Introducing Shared Character Control to Existing Video Games
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ABSTRACT
Many people enjoy the social aspects of gaming, but most video games are designed to be played by one person at a time. We introduce Legion:Gaming (LGaming), a system that increases the sociability of single-player video games by allowing joint co-located play. The LGaming mediation framework flexibly merges the inputs of multiple players into a single control stream before forwarding it to the gaming system in real-time, and supports visual overlays to give players feedback on the newly-injected social dimensions of the game. Studies with more than 50 participants explore the new space enabled by LGaming, showing social and preferential effects of several archetype mediation strategies. The LGaming approach has the potential to improve social aspects of existing single-player games, allow novices to learn from experts while playing together simultaneously, and improve players’ gaming performance.

Author Keywords
Video Games; Collaboration; Social; Multi-Player Games

ACM Classification Keywords
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INTRODUCTION
Many people enjoy playing video games with others as a co-located social activity, but the number of games that are designed for co-located group play has, for the most part, been decreasing since 2006 [10]. Individuals often use workarounds, e.g. trading off the controller among individuals in the group, but these methods are cumbersome and leave most players idle at any one time. Games designed for multiple players increasingly require participants to use separate gaming systems, which encourages remote synchronous play, despite co-location generally affording a better multiplayer experience [5]. Multiplayer games, such as World of Warcraft (Blizzard Entertainment, 2004) and Rockband (Harmonix Music Systems, 2007), generally expose a shared virtual playing field in which each player controls his or her own individual character. In this paper, we introduce LGaming, which takes a different approach to supporting co-located group play: allowing multiple players to jointly control a single character in existing games.

When using LGaming, each player issues commands intended to control the same character, and a mediation layer captures and selectively forwards these commands to the game. A primary challenge for LGaming is that the games it targets were explicitly not designed for group play, and so naive approaches to adding group control lack many of the qualities comprising good game design. For example, with multiple players trying to simultaneously control the same character, players may not receive good feedback as to the result of their actions. To allow this to be addressed, we added a visual overlay for feedback. Thus, within the LGaming framework, creating game play experiences that are enjoyable and that encourage social interaction is dependent on the design of the mediators and visual overlays.

Players often share controllers with friends to make single-player games more social. This physical hand-off interrupts game flow and makes close collaboration difficult, which may explain why it is most often reserved for natural breaking points in the game. For instance, nearly half of players in our study used failure as a trigger for passing the controller. In addition, handing off the controller does not keep all players equally engaged since only one player can actively play, while the rest are limited to spectating and commenting. To surpass this limitation, LGaming eliminates physical hand-off and automates turn taking in one mode, and facilitates collaborative control of single player games from multiple controllers simultaneously in another. Thus, players can enjoy co-located collaborative play without encountering unnecessary breaks in flow and without purchasing special hardware.

To explore the new space enabled by LGaming for existing games, we iteratively designed and implemented several archetype input mediators and visual overlays. The mediators we developed allow multiple players to share control of an in-game character in ways not previously supported by the
game. Different mediators allow the group (i) to collectively control all aspects of a character, (ii) to split control of specific features between players, e.g. moving and shooting, (iii), to trade off control at fixed intervals or randomly in order to keep everyone engaged, and (iv) to serve different roles, e.g. a standard player and an advisor who is given a cursor overlay to point out on-screen elements that might be important.

A formative study of LGaming considered four mediators modeled on the existing concept of handing off controllers in order to allow multiple co-located players to share control of a single-player game. This model “forced” everyone to play and increased social activity while playing the game, but highlighted the known problem of players with different skill levels playing with one another. Namely, the experienced players felt as though they were being held back by the weaker players, and the weaker players felt uncomfortable contributing because they might “mess up.” We then designed new mediators that encouraged everyone to contribute, but did not tie overall performance to the weakest player. These mediators stressed collective control, eliding each individual’s performance into the collective to reduce anxiety. A summative study showed that these mediators encouraged group participation while adding enjoyment via social interaction. In longer trials, participants not only became better at the game but also showed improvement in working together within the framework of LGaming. They came to see LGaming as a meta-game that they could play together in the context of the original game they were playing.

The primary contributions of this paper are: (i) we introduce LGaming to improve upon the common approach of turn-taking (passing the controller) for multiple players interacting with a single-player game, (ii) we present a feasibility study that explores the space of shared control in existing video games enabled by LGaming, and (iii) we discuss how collaborative control may help players learn from one another, play better, and allow for seamless player substitutions.

BACKGROUND
LGaming builds from work in (i) multiplayer gaming and (ii) shared control of games and other user interfaces.

