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Cross-Device Transfer in a Collaborative Multi-Surface Environment without User Identification

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***Abstract*— Combining large interactive surface computers (e.g., digital walls and tables) with smaller, multi-touch surface devices (e.g., smartphones and tablets) provides groups of users with both private and shared workspaces during collaborative (or competitive) activities. Such multi-surface environments introduce the need for effective interaction techniques that enable the transfer of digital content from one device to another, commonly known as cross-device transfer. Utilizing popular existing cross-transfer methods, such as Pick-and-Drop, in a multi-user multi-surface environment, however, require systems that can distinguish between users in order for the environment to accurately know who is transferring what content to what device. Yet, most commercially available digital tabletop systems are not capable of distinguishing between different users. Therefore, existing cross-device transfer methods must be adapted to work in such a user-information limited context. This paper presents a user study comparing the effectiveness of two adapted transfer methods in the context of a strategic digital tabletop card game task. The two transfer methods included a virtual portals-style method, called Bridges, and an adapted Pick-and-Drop method (A-PND). The studied transfer methods both supported the high-levels of card-transfer between private (tablet) and tabletop surfaces required by the game task. Also, participants' reported preferences were equally divided between the two techniques. An in-depth qualitative analysis of the study data revealed that each transfer method provided unique advantages and disadvantages for the game task, which aligned better or worse with different players' personal task goals.**

Keywords-cross-device transfer; digital tabletop; multi-touch surfaces; tablets; empirical study

I. Introduction

The single, shared surface provided by a digital tabletop has been shown to provide a number of collaborative task benefits, such as enhanced workspace awareness and task coordination [1, 2] . However, this shared surface introduces challenges for supporting information privacy [3]. Hagen and Sandnes [4] identify several collaborative situations where information privacy is important. For example, during a group meeting around a digital tabletop, one group member may want to share an email with others without showing their entire inbox. Other situations may involve confidential information (e.g. medical records) or restricted (e.g. military intelligence data). To support such situations, there is a growing desire to use individual private workspaces, such as laptops, tablets, or smartphones, in conjunction with large, shared displays [3, 5].

Providing collaborators with both private and shared devices, in turn, creates a need for intuitive, appropriate interaction methods that enable content to be moved between the digital tabletop and the private devices [6, 7]. The work presented in this paper is motivated by two key factors: recognition of the importance of developing efficient, easy-to-use interaction methods to enable the transfer of digital content across private and shared spaces (called cross-device transfer methods [7, 8]); and the need to explore the use of such transfer methods in the context of a realistic use case.

Thus, this research explores cross-device transfer in the context of a popular commercial strategic card game, *Dominion*[1]. This card game task presents several advantages for investigating cross-device transfer. *Dominion*, like many card games, relies heavily on the transfer of objects (i.e. cards) between spaces of various levels of secrecy (e.g. a player's hand, the table). This allows the study of cross-device transfer in a context where object transfer plays a central and frequent role. Moreover, using a popular game enables researchers to recruit experienced participants who are familiar with the task and intrinsically motivated to perform it (i.e. play the game).

Another contribution of this work is that it investigates cross-device transfer within the constraints of readily available digital tabletop technology. As will be discussed in Section 2, some commonly used cross-device transfer techniques require device capabilities, such as user identification or external object recognition, that are not available in common digital tabletop platforms. This research explores how existing transfer techniques can be adapted to suit this real-world constraint within the context of the card game task. We implemented several variants of existing cross-device transfer techniques in a custom digital tabletop version of *Dominion* to support card transfer between a digital table and players' personal devices (tablets). We then conducted a comparative user study of these transfer methods in a laboratory setting.

To set the context for the study, we overview existing literature on digital transfer and provide a brief description of the *Dominion* card game. Next, we describe the adapted transfer techniques, and present the user study and its results.

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II. RELATED WORK

Cross-device transfer has been an area of interest in multi-display environments (MDEs) for some time. Existing techniques broadly fall into three main categories: contiguous virtual workspace, bridging using a virtual portal, and bridging using a physical proxy.

