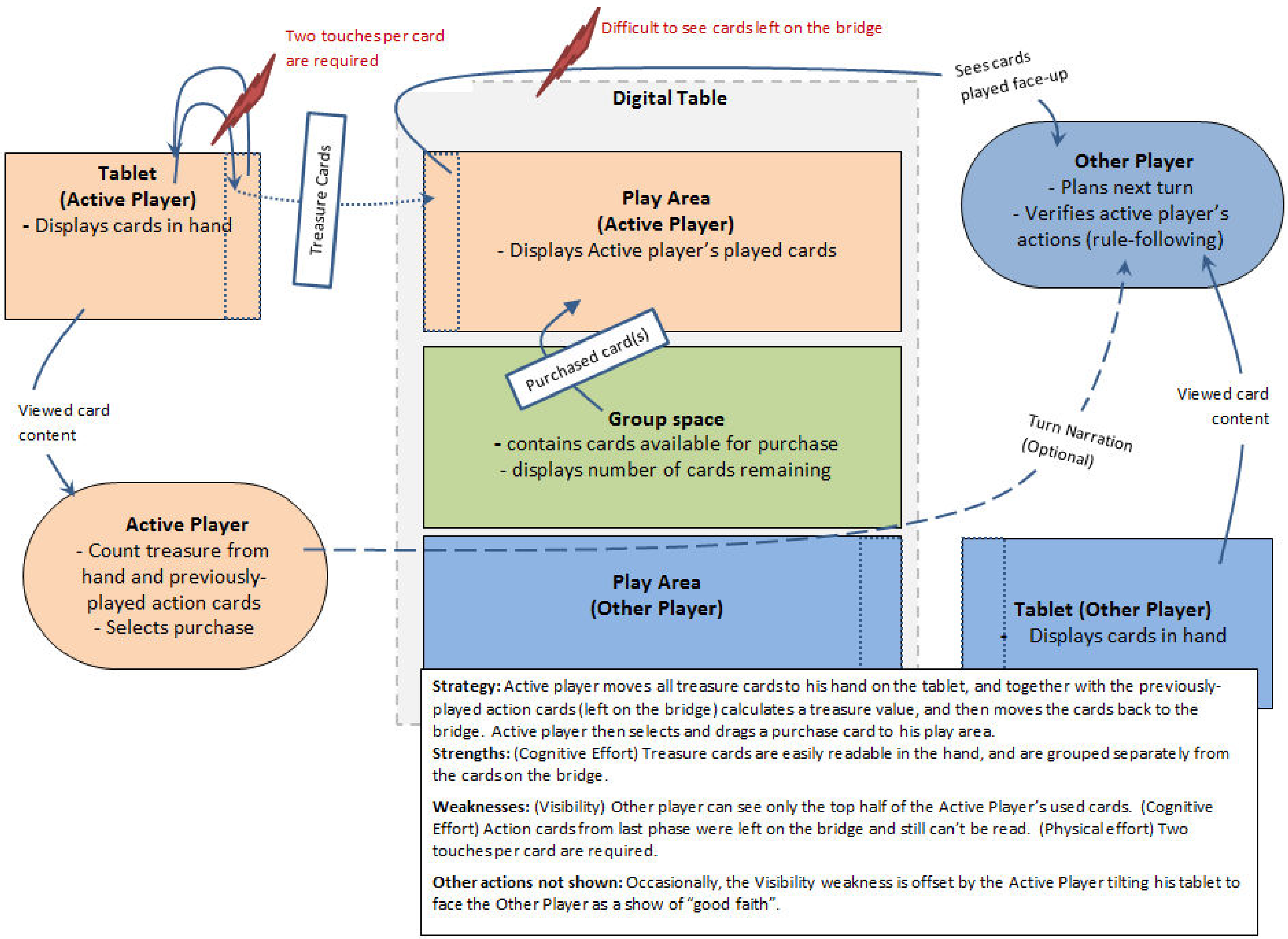


Figure 54: Interaction Strategy Flow Model #20