Multiplayer Gaming
LGaming makes single-player games into multiplayer games, and so our expectations of how it is likely to work can be informed by looking at analyses of current multiplayer games. McClintock [15] outlines several kinds of social motives, which map to different types of multiplayer play. During competitive play, each player aims to maximize his or her own standing in the game relative to other players. This format is slightly different from individualistic play, where players maximize their own standing regardless of others. A third form is cooperative play, in which players maximize their own standing by maximizing the standing of others, although cooperative games might still have an element of competition, such as individual score. LGaming is primarily a cooperative game, in which player interests always align and the incentive to do well is derived from social incentives to perform well in front of their peers.

LGaming can also support other kinds of play depending on the mediators and overlays that are designed. For instance, McClintock discusses altruism as another incentive for playing, in which people are motivated by their desire to maximize the standing of others. LGaming supports altruism by allowing players to take on a support role by pointing out on-screen items to which other players should pay attention. LGaming can support competition incentives by displaying metrics related to who the system has chosen to listen to most often even during cooperative control. Because LGaming is assumed not to have access to the internals of the games on which it is running, it does not support individual performance metrics based on how well players are doing within the game. Future versions may use techniques like optical character recognition [3] in order to find the points being awarded to the group, then assign to players most responsible for control at the time the points were awarded.

Substantial work has been done on how to create compelling cooperative and collaborative games. LGaming does not enforce these design elements in its framework, but is flexible to allow mediator and overlay designers to include them. Rocha et al. describe a number of common design patterns for cooperative games useful in designing LGaming mediators [18]. For instance, LGaming subscribes to the “Shared Goals” pattern by putting players in control of the same in-game character, which we assume has a goal prescribed by the original single-player game. Mediators make it possible to create using LGaming exhibit other design patterns. For instance, mediators that divide control of different functionality between players exhibit “Complementary” design pattern, in which players have different abilities that support one another during gameplay.

Zagal [20] developed several lessons and pitfalls from the collaborative board game Lord of the Rings (Reiner Knizia, 2000) that informed the design of LGaming. For example, visualizations of player input allow them to connect the payoffs they receive to the decisions they or others made. Zagal noted the importance of allowing individual players to act without group consent, and LGaming mediators do not necessarily require group approval for actions to be forwarded. LGaming’s support for “Complementary” play allows mediators to avoid the pitfall Zagal noted in which one player could control everything. Creating compelling experiences within LGaming is interesting because designers are not in complete control of all gameplay, but must instead work within the constraints set up by existing games. One consequence is that different mediator and overlay combinations may be more appropriate for different kinds of games.

El-Nasr et al. [4] explored the potential for shared character by observing children play Lego Star Wars (Traveller’s Tales, 2005). In Lego Star Wars, players can switch between which character they control, as long as the target character is not already in use by another player. In combined results from observing kids playing Lego Star Wars, Rockband (Harmonix Music Systems, 2007), Kameo (Rare, 2005), and Little Big Planet (Media Molecule, 2008), El-Nasr et al. found that shared character led to 11.4% of instances of laughter and
Figure 1. In LGaming, input from each player’s controller is passed to an input mediator that selectively forwards input to both an on-screen visual overlay and a virtual controller that issues commands to the underlying (off-the-shelf) video game.

excitement together, 8.1% of instances of working out strategies, and a large portion of instances of global strategies, in which each player takes on a particular role to work together. Although LGaming supports more complex mediators than Lego Star Wars, these results imply that even simple player sharing of an avatar can have a positive impact on the group’s enjoyment level.

Shared Control in Games and Other UIs
Prior work has considered shared control in both games and other user interfaces. Inkpen et al. explored shared control of a single-player game by having pairs of children share a computer and mouse [8]. Sharing a single input device caused conflict among the participants as they fought for control, especially in Male/Male pairs. In later work, children played a game together with either one or two mice [9] and utilized two control-sharing protocols: give and take when using the multiple mice. Give required one player to give control to the other player, whereas Take allowed either player to take control when they wanted. LGaming explores a richer space of mediators. In addition to supporting the original give and take control schemes, LGaming allows all players to collectively control a game character at once and can choose who to distribute control to in order to try to achieve a goal (for instance, increasing social activity).

Split control of an avatar has been used in existing games. For instance, Perfect Dark (Rare, 2000) allows two players to control avatars according to four preset control configurations. For the Global Game Jam 2012 (globalgamejam.org), participants formed teams and created games based on several constraints. One optional constraint was to have at least three people control a single avatar. Most games that used this constraint required each player to control a subset of avatar actions. One game used input summation, and one based action on the number of votes for every four second window. With LGaming, players share control of a single avatar with the option of delegating different in-game actions among players.