Contiguous virtual workspace techniques are based on the physical configuration of the displays across which objects can be transferred. In this approach, displays are connected to a common software architecture that maintains awareness of the physical configuration of the displays (which is either static or tracked in real-time). This information is then used to provide a contiguous virtual workspace across devices. Thus, moving an object off the edge of one display moves it to the nearest edge of the adjacent display [9-12]. For example, in PointRight [12], several large screen displays and an interactive tabletop share a single mouse pointer. A static adjacency map, based on the room topology, determines where the pointer moves when it leaves the edge of a screen. In Stitching [9], an ad-hoc adjacency map is created, with the system inferring the user's intention to join two adjacent displays when a "stitch" gesture is drawn across the two displays (i.e. originating on one and ending on the other). This map can then be used to move digital artefacts between several tablet computers. Marquardt et al. [13] propose a similar tablet-to-tablet transfer capability between adjacent tablets, but instead establish the initial connection by tilting one tablet towards the other.

A disadvantage of this approach for transfer of digital objects between a digital table and a personal device, such as a tablet or smartphone, is the asymmetry of the display sizes. The large edge of the tabletop does not map well to the small edge of the tablet or smart phone. The ***virtual portals technique*** resolves this issue by providing a dedicated area (typically much smaller than the display length/width) on each device for transporting and receiving digital objects. With this technique, a digital object is first moved to a specified area (e.g. a "portal") in the originating device, which causes it to appear on a corresponding portal on the destination device [8, 9].

The previous two techniques both require people to drag the object-in-transit from the virtual portal (or display edge) to the desired location, rather than placing it directly where it is needed on the surface. ***Physical proxy techniques*** address this issue by using a physical object to manage the transfer, which allows for direct placement of the object-in-transit at the desire location by taking advantage of the 3-dimensional space around the devices. This approach involves binding a digital object to a physical object and then moving the physical object to the receiving display. This can be done using an arbitrary physical object [11] or, more commonly, a system-recognized object. For example, Rekimoto's [14] Pick-and-Drop (PND) technique allowed someone to "pick up" a digital object using a digital pen and "drop" the object directly onto a different display using the digital pen. This technique evokes the commonly-used drag-and-drop concept, and bears strong similarity to the familiar action of lifting and relocating a physical object. While using a digital pen is common [14-16], the proxy can take many forms, like a set of keys [5] or a "puck" [17].

In a multi-user environment, the PND technique 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". Yet, this level of user-identification is not possible with most commercially available multi-touch digital tabletop systems, without specialized software or external tracking devices. Also, the only object that can be assumed across common digital tables and personal surface platforms is the fingers (and by extension, hands) of the people using these multi-touch devices. Our work explores an adaptation of the PND transfer method that binds digital objects to a person's hand during the transfer.

III. CROSS-DEVICE TRANSFER IN THE DOMINION DIGITAL TABLETOP CARD GAME

Dominion is a 2-4 player deck-building game, in which each player draws a hand of cards from a number of decks located on the table each turn, and the actions they may perform are defined by the cards they draw. These actions include "buying" additional cards from a shared bank of cards or "attacking" other players (i.e., forcing them to discard cards). At the end of each turn, cards are discarded from the player's hand of card back onto their discard pile on the table. Players must take care to maintain awareness of their opponent's actions, as a player's strategy may need to be altered to react to an opponent's actions.

To facilitate the investigation of cross-device transfer techniques in this game, a custom digital tabletop software application of the *Dominion* game was developed that incorporated the use of multiple, portable tablets to provide each player a private digital space (Fig. 1). In this digital *Dominion* game, cards can be freely moved and rotated using direct touch manipulation.