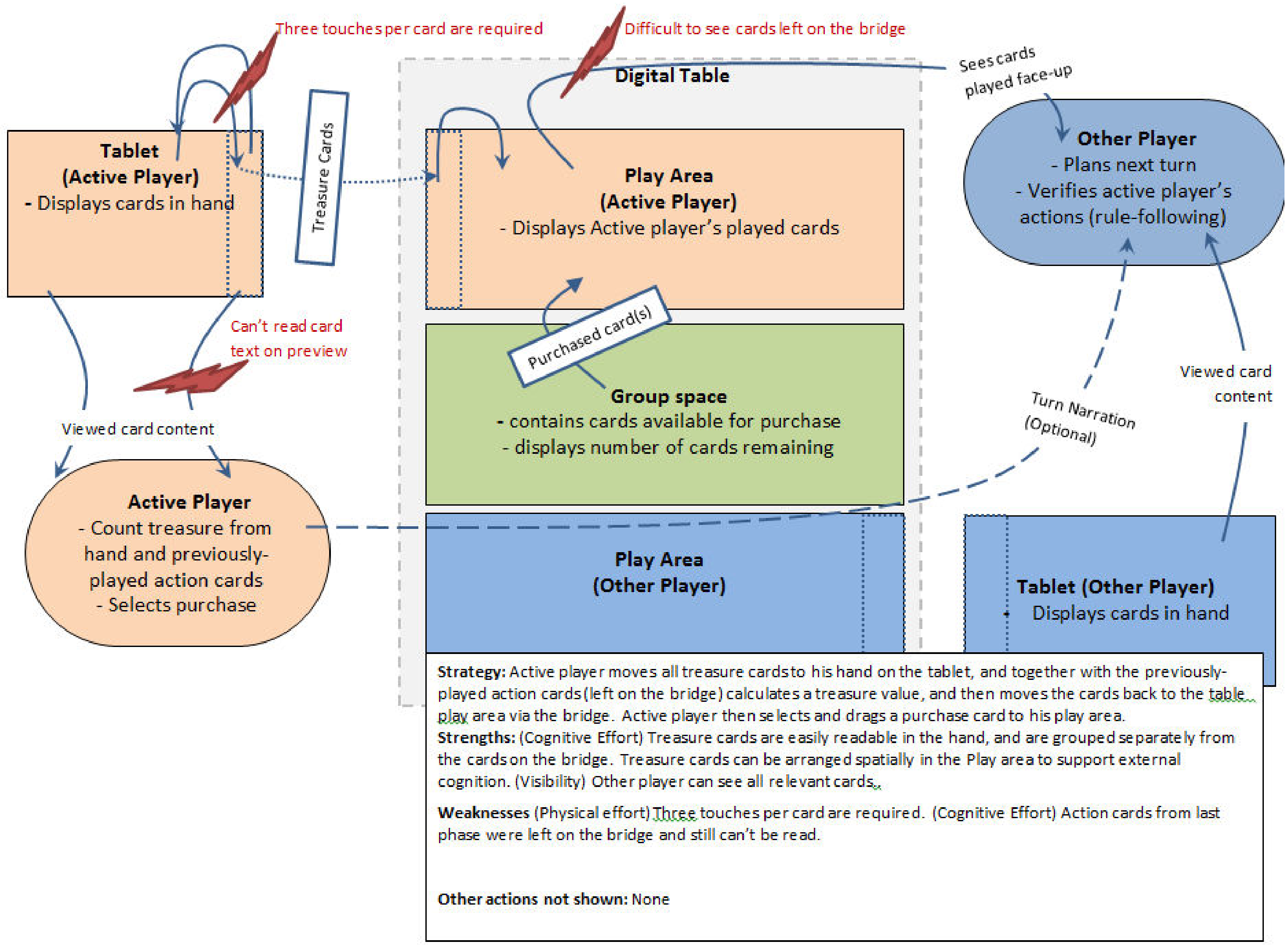


Figure 55: Interaction Strategy Flow Model #21

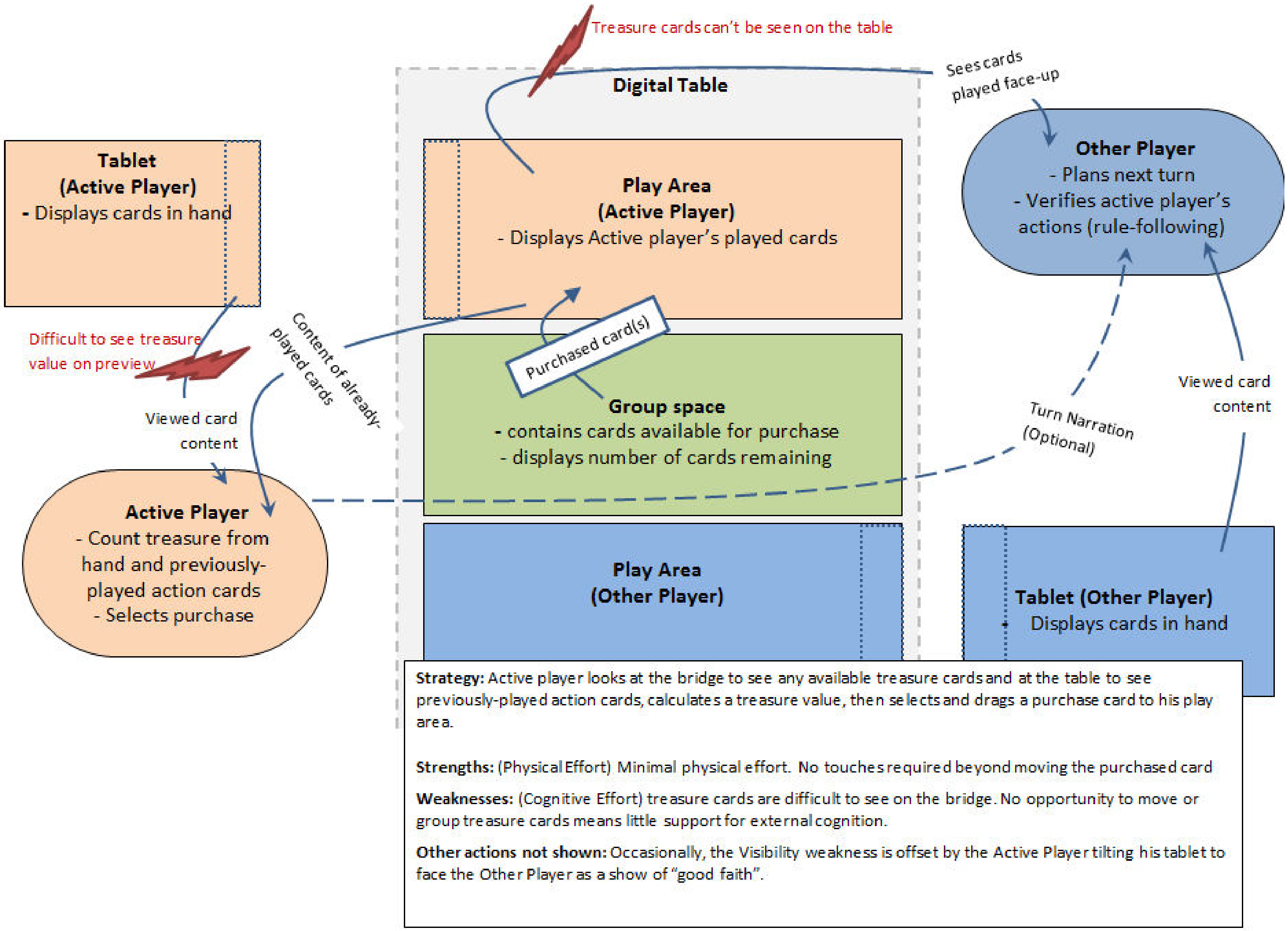