Prior systems have also allowed for joint control in non-game domains. For instance, Goldberg et al. [6] introduced the idea of a Multiple Operator Single Robot (MOSR) system, in which multiple people control a single robot. They instructed a group of users to maneuver a Ouija pointer through a maze drawn on paper via a robot arm. Users conveyed desired force through mouse movement, and their inputs were averaged to determine the resultant action. People were able to complete the maze faster when working together than on their own. Goldberg et al. [7] later created a more advanced MOSR in which users controlled a tele-actor that responded to input in real-time. Mouse clicks were interpreted using a clustering algorithm. LGaming has several alternative control schemes, which explore more complex kinds of interaction.

Lasecki et al. [13] introduced Legion, a system which allows the crowd, remote groups of anonymous web-workers, to control existing user interfaces by forwarding workers’ mouse and keyboard input to an input mediator. The mediator merges the inputs into a single control stream and sends it back to the interface. Legion was used to navigate an off-the-shelf robot through a maze, control a spreadsheet program, and create a crowd-powered assistive keyboard. Legion’s control schemes include serialization and weighing inputs based on past performance. Other types of real-time mediation were explored with Legion:Scribe, which showed the crowd could collectively perform a captioning task better than any constituent individual. Unlike Legion, where crowds were anonymously recruited from crowdsourcing marketplaces such as Amazon’s Mechanical Turk and no explicit means of player communication were provided, LGaming is geared towards small groups of intrinsically motivated players that often know one another and are able to collaborate in person. As a result, the group dynamics differ in ways that affect collaborative control, and thus change the design parameters for LGaming. Specifically, in LGaming players can easily communicate with one another about strategies and goals, and malicious players are less of a problem because the group can easily recognize and deal with them in person, however they choose to.
LEGION: GAMING
LGaming is implemented as a service-level program for the MS Windows operating system. It captures the input from multiple controllers and selectively forwards it on to an original game via a virtual input device and updates a visual overlay. Player input is captured in input cycles; each cycle holds information about the most current controller state for every player. It is sent to a mediator that determines based on a set of rules provided by a designer what input should continue on to the game. The mediator passes along input and information on who has control to an overlay program, which is responsible for visual feedback. The output of the mediator is also passed to a virtual controller that uses vmulti\(^2\) to convert and forward the input to the game (Figure 1).

Input Mediators
The input mediators determine how user input is collected and selectively forwarded on. For the initial system, we chose to implement four simple mediators inspired by the way players currently share control in single-player games: handing around a single controller. In later iterations discussed in the following sections, we used the experience from these early mediators to design mediators that move away from the concept of sequential control. The mediators are as follows:

- **Sequence** virtually passes the controller automatically in a fixed order every 10 seconds (a value determined to be good in play tests). The relatively short interval keeps players involved because even with a group of four they will need to pay attention as their off-period will be 30 seconds.

- **Random- 10 Seconds** adds unpredictability to Sequence by using a random order, with the goal of increasing players’ engagement in the game. Initial play tests showed the 10 second interval worked well for players who preferred a faster pace.

- **Random- 30 Seconds** increases the time between random automatic controller passes to 30 seconds. The result is that each players is given a bit longer to play the game and accomplish something.

- **Multi** forwards all players input to create a single control stream from the group. A similar mediator was shown effective at continuous control and navigation tasks in [13]. This mediator represents the limit of how fast the controller could be passed (if you press an input, you have control), although coordination may be difficult because the mediator does not show which player is currently in control. LGaming a sampling rate of 100ms, which we found to reduce jitter, or a ‘segmented’ feel.

These mediators vary on player engagement, level of predictability, and control sharing. All mediators work with any number of players, each with their own controller. Players were able to observe their controller input via an overlaid UI on screen (Figure 1). For turn-based mediators, a yellow star was shown above the controlling player’s controller on the overlay. As this player’s turn progresses, the star “drained” to reflect how much time the player has left.

\(^2\)http://code.google.com/p/vmulti/

Formative Evaluation
We conducted a formative study of LGaming using this first set of mediators in order to better understand how they compared with one another and with manually passing the controller. Four-player teams each played Half-Life 2 (Valve, 2004), a popular first-person shooter that includes many common game elements, such as puzzles and platforming. Our study consisted of 24 players (14 male), ranging in age from 18 to 29 (mean 20.5). Experience with console shooters ranged from rarely playing games to playing games more than 10 hours per week. Familiarity with fellow group members varied. We used Sony PlayStation 3 controllers, a desktop PC, and a 42” television, with players seated next to each other on a couch. Participants played this game collectively using the four mediators described above and by passing the controller amongst themselves. To avoid bias, the condition in which participants decided how to pass the controller among themselves was always done first, but the other four conditions were randomized. Segments were sequential and progressed in difficulty as part of the game.