To investigate cross-device transfer in the *Dominion* context, we selected two existing cross-device transfer techniques and adapted them to the specific constraints of our

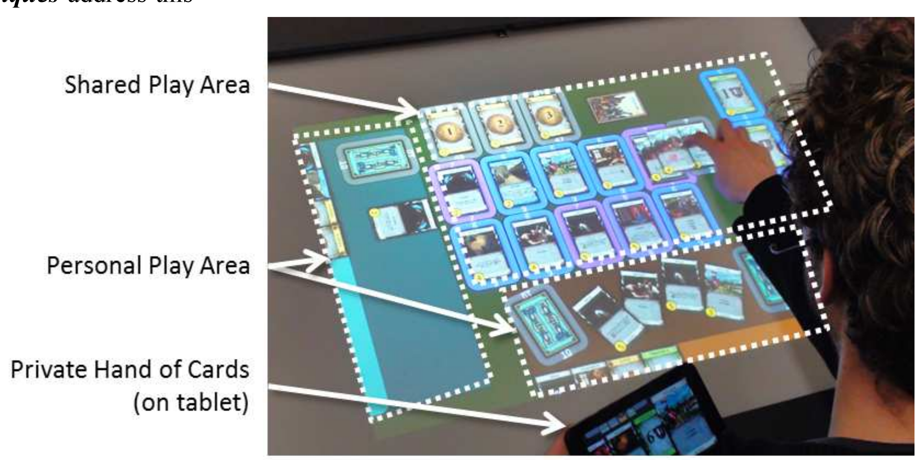

Figure 1. Dominion digital tabletop conversion

digital tabletop card gaming context. More specifically, we developed a virtual portals technique, called Bridges, and a Pick-and-Drop (PND) [14] physical proxy technique. A contiguous virtual workspace technique was not developed due to the asymmetry of edge sizes between the digital tabletop and the tablets. The following subsections describe how these two transfer techniques were designed to suit the constraints of our digital tabletop card gaming context.

A. *Bridges*

In the "Bridges" method, each player was provided a matching pair of interface regions, called "Bridges," that provided a virtual portal from the bottom of their personal play area to the top edge of their personal tablet, as illustrated in Fig. 2. The Bridges' positions were fixed on the devices. Each player's Bridges were color-coded to match the player's Play Area.

When a card was dragged to either of these two Bridges, the top half of the card would appear on the table Bridge, while the bottom half of the card would appear on the tablet Bridge (Fig. 2). Once on the Bridge, the card can be moved onto the target device by moving it off of the corresponding Bridge, moved back to the originating device by moving it off the originating Bridge, or simply left on the Bridges.

To simplify manipulation of cards, cards on the tablet device were always shown face-up. If the card on the Bridges originated from the table, it maintained its original face-up/face-down status on the table Bridge. Thus, a card could have its top half displayed face-down on the table Bridge and its bottom half displayed face-up on the tablet Bridge. Cards

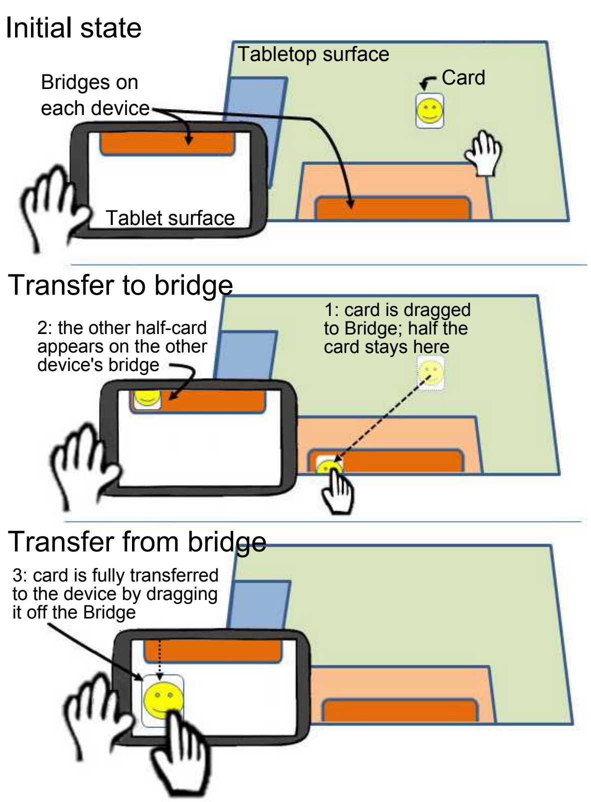

Figure 2. Cross-device transfer via Bridges.