Figure 56: Interaction Strategy Flow Model #22

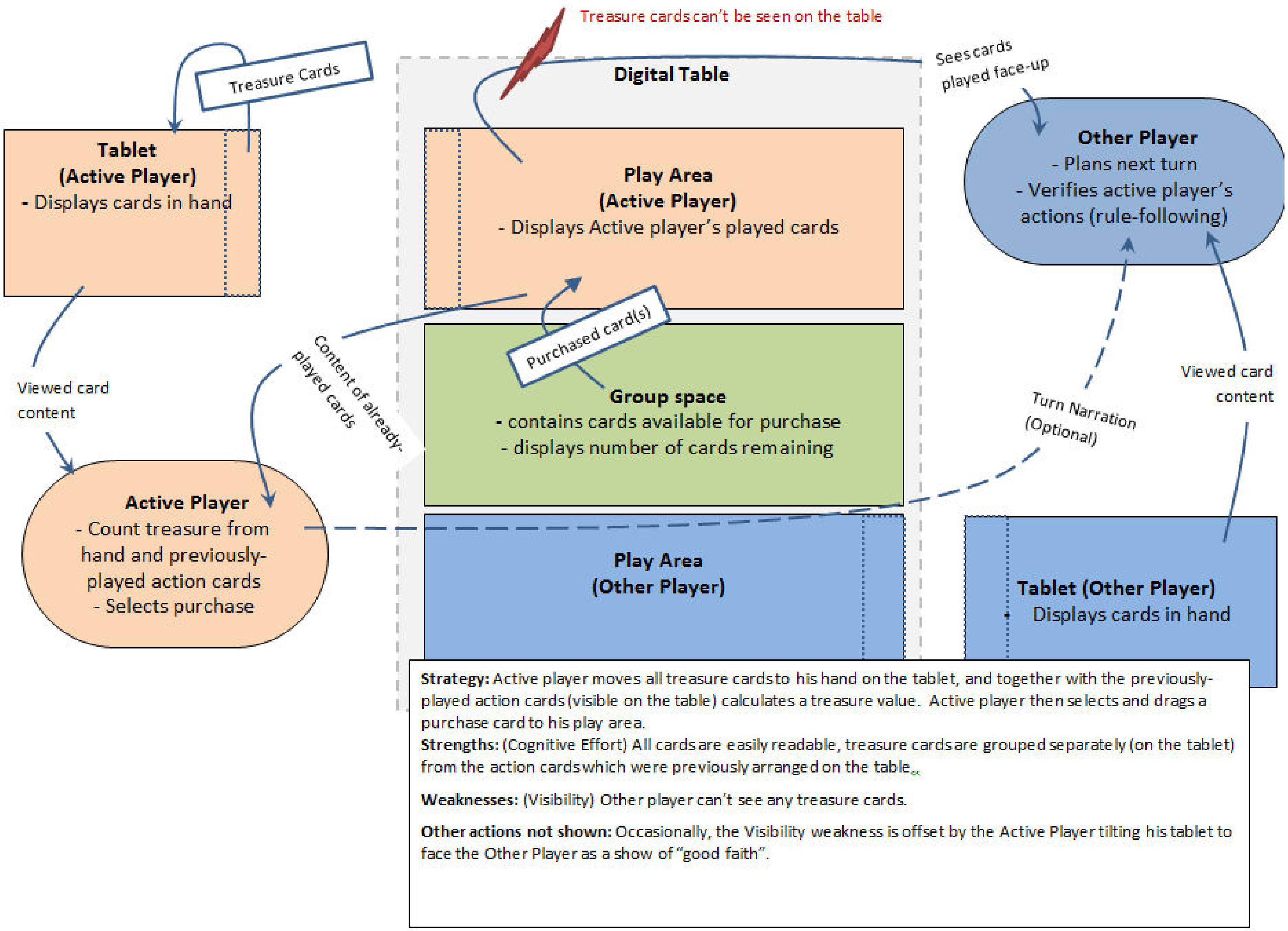