Observations
When each team started, they were asked to trade off control among themselves to control the game. In all cases, trading control was done at some sort of in-game “event,” e.g. when the player’s character died or completed a level. Sometimes, control was traded in order to tap into expertise, e.g. a novice player may ask a more experienced player to take over at a difficult point in the game. Relatedly, sometimes control was traded to allow players to play portions of the game they found interesting or hadn’t previously been able to play. Overall, each player’s control lasted an average of a minute or more.

The mediators that forced controller changes unsurprisingly increased the rate at which control changes happened. The mediators that randomly changed who was given control were disliked because the hand-off was more difficult for players to successfully execute. The player in control would generally need to pause longer in order to let the person taking control figure out that he or she was in control and then start playing.

Players who rated themselves as novices were more likely to mention that they felt scrutiny during turn-based play. Some of these players felt they were holding the group back by being forced to contribute equally. Some players preferred to contribute suggestions, rather than actively control the avatar. These players would often help the controlling player by pointing to different game objects, helping solve puzzles, and suggesting a course of action. We call these individuals passive contributors. They differ from people who play a strictly observational role, since they provide constructive input.

When using Multi, 6 out of 24 players independently commented that allowing for divisible independent control of a character was a missing key element. We also observed players with higher perceived skill level were often overbearing, and negatively impacted other players by being demanding and even ignoring or arguing with others’ suggestions. Many players noticed a lack of input feedback in Multi. Initially, we visualized input on-screen (Figure 1), but found that over-
bearing players used it to single out players who were not contributing (slowing progress). One novice user explained that this scrutiny from other players caused additional stress.

Participants thought of other ways to have individual control of some portion of the character they were controlling. For instance, several participants noted that they thought it might be a good idea if players were able to control different functions of the character at the same time. For instance, if one player could move the character around in the virtual world, while another aimed and shot at enemies.

Changes Following Formative Study
Following our exploratory study, we made a number of changes to LGaming. First, we added support for passive contributors by adding command mode. In this mode, players are identified by color and can use command mode to: (i) indicate visually a general direction via arrows that appear on-screen, or (ii) toggle a dot or ring shaped cursor that can be moved, highlighted, and resized on-screen, independent of the game. Communication support for inactive players has been implemented in several games, including Valve’s cooperative two-player game Portal 2 (Valve, 2011), where players can gesture, take on their partner’s view, set a marker at a location, and start a shared timer, as well as traditional verbal and text-based chat. Nintendo’s Wii U can be used in a support role with the purchase of extra hardware.

In our initial design, we had one naive method of simultaneous control (Multi). We developed the Legion Leader mediator inspired by the Legion system [13] to allow for better collective control through the election of leaders who assume temporary control. In this mediator, the more a player agrees with co-players, the higher the player’s weight. Every 100ms, we recalculate weight and determine a potentially new leader, who has exclusive control of the game. Change in leadership is gradual because weight shifts slowly. We chose to replace Random with Legion Leader in our next iteration because it combines the idea of trading off control while allowing all players to contribute.

To address players’ desire to divide control, we added the ability to control different sets of input separately from one another (Figure 2). For each subset of controls, all active players who want to contribute are merged together based on agreement, while players who are inactive for that subset are not considered. For example, two players can focus on controlling movement with the left analog stick, while two others focus on looking around with the right analog stick. This also addresses player’s interest in being able to pause or temporarily not contribute.

EVALUATION
Our evaluation consisted of two components: (i) a large study of controlled group play of two game genres across four mediator conditions, and (ii) a smaller study of extended play using Legion Leader, the mediator found to be most popular for the action game.

Study of Controlled Play
For this study, we use the puzzle game Continuity and the action game Ys Origin as archetypes of these genres. Our trials involved 26 participants (21 male) playing in groups of 4. Participant ages ranged from 19 to 30 with a mean age of 23. Playing habits ranged from rarely playing games to playing games more than 10 hours per week. The physical setup of our experiment was identical to our formative study. The play session was split into 8 blocks, each 5 minutes long. We used one game for the first 4 blocks, and the other for the remaining 4, randomizing order. For each game, players played one block for each of the following mediators: Multi, Sequence, and Legion Leader, as well as one block as a control (randomized order). As before, in the control block participants decided amongst themselves how best to share control using a single controller.