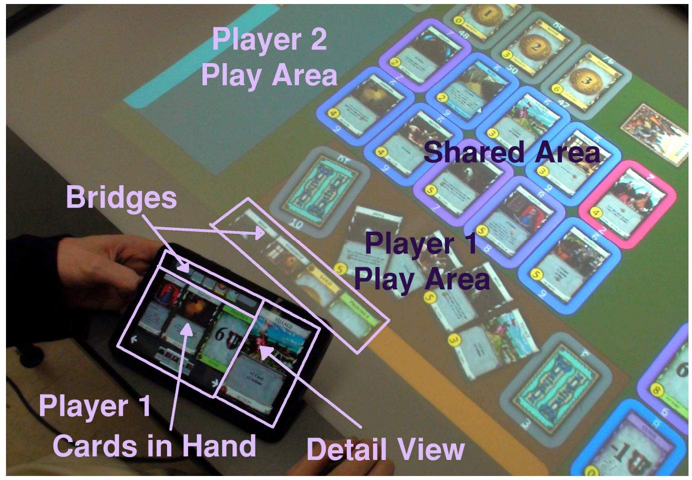

Figure 3. The Bridges interface of the Dominion game, as seen by Player 1. Each player has access to a private space on their tablet, to a personal Play Area shaded in a different color, and to a shared area.

transferred from the tablet to the table were always transferred face-up. Fig. 3 shows the Bridges interface in the digital tabletop *Dominion* game.

B. *Adapted Pick-and-Drop (A-PND)*

The constraints of our multi-touch tabletop environment required a number of adaptations to be made to the original PND concept. The primary constraint was the lack of user identification information available from the digital tabletop (a common characteristic of many multi-touch tabletop platforms). This constraint, coupled with the concurrent, multi-player card interaction common during *Dominion* game play, impacted our ability to accurately associate the originating and receiving device for simultaneous PND transfers by different users. We first describe how we addressed the user identification issue, and then how "picking" and "dropping" was implemented in a touch-based input environment.

1) *User Identification*

In order to address this issue, we drew from territoriality research [18], which has shown that space directly in front of a person at a table is typically reserved (through social protocol) for use by that person. Thus, we provided a virtual "Play Area" on the digital table in front of each player. Touches in these Play Areas were assumed to be from the associated player, and would be conceptually bound to their hand until they dropped the card on their tablet or back onto their own Play Area (see Fig. 4). The Play Areas were shaded in a different color for each player. Outside these Play Areas, a player could not pick up or drop cards using the A-PND technique. As several decks of purchasable cards were located in a shared area, a player could, for example, drag a card from one of these decks into their Play Area, and then pick it up using the A-PND technique. Similarly, to move a card from their tablet to a shared trash pile, they could first drop it in their Play Area and then move it to the trash pile.

To enable player's to temporarily take control of the shared area, for the purposes of "picking" and "dropping" directly to that area, we implemented two territory control mechanisms, an Explicit Control and an Implicit Control method. With

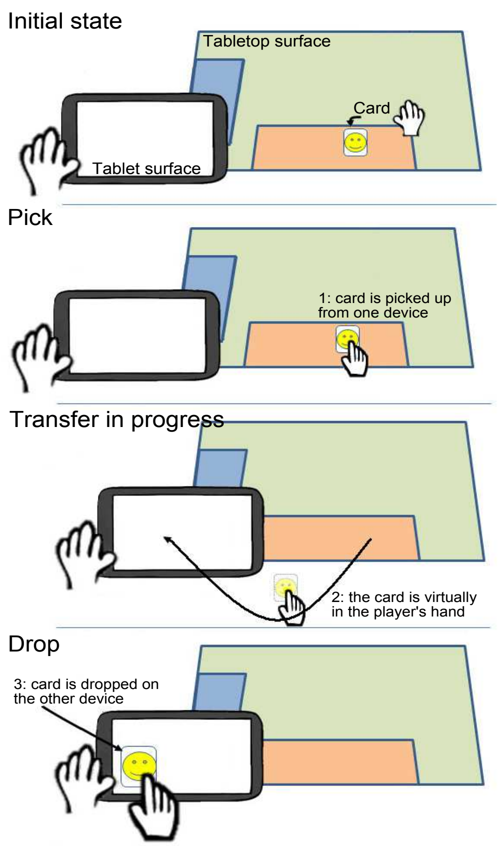

Figure 4. A-PND from the table to the tablet.

