The MOY Framework for Collaborative Play Design in Integrated Shared and Private Interactive Spaces

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ABSTRACT
A novel Mine-Ours-Yours (MOY) interaction design framework is proposed for designing collaborative play activities in environments that combine both private and shared interactive spaces. A collaborative game designed on a system that integrates multiple mobile devices with an interactive tabletop was presented to demonstrate the implementation of the proposed MOY framework. Observations from field trials involving two groups of children were used to summarize the collaborative behaviors that are likely to be observed under the different interaction design configurations.

Author Keywords
Multi-touch interaction; interaction design; collaborative play; cooperative design patterns

ACM Classification Keywords
H.5.2 [Information interfaces and presentation]: User Interfaces. – Interaction Styles; K.3.1 [Computers and Education]: Computer Uses in Education – Collaborative Learning

INTRODUCTION
The ability to collaborate is an important skill for children. Traditionally, such skills were fostered through shared activities around a table or physical game play in the playground. Physical co-location within a shared space is an important element in all these collaborative scenarios. Technology such as the multi-touch interactive tabletop has provided new opportunities for game designers to create co-located face-to-face collaborative games that can emulate such environments. Works such [3], [7], [8] and [17] describe some of the many efforts to engineer collaborative play on interactive tabletops. We are interested to explore the potential of enhancing collaborative play on an interactive tabletop by providing children with mobile devices that are seamlessly integrated with the tabletop. In this setup, the game designer has access to multiple private interactive spaces (mobile devices) and a shared interactive space (tabletop). In our opinion, this creates interesting possibilities for more effective and engaging collaborative game designs compared to the tabletop only scenario. We address two questions. Firstly, is there a systematic way to view the different interaction design configurations afforded by the integration of shared and private interactive spaces? Secondly, what collaborative play behaviors are likely to arise by incorporating each of these design configurations?

Figure 1. Children collaborating with their mobile phones to solve a problem on the interactive tabletop. The underside of each phone has a unique visual tag.

We developed the Integrated Multiple Mobile Devices and Interactive Tabletop (IMMDIT) system shown in Figure 1. A maximum of four Samsung (GT-I9070) mobile phones interfaces with the Samsung SUR40 interactive tabletop through a unique visual tag that identifies the mobile device, its position and its orientation on the tabletop surface. The mobile devices can communicate with each other through the shared interactive surface and game objects can seamlessly move between all these devices, as is illustrated by the animation of a boy walking from the tabletop into several aligned mobile phones.

Collaborative Game Design Objective
The main objective of this work is to develop game play activities on the IMMDIT system that will promote the practice and demonstration of collaborative play behaviors among children between 4 to 12 years of age. Johnson and Johnson [9] proposed five observable components that they identified as being essential for collaborative learning. Zea et al. [16] used these very same components to structure...
their guidelines for designing videogames that support collaborative learning. They are summarized as follow:

- **Positive interdependence (PI).** Awareness that they are a team and group success also represents individual success. An individual is observed to be helping other team members complete their task.
- **Personal accountability (PA).** Individuals contribute their best effort to a group goal or to the team. An individual is observed to be engaged with the group by demonstrating commitment and contribution to the group in order to achieve a good outcome.
- **Face-to-face promotive interaction (FPI).** Active and constructive discourse is observed among team members. Communication may be verbal or gestural.
- **Social skills (SS).** The group demonstrates attitudes that foster positive social relationships. Such skills include leadership, decision-making, conflict management, turn taking, trust-building and reciprocity.
- **Group processing (GP).** Team members analyze with each other the best way to tackle the problem and maintain an effective working relationship.

This paper proposes a novel framework for designing collaborative interactions in integrated interactive spaces such as IMMIDIT. We described a collaborative game that was designed using the proposed framework and summarized the different observable components of [7] exhibited during field trials with two groups of children.