Figure 57: Interaction Strategy Flow Model #23

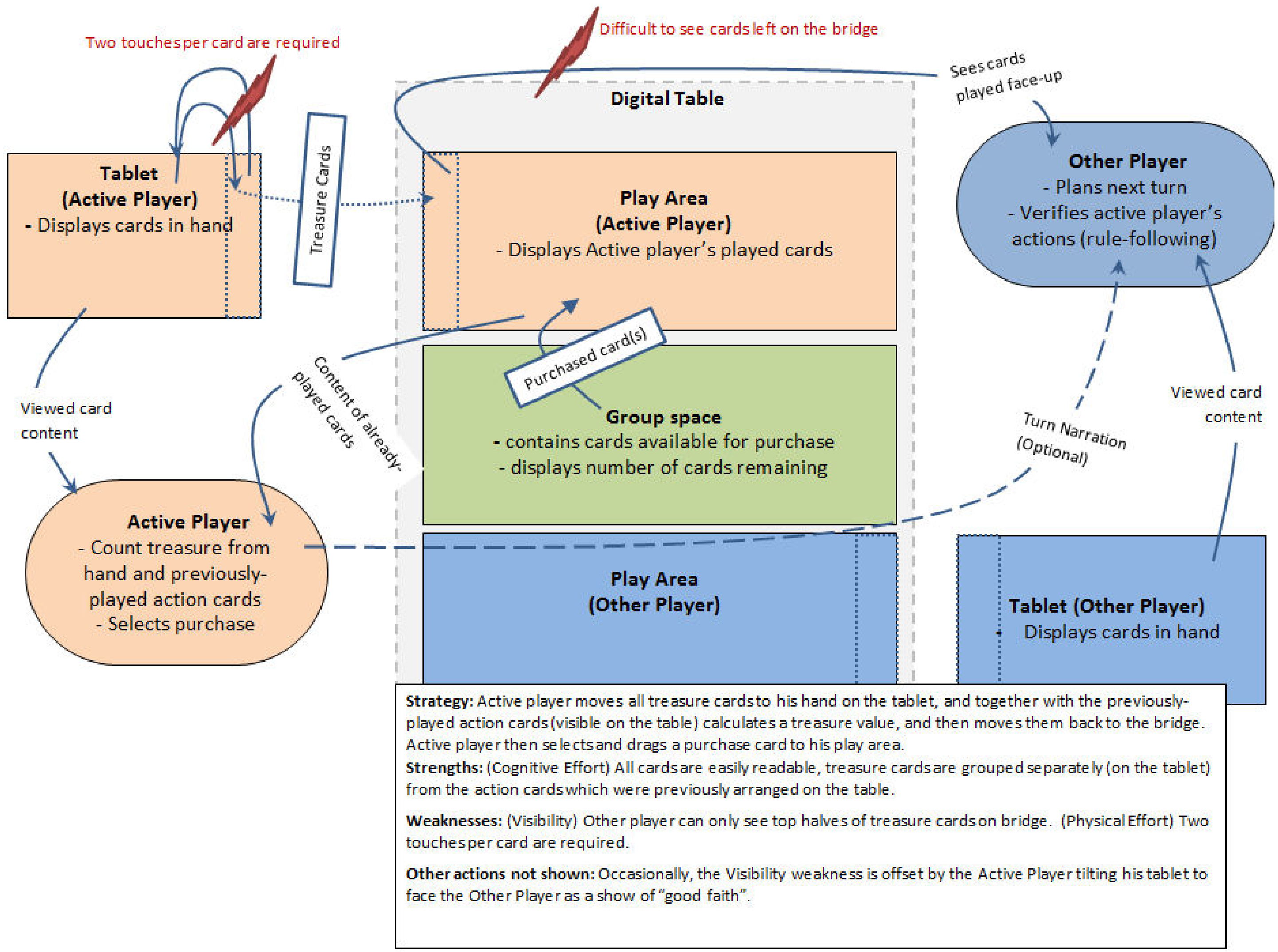