Implicit Control, the act of touching and holding any *empty* spot in a player's own Play Area, would extend their area to cover the shared area. This would give them control (for A-PND purposes) of the shared area. With Explicit Control, players were provided with a shared digital token labelled "I Control the Centre." Moving this token into a player's Play Area extended their area to cover the shared area until the token was moved back to the shared area.

2) "Picking" and "Dropping"

"Picking" up a digital object in the original PND technique involved pressing a button on a digital pen while it was touching the desired virtual object on the originating device, and then releasing the button while touching the pen to the receiving device to drop the object. As touch, not pen, input was only available on our table and tablet devices, an alternative method was needed to initiate the PND process, and to indicate which cards should be "picked" up. Picking up cards from the digital table was triggered from a contextual pie menu opened by tapping a card. Once opened, players could pick up a number of cards (in *Dominion*, cards are often drawn five-at-a-time from the player deck). Several cards could thus be transferred at once to minimize the level of effort required to transfer multiple cards in a single turn.

Cards were dropped on the digital table when a player touched it while they were transferring cards. If there was already a deck of cards at the drop location, the dropped cards were added to the top of the deck, and automatically adopted the deck's face-up/face-down status. If the location was empty, a new deck was created if more than one card was being transferred, and the direction (face up or down) was taken from the cards' state on the originating device (table or tablet).

On the tablet, cards were picked up or dropped using an upward or downward swipe gesture (i.e. an upwards or downwards drag gesture), respectively, intersecting the top edge of the tablet screen (see Fig. 5). Several cards could be transferred to the table at once by dragging multiple cards off the top of the tablet screen. Similar to the drop behaviour on the digital table, a drop action on the tablet would drop all cards being transferred onto the tablet at once.

Two specific cases were implemented to support common manipulations. First, when the tablet was empty (common at the beginning of each turn since cards are often discarded at the end of a turn), touching anywhere on the device screen would drop any cards being transferred to the tablet (a downward swipe would also still work). Second, when cards were individually moved from the tablet to the player's Play Area on the table, they were dropped face up regardless of their original orientation. Typically, cards would be picked up from the player deck, which was face down, moved to the tablet, and played one by one by removing them from the tablet and revealing them in the Play Area. In games other than *Dominion*, where cards from the Hand of Cards may be put back on the digital table face-down, a different design choice may be more appropriate.

IV. USER STUDY

A laboratory-based user study comparing the three cross-device transfer techniques (Bridges, A-PND Implicit Control, and A-PND Explicit Control) was conducted using actual competitive game scenarios between participating players. The study used a mixed-methods study design that involved quantitative (predominantly in the form of interaction logs and questionnaire responses) and qualitative (via video and audio recordings and observer field notes, as well as open-ended survey questions) study measures. The goal of the study was to examine the effectiveness of cross-device transfer mechanisms with particular focus on player awareness (understanding of changes in the state of the game, as well as a sense of an opponent's actions and strategy), effort (especially the perception of the level of effort as appropriate for the desired

Figure 5. A downward swipe gesture on the tablet is used to drop any cards being transferred onto the player's tablet.

goal), and enjoyment (in particular, the transfer method should not *interfere* with the players' enjoyment of the overall game experience). A within-subjects design was used, where each group of players performed the study under each of three study conditions.

A. Participants

Twenty-eight university students were recruited. Players were required to sign up with a friend and to have previous experience with the commercial version of the *Dominion* game to minimize social discomfort and game learning effects. Participants ranged in age from 20 to 44 years old (mean: 27, SD: 6.5), including 5 females and 23 males. Sessions of three games ranged in length from 1.5 to 3 hours, and each participant received $20 (CAN) remuneration.

