How to Lose Friends & Alienate People: Sharing Control of a Single-User TV System

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ABSTRACT

The single physical remote control, paired to a media system, is no longer necessarily the only (or indeed primary) mechanism of control, with new input modalities (e.g. gesture) and mechanisms (e.g. mobile devices) allowing anyone to contribute to the input and control. This paper investigates the potential for extending single-user interfaces in order to support multi-user use, as a means of utilizing new inputs without having to abandon the familiar interfaces, control management behaviours and mental models that users have established. A survey was conducted investigating existing behaviours for managing control in terms of prevalence and acceptability. These behaviours and potential new ones were then incorporated into a multi-user system where management of control was virtualized, using mobile devices for input. We found that behaviours derived from existing ones (e.g. passing/taking control) were at worst functionally equivalent to, and in some cases superior to, managing a single physical remote control. We suggest that sharing single-user TV systems implementing these behaviours offers a viable alternative to concurrent use TV systems.

Author Keywords

Shared control; multi-user; media systems; mediation of control; single-user;

ACM Classification Keywords

H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous

INTRODUCTION

Since 1955, interaction with the television has iterated upon a single device that is now considered a *de facto* standard: the remote control. It is a device of ubiquity in the living room and has a host of associated management behaviours; it can be passed, taken, shared, relinquished, hidden, denied. However, it is in the process of being supplemented with new interfaces relying on previously under-used input modalities (such as gesture or voice) and mechanisms (such as every mobile device in the room) for exerting control. In addition, it is becoming commonplace for modern SmartTVs to bundle multiple remotes (e.g. a standard button remote and a touchpad or gestural remote), whilst Android devices are now available with IR blaster support, thus potentially vastly increasing the number of devices capable of controlling a given media system.

As such, the constraint of "one user at a time" is being eroded, with new possibilities for seamless multi-user use (be it discrete or concurrent) becoming a reality; for example consumer televisions (e.g. Samsung SmartTVs[1] with gesture/voice/touchpad control) and set-top boxes (e.g. the Xbox One[2] building on previous work regarding voice and gesture controls [10]) feature the technological capability for multi-user use. However, existing behaviours and familiar interactions are potentially being discarded without due consideration. These new systems introduce two issues: concurrency of use and management of use.

Concurrency of use: In providing systems that support concurrency, we may be introducing additional complexity and undermining users' mental models of the media systems they interact with. This could have an affect on groups such as visually impaired people (with the state of the system changing outwith their control) or older adults (with concurrent multi-user use often enabled through multi-pointer/cursor approaches which both require a degree of dexterity and coordination, whilst increasing visual complexity; this is in contrast to systems reliant on discrete events for navigation for example). Additionally, there exists a significant legacy of single-user set-top boxes (cable/satellite receivers etc.) that do not support concurrency but could support a system mediating between given inputs.

Management of use: In facilitating ubiquitous control and moving away from traditional behaviours for managing control, we may be undermining the users' capability to manage who can interact with these systems, for example parents taking the remote away from a child. Whilst systems such as the Xbox One have the capability to identify users, and thus the crude physical management of control could be supplanted by a more reactive and programmed form of management, there are a number of issues e.g. privacy concerns regarding always-on sensors in the living room. As such, there is scope for arguing that traditional behaviours for managing use be preserved in some fashion, and furthermore that we identify

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[1] `http://www.samsung.com/us/2013-smart-tv/`
[2] `http://www.xbox.com/en-US/xbox-one/entertainment`

the components of these traditional behaviours that are most important (in terms of usage and acceptability).

This paper investigates how systems designed for control by one user at a time can be used my multiple users, examining how existing and new behaviours might fare in a system where the bottleneck of a physical remote control no longer exists, whilst retaining the single-user interface users are familiar with.

RELATED WORK

Sharing Single-User Systems

In 1990, Greenberg *et al.* [6] demonstrated a means of sharing single-user applications through view-sharing and turn-taking, and this concept has been frequently extended and re-implemented since. For example, two decades later, Abe *et al.* [1] examined tolerant sharing of single-user applications amongst multiple users. The idea of adapting single-user systems represents a pragmatic approach, one that is often deployed due to some constraint preventing the redesign of the underlying single-user system. Often it is a wish to retain the mental model and learned behaviours users have developed, or an acknowledgement that systems are often targeted at the single-user model, even though there will be use cases where multi-user use is likely to occur.

Concurrent Interaction

Concurrent use interfaces are either managed (e.g. You *et al* [18] used computer vision techniques to detect users and partition and rearrange personal space on a shared display), self-managed (e.g. Tse *et al* [17] demonstrated how users were found to self-partition shared workspaces in order to achieve optimal collaboration), or achieved through the combination of the two. This is a common feature of tabletop interaction, for example LunchTable [11] integrated a multi-touch display table with a large, vertical display for rich information, allowing the sharing of content among a whole group, whilst control of the display was managed concurrently via the multi-user table.

Outwith tabletops, Single-Display Groupware [16] multi-pointer systems are perhaps the most relevant example of concurrency [3], to the extent that strategies for multi-pointer management are becoming increasingly relevant [15].