**RELATED WORK**

Stewart et al. [22] proposed the Single Display Groupware (SDG) as a model for supporting collaborative work among users that are physically co-located. Their preliminary work back in 1999 revealed both benefits and shortcomings of co-present collaboration based on their proposed technological setup. Moraveji et al. [15] studied a larger group of 1 to 32 children interacting with their respective mice while jointly viewing a single large display in a classroom scenario. Their findings seem to suggest that large group sizes have minimal impact on performance if the visual targets the children are required to point to are of a reasonable size. Multiple mobile phones have also been used with shared single display in a children educational game called Electric Agent created by Ballagas et al. [2]. Co-located computer-supported activities are also available commercially. Some examples include Sifteo Cubes [14], Combiform [24] and arcade games like Konami’s Dance Dance Revolution [11].

Interesting observations were made by Scott et al. [20] in their study of children collaborative behavior when using co-located groupware systems. When children were made to share input devices, the likelihood of disengagement and boredom increased. However, addressing this by providing concurrent multi-user access through networked computers inhibited the development of mutual understanding of the shared virtual workspace. They proposed the possibility of applications that provided concurrent interaction on a single computer, which is now possible with interactive tabletops.

There have been recent works that sought to augment the interactive tabletop with additional physical components. Olson et al. [16] proposed using tangible objects to resolve conflicts relating to a toolbar that children could drag around on the tabletop. They noted that this physical object seemed to promote spontaneous turn taking behavior that helped resolved conflicts on the shared surface. Cao et al. [5] developed a tabletop system called TellTable which allowed children to create stories using a mixture of physical and digital objects. Their field study suggests that the ability to combine elements of the physical world with digital content increases the scope for creativity and self expression amongst the children using TellTable. Antle et al. [1] designed a hybrid tangible and multi-touch land use planning game called Youtopia as a platform to investigate how codependent tangible access on a shared tabletop can be used to support effective collaboration among children.

The other physical object that has been frequently augmented to the tabletop is the mobile phone. McAdam and Brewster [13] studied how mobile phones can be used as a general-purpose tangible controller on the interactive tabletop. Their results suggest that using a tabletop and phone for a dial manipulation task is often better than interacting with the tabletop alone. The tactile feedback afforded by the phone increases performance. Klompmaker et al. [10] compared the use of multi-touch, tangible interaction and accelerometer-equipped mobile phone for 3D interaction techniques and application potential afforded by the tabletop-mobile phone combination was well studied by Schmidt et al. in [19].

With respect to the combined use of mobile devices and tabletop for collaborative game design, Shirazi et al. [21] developed a digital card game called Poker Surface. Their study suggests that users prefer the easier tangible interaction of the mobile phone to the direct interaction on the tabletop. The private interactive space inherent in the phone also appealed to the users, especially in a game like Poker. More recently, Zhang et al. [26] exploited the same idea of a private and public spaces provided by the mobile phone and interactive tabletop to develop a Monopoly-like board game called CoPoly. The use of individual phones allowed players to link up and form alliances or groups in ways that was not possible on the public tabletop display. The collaboration in the group workspace was observed to improve empathy and engagement among players. These samples of studies and applications provide strong evidence that the incorporation of mobile phones can improve the scope and quality of interaction design and collaboration on the interactive tabletop. The positive features reported in such tabletop-mobile device setups generally relates to the
tangibility and additional private interactive space afforded
by the mobile device. Lucero et al. [12] found that people
are generally concerned about sharing their personal phones
unless it is with people they know and trust. This seems to
support the notion of mobile phone being viewed as a
personal or private space. However, they did find that most
participants in their studies felt that the benefit of engaging
in co-located social interactions using their phones outweighed the potential negative implications of sharing.
Their caveat is that the interaction designer must be able to
deliver useful and engaging mobile co-located experiences
to the users. This work proposes an interaction design
framework that can guide the design of engaging interactive
activities within such co-located private-public spaces.

DIMENSIONS OF INTERACTION DESIGN
Collaborative games designed on the IMMDIT system can
be viewed by an interaction designer as one that features
three basic interaction spaces, as illustrated in Figure 2. We
propose the Mine-Ours-Yours (MOY) interaction design framework as a means to categorize and aid the design of
engaging collaborative game play scenarios on platforms
that features both private and shared interactive elements.