B. Equipment and Setting

The study was conducted in a university human computer interaction laboratory. A custom-built infrared laser light plane (LLP) digital table was used with a surface size of 90x130 cm and a display resolution of 1280x800 pixels. During the study sessions participants sat at adjacent sides of the digital table with one participant positioned along a long edge of the table and the other positioned along the short edge to the first player's left. Each participant was provided a 7-inch Samsung Galaxy Tab tablet computer, which was preconfigured to be associated with the player's position at the table to facilitate the cross-device transfer techniques being studied.

C. Procedure

Participants first completed informed consent forms, then were asked to complete a background questionnaire that gathered demographic information and their prior game play experience. They were then given a short demonstration of the experimental hardware systems. Each group of two participants played three games in a row, one for each condition. The order of presentation of the three conditions (Bridge, A-PND Implicit Control, and A-PND Explicit Control) was counterbalanced. In addition, three different sets of ten previously-selected *Dominion* cards were used for the banks of purchasable cards, always presented in the same order to avoid interfering with the counterbalancing of the conditions. Learning effects related to card sets were not anticipated, as all players had previous *Dominion* experience.

Before each condition players were given a brief demonstration of the system and the cross-device transfer technique. Most groups also took 4-5 minutes at the start of each game to read aloud the description of each available card in the bank for the session. After each condition, players were asked to complete a post-trial questionnaire about that condition. Questions included 7-point Likert scales and open-ended questions to elicit feedback on their gameplay experience, perceived level of effort, and game awareness.

After the final game and post-trial questionnaire were completed, participants were given an opportunity to ask any final questions or provide general comments about the study. They were then thanked and paid for their participation. The study's design and procedure was approved by the local Office of Research Ethics.

D. Data Collection

Sessions were audio and video recorded. For each game play session the tabletop's user interface was captured in real-time using screen capture software. Players' system interactions were also captured in computer logs. Observational field notes were recorded by the researchers throughout the sessions, who were located several feet away from the digital tabletop (to allow participants to relax into their familiar game playing habits). Session video recordings were coded using custom video-coding software.

V. Results

Analysis of the study data revealed that, in general, both the A-PND (Explicit and Implicit) and Bridges transfer methods sufficiently supported the, on average, 322 card transfers that occurred per game. The following subsections first present players' reported experiences and preferences, and then a qualitative analysis of the advantages and disadvantages of these two techniques. During the study sessions, players almost never used either the Implicit or Explicit Control methods for controlling the shared play area during the A-PND conditions. Thus, for the comparative analysis provided in subsection B A-PND Implicit Control and A-PND Explicit Control are aggregated into a single A-PND condition that is compared with the Bridges condition.

A. Player Preferences

Participants were often quite vocal about their impressions of the interaction design of each transfer method, 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. Comparing the Bridges conditions, one player reported that "having the tableau [Bridges] that was partly on both screens was beautiful and very helpful", while another reported that "the hand [of cards] being in two places was a little unwieldy". Player comments about A-PND were similarly contrasting. One player reported that "Pick up [A-PND] is a much better mechanic [than Bridges]", while another player commented that "Picking up cards was NOT intuitive".

Similar to these conflicting qualitative comments, statistical analysis of player's quantitative feedback on each transfer method revealed no consistent preference or perceived utility or performance for one transfer method over the other. The post-condition questionnaire elicited player feedback on three main themes, enjoyment, support for awareness, and level of effort. A repeated measures Analysis of Variance (ANOVA) test was conducted on each question. In order to account for the dependency among players within the same group (i.e. each pair of players who played the same game), players' scores were collapsed into a single group score. Table I shows the mean ratings, with standard deviation, for each question and condition, along with the ANOVA test results. The analysis revealed generally positive ratings across most enjoyment and awareness questions (with mean ratings of 5.4 to 6.3 out of 7), with lower ratings on questions pertaining to level of effort (mean ratings of 4.3 to 4.7 out of 7) and awareness of the other player's actions (mean ratings of 4.3 to 4.6 out of 7).