Results
Following each block, participants rated how much they liked the mediator used in the previous round on a 7-point Likert scale. We used the Wilcoxon signed-rank test to compare pairs of mediators for each game. The control scored significantly lower than Sequence for the action game ($z = -2.02,$ $p = 0.045$).
8 players mentioned having trouble noticing the start of their turn when using Sequence. Although we show a draining star on screen and in our original version even flashed the color-coded text ‘Player X’ at the top of the screen, players did not seem to notice the cue. Players made several suggestions including vibration and sound effects. A potential problem with these indicators is that they can get annoying over time. One player suggested a hybrid of Sequence and Legion that would gradually transition from one player to the next over a few seconds to avoid abrupt changes. This suggestion is especially enticing because it combines turn-based and many-as-one gaming. When players noticed their turn was ending as they were about to perform an action that requires precision, they sometimes chose to instead wait and let the next player do it so that the control shift did not occur mid-activity. Weighted control between turns could make the transition between players less abrupt, and therefore may prevent this hesitation.

We found that some groups took advantage of split control, but only in the action game. Several participants avoided this feature because there are not enough controls for everyone to actively participate. As one player pointed out about the puzzle game, ‘Jumping and moving in platforming games...they’re all one motion,’ while another explained that ‘The action game for me was just a bit more complicated. ... They could focus on attacking and jumping and ... I could just hold the button so that we can move faster.’ These statements suggest that split control may be more appropriate for technical games.

Extended Play
Natural play times are generally much longer than the controlled blocks in our first experiments. Therefore, we had 4 casual gamers play three games using the most popular mediator for simultaneous control, Legion Leader: the action/adventure game, The Adventures of Dear Explorer, the platforming game Exit Path, and the first-person shooter Bulletsorm. We chose these more action and precision-oriented games because we wanted to see if performance issues stemming from our system are mitigated over time as players get used to the mediator. We suggested that players spend 20 minutes on each game, but they were allowed to stop playing at any time or continue playing for longer, which they did.

When playing the platforming game, players commented that ‘it was fun even if we didn’t do well,’ and in fact ‘we played better than I do alone.’ They were surprised at how far they got in the game. Here we can see that although high-precision can be hard to coordinate with simultaneous control, people still felt that the group did better than the individual. Part of this success may be due to the fact that ‘it isn’t as frustrating to die because you can just let go for a moment and keep watching your character try.’ Players could hand off control if they felt that they were negatively impacting precision and jump back into the game very quickly once the rest of the group completed that portion of the level.

When playing the shooter game, we asked players to try splitting up controls. One player explained that ‘I think splitting...
up the controls worked better,' referring to how it worked better in the shooter game than in some of the others he had tried previously. The players designated responsibilities, but contributed to other players’ commands from time to time.

Players adapted their strategy to our system. At one point when players got stuck, one suggested that the group should let a single person control the game until the difficult section was complete. Upon success, the group resumed playing without having to consult each other about control. Over time, additional adaptations may occur as players become more familiar with our system. While we started the project with the idea that LGaming would improve players’ abilities or enjoyment in the terms of the existing game, it may be that the more interesting aspect to consider is the meta game created by LGaming itself.

One long-term effect that we were unable to catch within our 20 minute trials is whether players learn everyone’s strengths as they play. Such knowledge can be used not only to determine who takes over when facing certain kinds of challenges, but also for responsibility delegation for split control.

FUTURE WORK
In this paper, we introduced LGaming, a system that introduces collective control to existing video games. We believe LGaming opens a new space of social play on top of single-player games, which represents interesting new challenges for future work in designing compelling experiences within the constraints of existing games. Through the development and study of several archetype input mediators and visual overlays we started to explore this rich space.

Command mode allowed players to enhance their communication with one another via on-screen visual cues that were easily understood. Future work will explore new types of overlaid feedback and support for extensions of existing roles. We will also explore how players choose to customize their controls using a simple selection menu, and how players might learn new techniques and acclimate to using LGaming.

By allowing novices and experts to collaborate together, LGaming may have implications for education. Members of a group might implicitly learn from the actions of the collective [14], suggesting that LGaming could possibly facilitate in-game learning without impeding experienced players. In the future, we will explore how split control may allow novice users to master one action or set of actions at a time. Our approach may also extend beyond co-located gaming to inform other collective control tasks, such as robot guidance or even remote surgery.

CONCLUSION
LGaming provides a framework to allow a group to play existing single-player games more socially. When using LGaming, all players have an individual controller, but share control of the same in-game character. Across several studies, participants found the mediators provided by LGaming preferable to sharing a physical controller, and in an extended study players felt that LGaming actually improved the games they played.

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