![Figure 2. The three basic interaction spaces in the MOY interaction design framework. They are one’s mobile device (Mine), the shared interactive tabletop (Ours) and the mobile device of another player (Yours).](image)

Assuming each player in the game is given a personal
mobile device and they collaborate with one another on the
interactive tabletop, then the Mine (M) private space
represents the resources, tasks and interaction available to a
player on his own device. An individual has complete
control and ownership in his own M space. The Ours (O)
common space represents the shared resources, tasks and
interaction available on the tabletop. The O space provides
a universally accessible interaction space where
collaboration between the players can take place, either via
their mobile device or through joint interaction on a large
interactive surface. Finally, from the perspective of each
individual player, the Yours (Y) space represents the
resources and tasks available in the mobile devices of other
players in the game. This is the only interactive space a
player does not have direct control over. The existence of a
physically non-accessible Y space presents interesting
interaction design possibilities not available in interactive
systems where only a shared tabletop is employed.

The MOY Interaction Design Framework
We propose the MOY interaction design framework as a
structured way of designing collaborative activities in an
environment where there is a common shared interaction
space (e.g. interactive tabletop) and multiple private spaces
(e.g. mobile devices). There are six non-repeating
combination pairs possible in the MOY framework. However, Mine (M) and Yours (Y) can often be
interchangeable since the notion of “You” and “I” observed
from a third-person’s perspective is indistinguishable. We
therefore suggest three general configurations for designing
interaction within these spaces. They are the (MO-YO),
(MY-YM) and (OM-OY) configurations, as summarized in
Table 1. However, in terms of the type of interactions that
may be solicited by these basic design configurations, we
posit that all six non-repeating combination pairs (see Table
1) do exist and the resulting quality and nature of
cooperative play behaviors for each can be very different.

![Image](image)

Table 1. Summary of the three basic interaction configurations and six interaction types in the MOY interaction framework.

<table>
<thead>
<tr>
<th>Basic MOY Interaction Design Configuration</th>
<th>MO - YO</th>
<th>MY - YM</th>
<th>OM - OY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interaction Design and Implementation</td>
<td>Group-based task in the shared-space with solution elements in the private space of each individual</td>
<td>Solution elements in the private space of other players with task residing in the private space of the individual</td>
<td>Solution elements in the shared-space with task residing in the private space of each individual</td>
</tr>
<tr>
<td>Types of MOY Interaction</td>
<td>MO</td>
<td>YO</td>
<td>MY</td>
</tr>
<tr>
<td>Behavioral Expression of MOY Interaction Type</td>
<td>Each individual contributes private resource to shared the task</td>
<td>Works with each other’s private resource to solve shared task</td>
<td>Individual voluntarily gives private resource to others</td>
</tr>
</tbody>
</table>

In any collaborative game that involves a group of players
trying to complete a specific task or challenge using
whatever solution elements available to them, the three
basic MOY design configurations can be used to guide the
distribution of these tasks and solution elements across the
shared and private spaces. The proposed MOY framework
itself does not specify how these tasks or challenges should
be designed nor what these solution elements can be. We
will demonstrate with our case study example and field trial
observations that the way the task and solution elements are
designed can solicit one or both of the MOY interaction
types under each of the three basic of interaction design
configurations proposed.

MO-YO Interaction Design Configuration
Mine is Ours and Yours is Ours (MO-YO) interaction
design can be engineered when the solution to a shared task
presented on the tabletop requires the contribution of
private resources from each individual. An example of this
could be an incomplete jigsaw puzzle on the tabletop that
requires a unique piece from each individual’s private
space. The nature of the resulting collaboration allows us to
distinguish between a MO or YO interaction type. In a MO interaction, each individual sees how his private resource can contribute to solving the shared challenge and he does so without much interference or manipulation of the private resources of other players. On the other hand, a YO interaction will see the group freely manipulating each other’s private resource in the attempt to solve the shared challenge after they have contributed their respective resource into the shared space. YO interaction is more difficult to achieve as the shared task must be designed in a manner that the individual’s tacit ownership of his private space is laid aside in deference to the need to collectively manipulate all the available resources in the shared space in order complete the task. A more complicated task requiring certain among of group discussion and trial-and-error formulations may do the trick.