Consistent with the contrasting preference comments reported above, the ANOVA results revealed no significant difference in preference ratings across the three transfer conditions. The qualitative analyses, presented next, suggest that the lack of clearly preferred transfer method across players was due to the fact that the effectiveness of each transfer method was highly player- and context-dependent. The following sections provide a more in-depth look into this issue.

B. *Comparison of A-PND and Bridges Transfer Methods*

An in-depth qualitative analysis of the study data revealed four main themes related to the advantages and disadvantages of the A-PND and Bridges transfer methods: cognitive effort, physical effort, flexibility, and privacy and secrecy.

1) *Cognitive effort*

Some players found that the A-PND transfer method required more cognitive effort than the Bridges method, as illustrated by the player comment, "not seeing cards that are 'in the ether' [cards in transit] while picking up confused me a couple of times." With this method, the burden to keep track of how many cards were picked up was placed on the player. This led to two observed areas of difficulty. First, players felt that they needed to take care to attend to each card pickup as it was initiated. If the pick-up animation was missed or occluded from view by their arm or hand, then the player (especially in their first few interactions) would be uncertain of how many cards they had picked up.

Similar uncertainty regarding the number of cards being transferred occasionally arose during transfers from the tablet to the digital table, particularly when a player's swipe-off-the-top-edge gesture was not recognized by the tablet. This uncertainty led to either the player picking up too few cards, forcing them to go back to the tablet and pick up additional cards, or the player picking up too many cards because they mistakenly thought a previous pick-up was unsuccessful. Overall, these situations led to additional effort and player frustration.

In contrast, the Bridges transfer method required minimal cognitive effort to maintain awareness of the state of any cards involved in a transfer operation. By design, the Bridges method had no modes and never hid the state of any object involved in the transfer. Since players were required to manually move each card onto the local Bridge (compared to A-PND's menu-initiated pickup), players appeared to find the transfer method more explicit; players never appeared unsure of whether an attempted transfer was successful or how many cards had been moved. As a result, players frequently commented that Bridges was the "easier", "more natural," and "more intuitive" of the two transfer method. Players also reported that Bridges made it "easier to keep track of cards", and that its simplicity was "beautiful".

An unexpected use of the Bridges method was adopted by several players, whereby they would only partially transfer cards, and leave them sitting on the Bridges interfaces, half on the table (face-down) and half on their tablet (face-up). In this partially-transferred situation, if a player wished to play a particular card from the Bridge, they needed to remember that the desired card was, for example, the 2nd card from the right. This occasionally led to players dragging the wrong card off the table Bridge, which then required additional actions to correct this mistake.

2) *Physical effort*

While A-PND was the more cognitively challenging of the two transfer methods, it was found to be the more physically efficient method. When transferring cards from the Play Area to the tablet (and vice versa), A-PND allowed users to move cards from their initial locations directly to their intended destination. In contrast, Bridges required that all cards, whether originating in the shared area or the player's personal Play Area, to be moved across the table to pass through the local Bridge, which created an interaction bottleneck. When managing many cards, this "extra step" imposed by the Bridges method was seen by players as an increasingly tedious obstacle, as evidenced by the comment, "Not having the ability to drop a

TABLE I. POST-CONDITION LIKERT QUESTIONNAIRE RESULTS, BASED ON A 7-POINT SCALE WHERE 1=STRONGLY DISAGREE AND 7=STRONGLY AGREE.

Theme	Question	Pick-and-Drop Implicit Control		Pick-and-Drop Explicit 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 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
	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 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
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

bunch of void cards [cards being discarded] at an area added so much more effort. The hand zone [Bridges] was super annoying. […] It just added more clicks to the game." The "partial-transfer" strategy in Bridges helped to minimize the number of actions necessary to gain access to cards on the tablet, which may explain, in part, why players chose to use this strategy when possible.