Figure 58: Interaction Strategy Flow Model #24

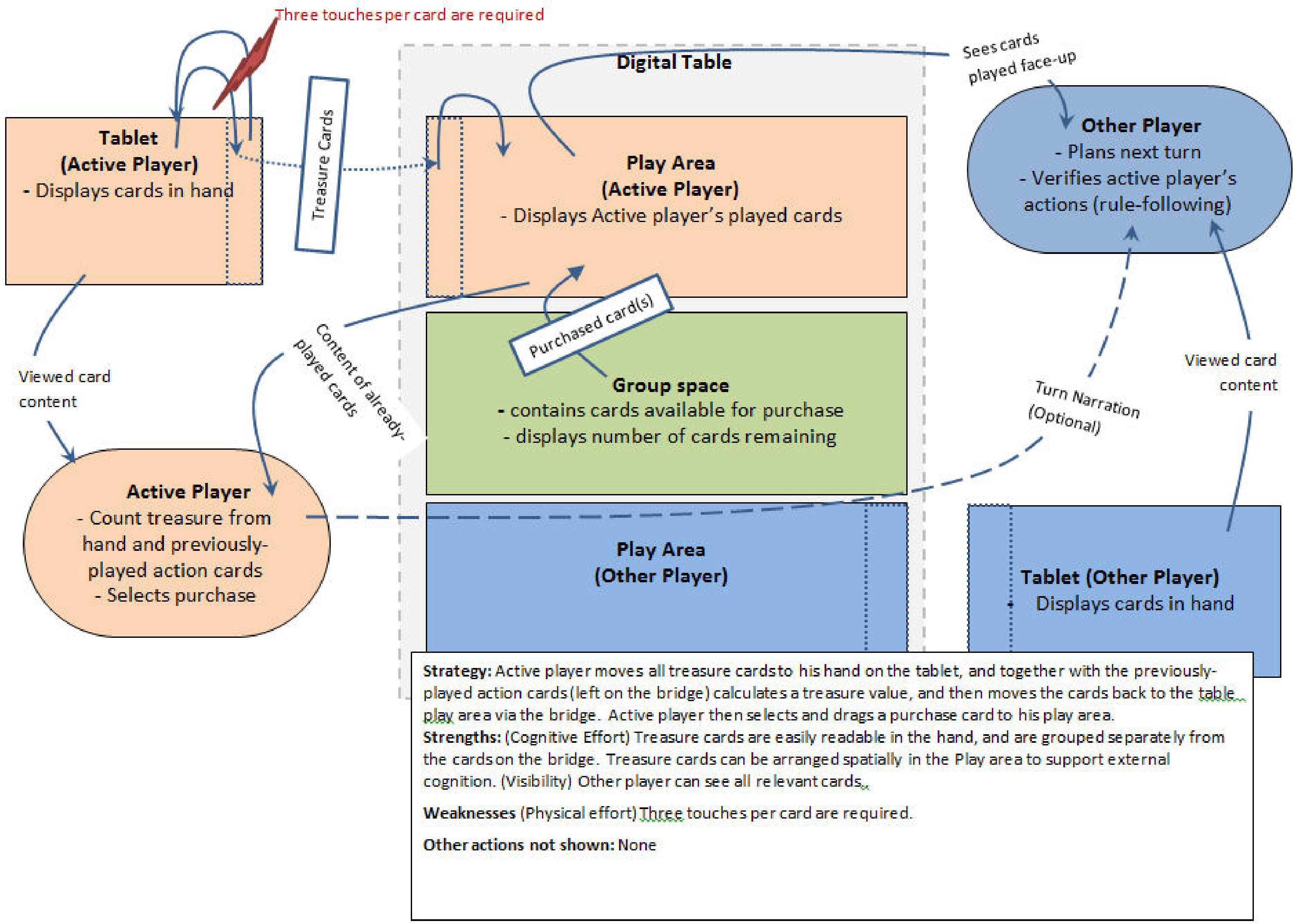