**MY-YM Interaction Design Configuration**

Mine is Yours and Yours is Mine (MY-YM) interactions can be designed by requiring players to share resources in their respective private spaces with each other in order to complete a particular task within his private space. For example, player A needs to collect red objects to complete her tasks and player B needs to collect blue objects to do likewise. As a result, they need to exchange private resources with one another in order to accomplish their respective goals. There are subtle differences between MY and YM interactions. In the case of a MY interaction, an individual voluntarily shares or gives away what is in his private space to others in order to help them progress towards their respective goals. For example, a player observes he has several “key” objects while others have only “locked doors”. He knows that he has a resource needed by others and volunteers to give the key to each of them. An overarching shared group goal (e.g. “progress to next level when all doors are unlocked”) could be incorporated to encourage spontaneous MY-engineered cooperative behavior as not sharing with others means no further progress in the game for all.

On the other hand, YM interaction results in a situation where an individual knows what she needs belongs to someone else and is encouraged to solicit contributions from another player in order to complete a task within her private space. The YM and MY interaction designs may exist together in scenarios where mutual exchange of items is required. In addition, constraining the exchange process so that it occurs sequentially may encourage some level of trust building, negotiation and turn taking since someone has to give first before an assumed or negotiated reciprocity takes place. Private resources can be exchanges between individual via the shared space (see Figure 8).

**OM-OY Interaction Design Configuration**

Ours is Mine and Ours is Yours (OM-OY) interaction design configuration can be implemented by populating the shared tabletop with common resources that can be collected into the private spaces of each individual. In the case of an OM interaction, it encourages an individual to gather common resources on the tabletop into her own private space. Of all the six possible configurations, this appears to be the least cooperative in terms of intent. Should we even consider the use of this configuration in the design of collaborative games? Our case study observations suggest that OM-based interactions generate a great deal of excitement among the children as it taps into their intrinsic competitive nature of ‘grabbing whatever we can for ourselves’. Incorporating some measure of OM interaction designs into the collaborative game may not necessarily be detrimental to cooperative play as it may increase the overall enjoyment of the game, thus providing the motivation to sustain engagement. Game designs such as matching certain tabletop resources to each individual’s private space (e.g. “Blue phone collects only blue items on the tabletop”) can be employed to instill a more orderly MO interaction but it would not be anywhere as fun as the “grabbing what you can!” scenario (see video).

In the case of an OY interaction, it encourages an individual to help another player acquire common resources on the tabletop. OY-related interactions can be designed to be either grudgingly encouraged or spontaneously altruistic. In the former, an individual collects items on the tabletop for another because the item cannot be collected into his own private space (e.g. “Blue phone but no more blue items left to collect”). In the altruistic scenario, an individual is able to collect the shared items on the tabletop but nonetheless gives it to another player due to her sense of fair play or empathy. There could be a third option where the game play scenario encourages an individual to distribute shared resources equally among players to gain strategic advantage in the subsequent stages of the game. Whatever the case, our observations suggest that OY interaction is challenging to solicit and often requires the common resources to be made user-specific and they are issued on the shared tabletop in sequential fashion (e.g. one batch at a time).  

**COLLABORATIVE GAME DESIGN CASE STUDY**

As a study on how a collaborative game can be designed using the proposed MOY framework, we describe the design of a collaborative game that incorporates the different combinations of MOY interaction designs. We later present observations from field trials of this game and evaluate the types of cooperative play behaviors solicited by the different MOY interaction designs.

**The CARE Game**

The Collaborative Assist Retrieve Exchange game, or the CARE game is a multi-player game played on the IMMDIT platform. This game can be played by 2 to 4 players, each equipped with a touch-enabled mobile phone that has been color-coded for easy association of ownership. The collaborative game consists of three basic sequential stages of game play. We describe each in turn.
The Assist Stage

The game starts with the Assist stage, where a collaborative visual-spatial puzzle, like the example shown in Figure 3, is presented to the players on the tabletop. All players need to contribute a bridge segment on their respective phone in order to assist the boy in getting to the gift box on the other side of the river. This is an example of a (MO-YO) interaction design, where an individual has to contribute private resources in his phone to solve a shared problem on the tabletop. Without each individual’s contribution, the group cannot proceed to the next stage of the game.