3) Flexibility

One of A-PND'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 at 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 not offered by the Bridges simple design. There is no basis by which to judge the player's intent for the cards at the time of the transfer, as all transferred cards must pass through the Bridge with no mechanism to indicate their ultimate destination on the table. Many players commented upon this—appreciating that A-PND offered "a lot of flexibility with regard to how cards are played." In another player's words, "with this [A-PND] system, 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."

While not as flexible in this regard, many players found ways to repurpose Bridges' rigid design to provide other advantages. A common way in which this was accomplished was with the previously mentioned partial transfer strategy. This resulted in the tablet displaying only a small preview of the cards located on the Bridge. Effectively, the Bridges became an additional container, with the cards it contained (i.e. those left in the "half-transferred" state) remaining readily available for use on either the tablet or the digital table, as suited the player's needs.

4) Privacy and secrecy

As aforementioned, Bridges was less context-aware than A-PND. As a result (and in order to keep the tablet interface simple), Bridges applied a default behaviour: all objects transferred between the tablet and the digital table arrived 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. Additionally, whereas A-PND interactions could be initiated and completed from almost anywhere on the play surfaces, transfers using Bridges were confined to the areas immediately in front of each player. As a result, it was more obvious with Bridges when an opponent was transferring objects between devices than when the same player was using A-PND; a player need only notice *where* their opponent was interacting rather than *what* they were doing at that location.

Stemming from these two factors, players reported that Bridges offered them far more awareness of their opponents' actions and, thus, A-PND interactions seemed more private. Many players valued this additional awareness, as highlighted by the following player comments, "the new hand style [Bridges] allowed you to show what you were doing much more easily", and "not being able to see what my opponent was doing [in the A-PND condition] was unnerving." On the other hand, some of the more competitive players were annoyed by Bridges' openness, going so far as to use the partial transfer strategy, which resulted in cards remaining face-down on their table Bridge. This transfer strategy avoided revealing the cards when they were transferred back from tablet to digital table, and allowed players to reveal cards only when strictly necessary. For example, once a face-down card was moved off the Bridge onto the table, a player could either reveal the card (by flipping it via the contextual menu) or leave it face-down in order to discard it at the end of their turn. Keeping the discarded cards secret (the latter option) provided a strategic advantage to players since it prevented opponents from learning which cards the player chose *not* to play. However, employing the partial transfer strategy provided these players with only a small, partial preview of the card on their tablet to plan their turn, requiring the players to be very familiar with the content of these cards to use this strategy effectively.

VI. Conclusion

We investigated two existing cross-device transfer methods, a *virtual portals technique* (Bridges) and a *physical proxy technique* (Adapted-Pick-and-Drop (A-PND)), adapted to a multi-surface context without user identification. The study revealed that both methods effectively supported the significant amount of transfer required by the experimental task (the *Dominion* card game). Indeed, study participants' were equally split in their preferences among the two transfer methods. Analysis of the video data elucidated this discrepant participant feedback by revealing that each transfer method provided unique advantages that suited different people's play styles. A-PND was an efficient, context-aware interaction method, but its lack of clear feedback during transfer led to player confusion and interaction errors. In contrast, Bridges required more physical effort (perhaps tediously so), but its simplicity and transparency made it very easy to use. Bridges also allowed players to employ an unanticipated "partial transfer" strategy that was more efficient than either A-PND or the full Bridges transfer method. However, this transfer strategy introduced limitations on the accessibility of cards after the transfer. Further work is needed to determine how to address the limitations of each technique in order to develop a flexible cross-device transfer method that can satisfy a wide range of individual task goals within the same task context.

Though our study examined cross-device transfer in a card game task, the studied methods are generalizable to other collaborative tasks. The *virtual portals* and *physical proxy techniques* upon which Bridges and A-PND are modeled have been previously used to support various tasks involving transfer of a wide variety of digital content, including documents [8, 14], images and photo shows [9], and design sketches [11, 16]. Also, while the Personal Play Areas and individual table Bridges had fixed locations in the study, this is not necessary for either method. In tasks where people may move around the table, these virtual areas could be repositionable on the table, similar to the movable menus in the Personal Digital Historian tabletop application that could be slid along the table edge [19].

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