Figure 59: Interaction Strategy Flow Model #25

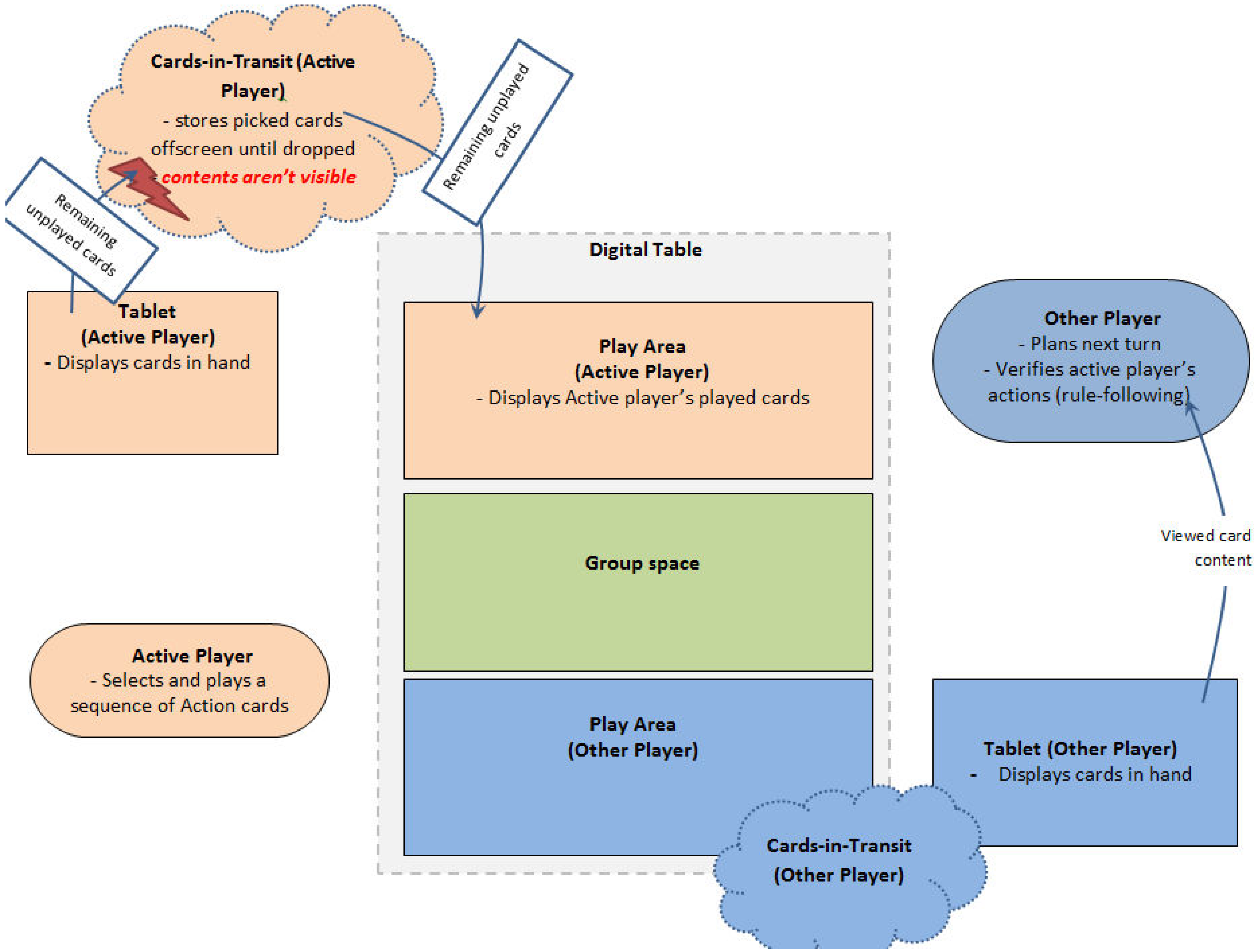


Figure 60: Interaction