Figure 3. A simple collaborative puzzle on the tabletop that employs a (MO-YO) interaction design. Phones are color-coded to help users identify their assigned phone.

In an attempt to solicit YO interaction, the complexity of the group puzzle increases with each level of game play. For example, an order-sensitive arrangement of different resources in each phone is now required (see Figure 4). This should encourage the group to evaluate what bridge construction segments they have available amongst themselves and how a workable solution can be formulated. This process will require physical manipulation of all available resources and increase the likelihood of individuals freely sharing their private resources with others on the shared tabletop. In addition, a countdown timer (see top-middle of Figure 4) is used as a game scoring mechanism to further motivate urgency and collaboration.

Figure 4. YO interactions are designed using complex collaborative puzzles with solutions derived from combining different resources in each individual’s phone.

The Retrieve Stage

The Retrieve stage begins when the boy reaches the gift box. At this point, numerous draggable wrapped presents distribute themselves on the tabletop where they can be retrieved by each player into their phone. Figure 5(a) illustrates an example of an OM interaction design, in which shared resources that are distributed over the entire tabletop is being collected into each individual’s phone. Based on the notion of territoriality [23], each player will first gather items that are closest to where they are and may then proceed to invade the space of other players thinking everyone has an equal chance to grab as many items as possible. There is unlikely to be much extrinsic motivation to cooperate during non-user specific resource retrieval.

Figure 5. (a) A typical OM interaction design with items equally distributed. As such, each player collects presents on the shared tabletop into their individual phone without much consideration for others. (b) A lopsided distribution of items may encourage OY interaction.

An alternative design would be to distribute all the items to one side of the tabletop, as in Figure 5(b). Since all shared resources are now within the territory of only one player, there may be a higher likelihood that OY interaction may arise. The individual may perceive the unfairness of the situation and will be encouraged to share these resources with others by pushing it to them. However, as observed by Rick et al. [18] and Fleck et al. [6], the sense of territoriality is not strong among children, which will likely lead to resource grabbing. This weakens the assumption on which the proposed OY interaction design is based on, especially in groups that are naturally competitive in disposition (as was observed in the field trials).

Figure 6. Example of an OY interaction design. Feeding food items to the right animal. If not, the food gets spat out. Player #1 is helping #3. Player #2 has incorrectly fed the bamboo to his rabbit and it is quickly spat out.
We introduced an additional (OM-OY) interaction design in the form of an Animal Feeding stage. Goh et al. [7] observed in the Keep Our River Clean game that players were more willing to help others complete their task when they could no longer help themselves. In other words, the practice of positive interdependence could be scaffolded by tapping on one’s sense of personal accountability to the overall shared task of the group (i.e. help others so we can finish the game as fast as possible). In this stage, food items for each animal are distributed across the shared tabletop, one food group at a time. Only the phone with an animal that matches the food group can collect and consume the food items. For example, only panda bear can consume the bamboo items as shown in Figure 6. When all items in the current food group are consumed, another food group appears. This stage is completed when all animals are fed.

The Exchange Stage
Once all the presents have been retrieved, the Exchange stage begins. Different private challenges are issued to the players at each game level as shown in Figures 7.

Irrespective of the type of private challenge, what is distinctive in the Exchange stage is the need for each player to acquire a specific set of items. By ‘hiding’ these objects in wrapped presents, our allocation algorithm can intentionally ensure that each private space has an incomplete set and/or unwanted items belonging to others. With solution elements residing in the private space of other players, transaction of resources between users will be required. In the MY interaction, an individual realizes that he has items he does no need and voluntarily enquires with another player if he can help by giving these items to her.

An interesting collaborative situation arising from having resources spread across physically separate private spaces is the need for users to make verbal enquiry with others in order to find out what resources are available within the community. As a result, this same activity of exchanging items among players can give rise to YM interaction, where an individual completes her private challenge by articulating her needs to others. Such situations could be a learning opportunity for timid children to learn how to ask for help.

Figure 8 shows the tabletop layout for the Exchange stage. Observe that in this design, item exchange is constrained to occur between two phones at any one time. This tabletop interaction design should facilitate social skills like turn taking, negotiation and conflict management among the players. Items exchanged between two phones are also limited to a uni-directional transfer, which means the two players has to decide amongst themselves who is to give and who is to receive during an exchange event.