However, the multi-pointer approach is not without its flaws, requiring greater dexterity/continual adjustment when manipulating said pointer (moving away from the discrete, button based controls traditional in remote controls), increased visual noise, and potentially decreased performance [9].

Mediated Interaction

There have been a number of papers proposing shared-use media systems. For example, Ballendat *et al.* [2] developed a system whereby a large vertical display enabled media related tasks (browsing, viewing), adapting the presentation based on the angle and proximity of the user, and pausing when the user was no longer engaged with the system. In this scheme, the user closest to the system was considered most engaged with it, thus essentially sharing the system through a hierarchy of proximity.

Pohl *et al.* [13] proposed that interaction could be defined by the extent to which the user was engaged in a task. They suggested that there was a set of scenarios where casual interaction might be better suited for a given task, and that determining this level of engagement (and thus which form of interaction, casual or focused/engaged) be up to the user. The system would then adapt depending on how much attention and effort the user chose to invest. They too discussed proximity, for example pointing to the fact that the bandwidth of user interactions decreases proportional to distance to the device with which the user is interacting, thus mapping engagement to proximity.

However, these approaches may not be appropriate for collocated groups in shared spaces interacting with media systems. For example, the proxemic approach does not take into account the fact that proximity to a media system is dictated not by engagement, but by seating arrangement: it might be just as likely to be fully engaged in the system, without being the closest person to said system, as being entirely disengaged from the system at close proximity, given the variety of seating arrangements in living spaces.

In contrast, approaches have been undertaken to design "seamless" interaction techniques such that, regardless of proximity, the same mechanics for interaction would be retained. Clark et al. [5] proposed a proximity-based interface that allowed users to interact with a media system both within range of touch, and at a distance, transitioning to pointing or device input when far away. Of note here was the fact that in the evaluation of this system, the proximity-based interaction was not frequently used; additionally, having the interface change depending on distance via zooming was found to be counter-intuitive.

This raises some important discussions regarding whether an interface should be adaptive within the domain of the living-room: is there enough space typically available such that the interface becomes unusable at a distance and thus needs to adapt? And how is shared use facilitated? If a group of users is currently attending to the display, with one user browsing through available media, to whom should the display be targeted?

Group interaction with media systems overlaps with these techniques, but is fundamentally different in many ways. Proximity is in all likelihood rendered irrelevant in static seated contexts, whilst attentional interfaces are muddled by the fact that many users may be attending to the display, and all may intend to interact with it at some point.

Additionally, attempting to adapt to attention is fraught with difficulty: if a user looks away from the screen, perhaps to talk to someone, that does not give sufficient justification that they might want their media paused: in providing interaction techniques that are low effort and seamless, both casual and engaged interaction are potentially adequately facilitated.

Finally, there are also social and cultural issues: any given interaction technique may contradict societal norms (e.g. undermining the control of the head of the household) or cultural norms (e.g. a particular gesture set being inapproriate).

Summary

Shared use of media systems by co-located groups occurs frequently, and as such these media systems should be able to flexibly facilitate such usage, whilst taking advantage of new modalities and input mechanisms available to users. Schemes have been proposed that implement new behaviours and interfaces, supporting concurrent or mediated usage, which have had some success. However, they do not adequately take into account the breadth of reliance on single-user media systems, and the existing behaviours for explicitly managing use or control of these systems that have been developed over a considerable period of time.

EXISTING BEHAVIOURS SURVEY

To gain an understanding of existing behaviours for sharing control in home media systems and their acceptability, a short survey was conducted, reaching 156 respondents in all (for demographics see Figure 1). The survey was sent out to available University mailing lists (covering staff and students) as well as online forums/social media, with printed copies distributed to respondents in demographics less likely to be reached via email.

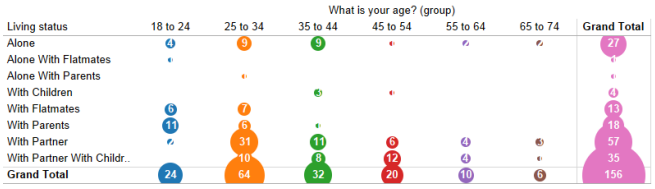

Figure 1. Demographics of respondents, broken down by age and living status (gender omitted, however split was approximately 60-40 biased towards males).

Its intention was exploratory, consisting of questions (predominantly 5-point Likert-type) constructed to explore control methods, decision making and media consumption activities across various different intimacy groups (groups of friends, family, colleagues etc.). Full survey results are available on request.

Control Is A Commodity

The most relevant and interesting result of this survey was in two questions regarding how control was shared in home media systems and how acceptable these methods were (see Figures 2 and 3).

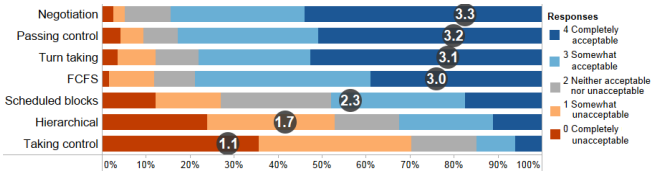

Figure 2. Responses to the question "How acceptable do you find the following ways of controlling media systems?". Responses were Likert-type five point scale, ranging from completely unacceptable to completely acceptable, and converted into 0-4 scale for mean acceptability (labeled in grey circles, higher is better) for relative comparisons.