Strategy Flow Model #26

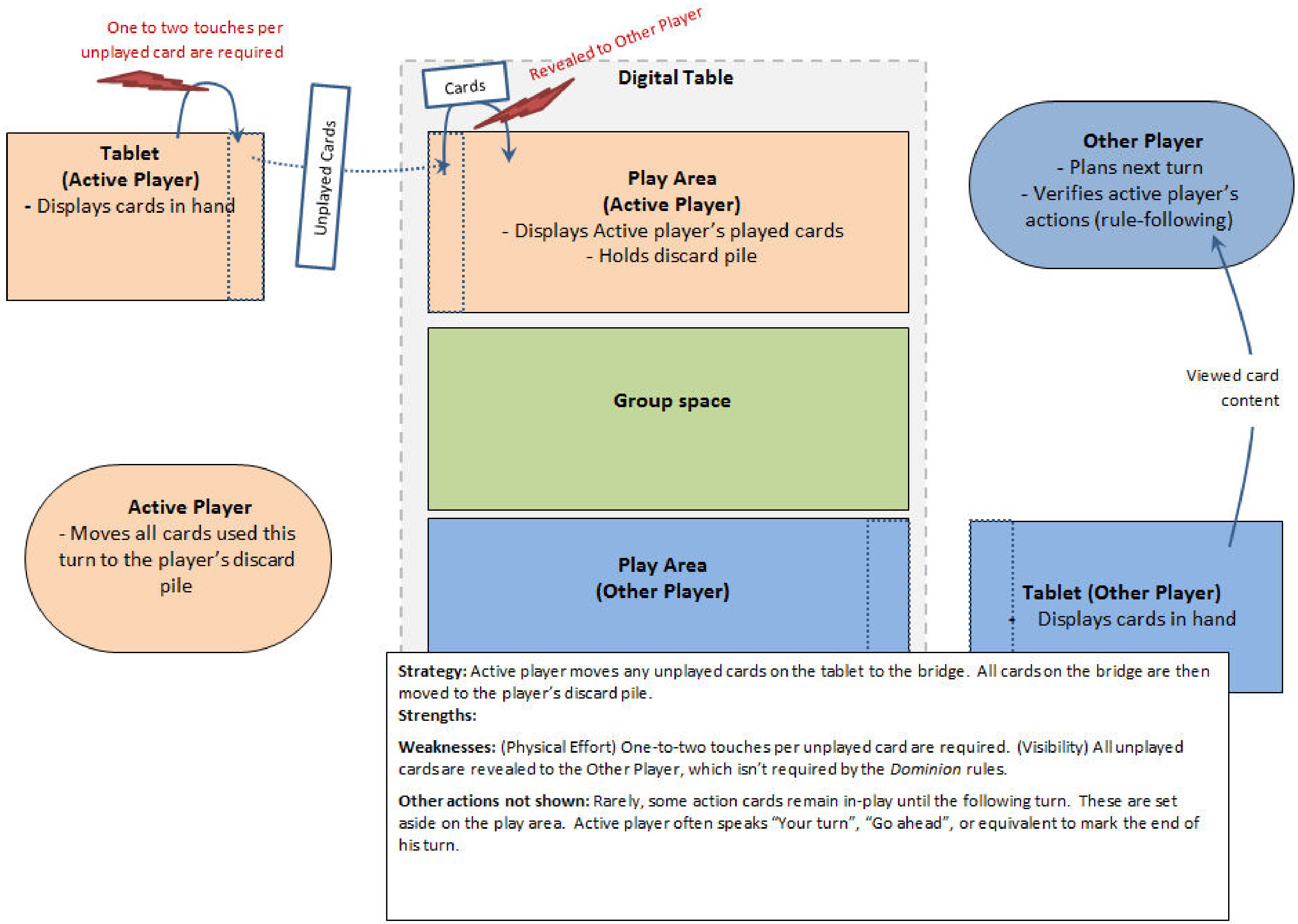


Figure 61: Interaction Strategy Flow Model #27