Figure 8. Exchange stage on the tabletop. Player #2 drags out a banana and slides it over to Player #1 via the exchange channel (blue arrow). The transfer direction is determined by the phone that first drags out an item. A third player learns to wait his turn to do the exchange.

OBSERVATIONS AND EVALUATION
Field trials for the proposed CARE game were conducted with several groups of typically developing children aged between 7 to 12 years. We report observations on the collaborative play behaviors of two groups of children with different age, gender and relationship profiles.

- **Group 1** – Three 7-year old children who were classmates and are familiar with each other. Two girls (G1F1 and G1F2) and one boy (G1M1)
- **Group 2** – Four children (three boys and a girl) aged between 8 to 12 years. Children are either siblings or cousins. The girl (G2F1) and boy (G2M1) aged 12 and 9 respectively are siblings. The other two brothers (G2M2 and G2M3) are aged 11 and 8 respectively are their cousins.

Both groups were collaborating within a social environment of high psychological safety since they know each other well, especially children in Group 2. An interesting difference between these groups was the gender ratio. Group 1 has a majority of girls, while Group 2 a majority of boys. Gender-based behavior differences were observed.

Field Trial Protocol
At the start of the session, the group was asked to gather around the front of the tabletop and each child was then issued with a mobile phone. They were instructed to use their phone to play the game and to remember their
respective phone through its color band. The CARE game was designed with a Practice level with no countdown timer. Each group was allowed to play as many rounds of Practice before starting the actual game. No further advice was given to the children except that they should try to complete the game as fast as possible and to listen to instructions from the tabletop and mobile phone. Occasional promptings were given during the practice level when the children were unfamiliar with the way objects on the interactive surface could be brought into their phones.

**Observations of MO and YO Interactions**

MO interactions were mostly observed in the Assist stage of the game because there was a shared problem on the tabletop that requires the children to use their respective phone to help the boy cross the bridge. All children in Group 1 demonstrated personal accountability, as each of them quickly brought their phones to the tabletop and started adjusting its alignment with respect to the other phones. G1F2 could be heard saying “Must be straight, later he will fall down”, as she cautions the group to be careful in the phone arrangement, as seen in Figure 9(a). Group 2 was also observed to demonstrate MO interactions during the Practice level of the Assist puzzle. G2F1, who was standing furthest to the left of the tabletop initiated the process of solving of the puzzle by placing her phone at the first bridge gap at the furthest left. When the rest of the boys started placing their phone on the tabletop, G2M2 could be heard telling G2F1 to place her phone over to her own side of the bridge so that they can each place their phones in the gap closest to their respective position on the tabletop.

**Observations of MY and YM Interactions**

YO interactions were also observed in the Assist stage, especially when the shared problem became complicated. As shown in Figure 9(b), this was observed when Group 2 was solving a more challenging Assist puzzle in level 2. When the boy fell into the river in his first crossing, the children started to treat everybody’s phone on the tabletop as common property as they figured out the correct arrangement that would worked. Significantly more face-to-face promotive interaction and group processing occurred as phrases like, “No! No! I know, I know, go like this” and another saying “This one must go up”. All four children, with arms criss-crossing, worked together swapping phones around to compose the correct bridge pattern without regards to whose phone it was. YO interaction was also observed in Group 1 when a G1F1 (who appears to be the spontaneous leader in the group) suggested to her team mates to solve the Assist puzzle by placing their phones into the respective gaps in the bridge according to their physical positions along the edge of the tabletop.

**Observations of OM and OY Interactions**

MY and YM interactions were mostly observed during the Exchange stage. For example in Group 1, G1F1 was demonstrating positive interdependence and leadership skills when she started the exchange process by asking the group, “Who needs lollipop?” G1F2 then exemplified an YM interaction by replying, “Me! I need, I need.” G1F1 then proceeded to give her lollipop to G1F2. In return, G1F2 observed that she had multiple potato chips in her phone and then exemplified a MY interaction by saying, “I need to send you the chips.” She reciprocated by sending potato chips over to G1F1’s phone (see Figure 10). Like in Group 1, there was significant verbal communication between the children in Group 2 during the Exchange stage. The pair-based exchange constraint also taught the children patience and consideration for others as they waited their turn to do the exchange. It was observed that no pair monopolized the exchange channel as they were asked to relinquish control after one or two exchanges. G2M1 was heard saying to G2F1, “OK, move” and then took over the exchange channel from G2F1. He then executed a MY interaction when he said to G2M2 who was at the other side of the channel, “Come, I give you Kinderjoy.”

**Observations of OM and OY Interactions**

The OM interactions were observed during the Retrieve stage. In both groups, the children got very excited as they anticipated the emergence of wrapped presents over the tabletop, which they can all collect into their phones. When the distribution was spread evenly across the tabletop, the children in Group 1 were observed to begin collecting items around their own territory but quickly moved into the territory of the other players who were slower in gathering theirs. This sometimes led to some friendly skirmishes with
remarks like, “Oooii! I get it one!”. The friendly competition in grabbing presents among children in Group 2 was observed to be even more pronounced. This is probably due to their greater sense of psychological safety since all these children spend a great deal of time playing together as siblings and cousins. When all the presents were distributed to one corner of the tabletop, all phones raced towards that side, with bodies and arms all splayed and outstretched across the tabletop as shown in Figure 11. The assumption that a lopsided distribution that exploited territoriality will give rise to OY interactions (see Figure 5(b)) seems purely theoretical, at least with these children. Our observations suggest that respect for tabletop territoriality in a gaming environment with high psychological safety is wishful thinking. However, in one instance, G2M1 was heard saying to the rest, “Stop fighting, it is just presents!” This remark did not change the rest in their urgency to grab as many presents as they could. Neither did it change G2M1’s. As insightfully suggested by Fleck et al. [6], one should not be too quick to consider undesirable tabletop interactions like grabbing and blocking as unbeneﬁcial. On the contrary, these can be learning opportunities for children to practice negotiation and conﬂict management skills. It would seem that positive collaborative behavior was not produced during OM interactions but our observations suggest that the level of excitement accompanying such competition-based activity makes the overall collaborative game more enjoyable, especially so in our observations of Group 1 and 2 because in both cases, the “present grabbing” episodes came across as fun-ﬁlled friendly competition among friends.

Figure 11. The OM interaction design creating great excitement and friendly “grab your presents” competition among children in Group 2.

OY interactions were observed in the stage of the game where the children had to feed the animal picture in their phone with a matching food type. When the first batch of food items (i.e. acorn) came on to the tabletop, all the children started grabbing them into their phone, just like they did with the presents. They continued grabbing these items until G2M1 realized that only his phone with the squirrel picture was able to collect the acorns. He then told G2M2 and G2M3, who were both trying to grab the acorn, “Pass it to me, it is not your food.” Later, when the bamboo came on to the tabletop, G2F1 was observed to say “Help G2M3!” as G2M3 had the picture of a panda on his phone. All the children were then observed to demonstrate personal accountability and positive interdependence as they worked together to collect bamboo into G2M3’s phone.

Figure 12. OY interaction observed among children in Group 2 when they all fed bamboo shoots to the Panda.

The MOY Interaction Types and their Observed Collaborative Behaviors

Summarizing the field trial observations from both Groups 1 and 2, we tabulated the types of collaborative behavior observed under the six different MOY interaction types. We employed Johnson and Johnson’s [9], [25] five collaborative behavioral components discussed earlier as a means to label the nature of the observed collaborative interactions and discourses among the children.

<table>
<thead>
<tr>
<th>MOY Interaction Type</th>
<th>MO</th>
<th>YO</th>
<th>MY</th>
<th>YM</th>
<th>OM</th>
<th>OY</th>
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<tr>
<td>Positive Interdependence</td>
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<td>✓ ✓</td>
<td>✓ ✓</td>
</tr>
<tr>
<td>Social Skills</td>
<td>✓ ✓</td>
<td>✓ ✓ ✓</td>
<td>✓ ✓ ✓</td>
<td>✓ ✓ ✓</td>
<td>✓ ✓</td>
<td></td>
</tr>
<tr>
<td>Group Processing</td>
<td>✓ ✓</td>
<td>✓ ✓ ✓</td>
<td>✓ ✓ ✓</td>
<td>✓ ✓ ✓</td>
<td>✓ ✓</td>
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</table>

Table 2. Collaborative behaviors associated with the six different MOY interaction types observed in Groups 1 and 2.