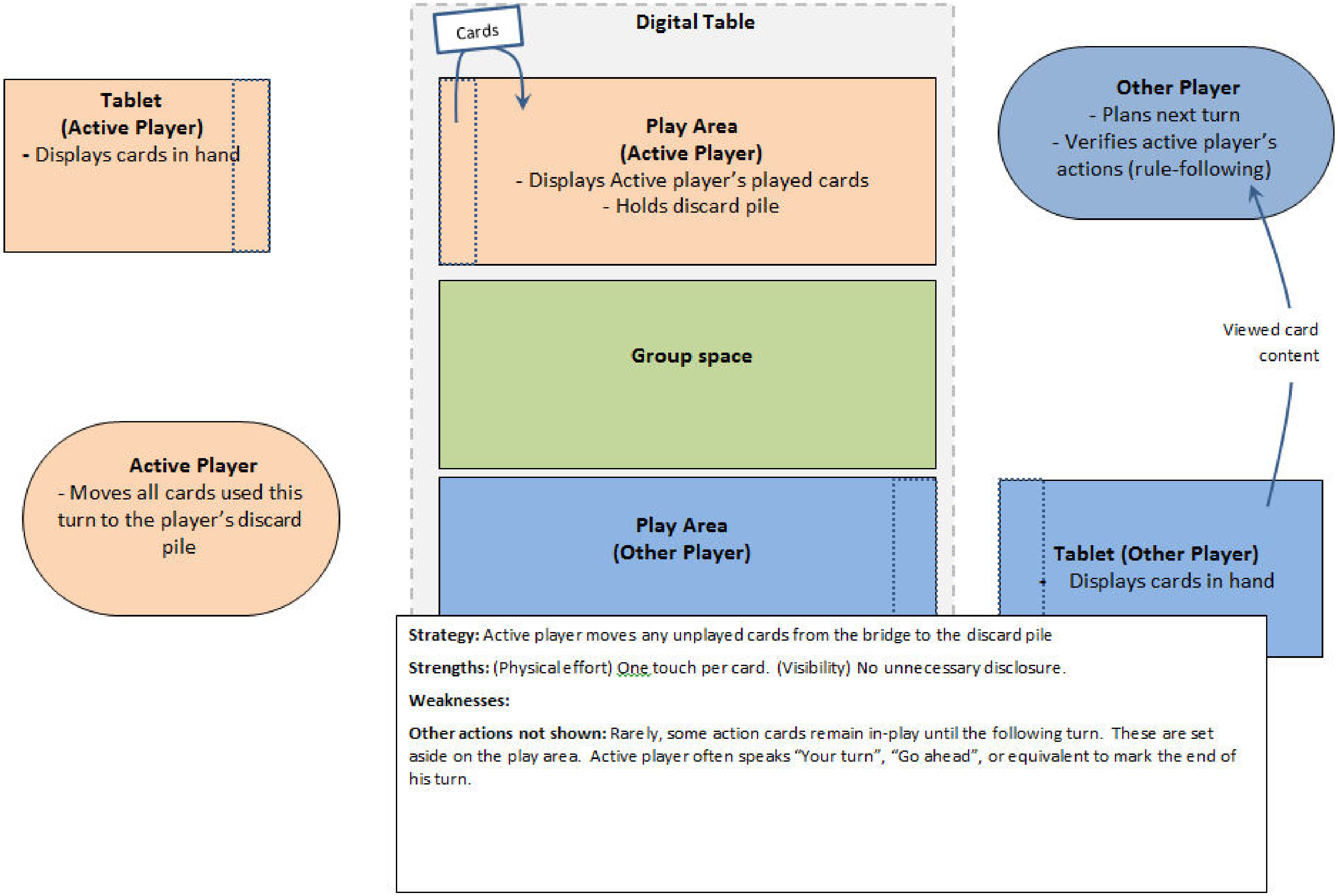


Figure 62: Interaction Strategy Flow Model #28