We first classified all active game play segments in the video observations that can be considered either a MO, YO, MY, YM, OM or OY interaction type. We then labeled the types of collaborative behavior (which may be more than one type) observed during these MOY classified segments.
Four rating levels were then used. If the behavioral component is consistently observed among all the players during the MOY interaction type, a high (✔✔✔) score is given. If it is observed more than half the time and among a majority of the players, a medium (✔✔) score is given. If it is less than half the time and only among a minority, a low (✔) score and if it is not observed at all, a nil (✘) score. Table 2 summarizes the type of collaborative behaviors solicited by each of the six MOY interaction types.

DISCUSSION
As highlighted in Table 2, demonstration of positive interdependence, personal accountability and social skills like negotiation, reciprocity and turn taking were frequently observed when the children engaged in activities requiring them to share private resources between phones (i.e. Exchange stage). MY and YM interactions could be easily realized because of the physical separate ownership of resources provided by the mobile phones in the IMMDIT platform. The level of face-to-face promotive interaction (especially verbal exchanges) among players significantly increased because they could not see what resources others had and also needed others to physically place their virtual resource on the shared tabletop in order to execute a transfer. This would not have been achievable if only virtual phones were implemented on the tabletop for each player since territoriality alone cannot enforce a strong notion of private ownership and hide private information.

The MO interactions in the Assist stage that employed some elements of enforced collaboration [3] did produce collaborative play behaviors such as personal accountability and positive interdependence. However, some of the other behavioral components like social skills and verbal communication were not of the quality seen in the MY and YM interactions. Benford et al. [4] suggested that encouraging instead of enforcing collaboration produces longer term educational benefits as peers learn to build mutual trust when they discover the value cooperation and reciprocity. Such engagements are likely to encourage the transfer of positive game play behaviors into everyday social situations. Interestingly, when the complexity of shared challenge on the tabletop was increased to match the problem solving skill level of the group, we started to observe significantly more YO interaction as in Figure 9(b). As seen in Table 2, the YO interaction is the one that resulted in the highest quality of collaborative play. The notion of private ownership temporarily dissolved into their phone belonged to them or to everybody. To our surprise, every child in both groups replied, “Everybody!” We believe that the competitive grabbing of presents in the Retrieve stage was more than offsetted by the collaborative re-distribution of private resources during the Exchange stage. Further evidence that the children took away positive reinforcements from the game play was observed when the children were asked what they learnt from playing the CARE game. We received replies such as “Teamwork” and “Share”. The symbiotic tension between competition and collaboration in the CARE game design is best summed up by G1M1, who when asked, “Which part of the game was most enjoyable for you?”, he replied, “Collect presents, because you can give to other people.”

CONCLUSION
We presented a novel MOY interaction design framework for designing collaborative play using integrated shared and private interactive spaces. We believe the MOY interaction design framework can be extended beyond the digital domain and applied to more traditional collaborative board games for example. It would be interesting to analyze collaborative board games such as Forbidden Island or Pandemic to see how the MOY interaction design configurations have been incorporated into their game play. This paper provides a useful way of thinking about the process of designing collaborative play and the likely behavior that will arise with an associated MOY interaction design. However, with each game, it is the unique design of the group tasks, private challenges, common and private solution elements that will ultimately determine the quality of the resulting collaborative play behavior and the level of engagement. Our own experience suggest that the YO and OY interaction types will result in very rich collaborative play but they are also the most challenging ones to design. In our case study example, we suggested generalizable design techniques such as matching shared task complexity to the ability of the group (e.g. through progressively game levels), the use of user-specific common resources and the sequential presentation of these resources (e.g. in the animal feeding stage). In practice, such interaction design strategies are much easier to implement and executed on programmable interactive platforms like IMMDIT than traditional board games.

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