We asked participants to rate hypothesised control management behaviours (and suggest their own if not appropriate). Of these, "first come, first serve", "passing control around", "negotiation e.g. asking for control" , and "turn taking" were the most used strategies, with "hierarchical (an individual is typically in control)" , "scheduled blocks for sharing control of the TV", and "taking the control from whomever currently has it" falling behind. This supported the view that control of these systems is a commodity or resource in and of itself. As the person currently in control plays a large part in dictating events, if you acquire control, you might be reticent to relinquish it; societal norms of fairness may, however dictate that strategies be introduced to accommodate other's wishes and uses, hence passing control, turn taking and negotiation feature.

Of these frequently used control schemes, in terms of acceptability they were largely similar (see Figure 3). We would suggest that the behaviours that have developed around control of these media systems have evolved towards ones that are broadly acceptable. They may not be perfect (for example, first come first serve featured ~60% of respondents in the somewhat acceptable or lower category), but people are familiar and comfortable with passing control, and negotiating amongst themselves, an indicator of the social nature of managing these systems.

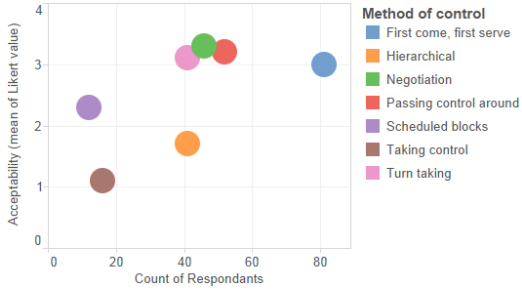

Figure 3. Plot of acceptability (mean of converted five point Likert scale to 0-4 scale for scoring, higher is better) against count of respondents that had previously responded to using that method of control often.

Of the less frequently used schemes, taking control was deemed unacceptable (~70% of respondents considering it somewhat to completely unacceptable), as was hierarchical control (~50% considering it somewhat to completely unacceptable).

From this survey, we arrived at an understanding of current behaviours for managing control: whilst these behaviours ranked highly in terms of acceptability, their suitability in scenarios where the token of the single remote control was removed (e.g. gesture or device control) would be questionable - are these acceptable behaviours (such as passing control) to be marginalised in the face of allowing anyone control at any time, and how will we design systems that can handle such an eventuality?

STUDY: MEDIATION OF CONTROL

Given the findings of the survey and the literature review, we elected to develop a system for virtualizing control, such that it could be managed in software by users, in order to investigate the following questions:

1. How relevant are existing behaviours for managing control, given the eventual removal of the bottleneck of a single remote control?
2. Can users self-mediate control, in the case where everyone is in control? Is mediation of control necessary?

3. What new behaviours can we facilitate given a virtualized control and how do these compare to existing behaviours?

We chose to examine these behaviours on a TV media system designed for use by one user at a time. This allowed us to retain the interface and mental models that users are familiar with, whilst also examining the potential for facilitating multi-user use of existing single-user media systems. Furthermore, this provided the added benefit of being able to examine our virtualized management of control without the potentially confounding effect of a concurrent use, multi-user interface (for which there is as yet no established standard).

Thus, our control scheme was to be similar to that of a standard remote, with the ability to move left/right/up/down, and select items of interest. Multi-user use was to be facilitated through virtualized management of control.

Proposed Control Schemes

For this study, 10 different control schemes were proposed (see Table 1 for details), broadly categorised as either "one user in control at a time" (hereafter "one user"), and "multiple users concurrently" (hereafter "everyone"). The "one user" schemes were based on existing behaviours: **passing**, **taking** and **turn taking**. Additionally, a variant of passing/taking was introduced: ***lending***, essentially a hierarchical means of managing control where control could be lent out, and revoked, from an individual with authority. The **control** condition also fell into this category, being one remote control physically shared amongst participants.

The "everyone" schemes were introduced on consideration that, if everyone could potentially be in control of a single-user interface, would an amount of self-organisation/mediation take over, thus demonstrating that system-based mediation of control was not necessary? As such, conditions were added allowing for **everyone** in control, **subsets** of control (where different group members had control of different functions, thus requiring cooperation), **hierarchy** (where one member's input would override that of the others), **plurality** (where selection decisions were based on majority votes but navigation was concurrent) and **blocking** (where members could selectively and temporarily block each other from control).

Participants

Three person intimacy groups (2 groups of friends, 1 group of cohabitants, 1 family group (siblings), 1 group of colleagues) were recruited, five groups in all, fifteen participants total (male=7, female=8, mean age=21.2, SD age=3.5). These participants were to be evaluated across two sessions in a repeated measures (within-subjects) design, with five conditions in one session, and five in the second.

Each session was one hour long, with conditions assigned to sessions in a pseudo-random manner. Additionally, participants were given time to trial each mediation of control scheme until they felt comfortable in its operation.

Task Design & Implementation

The task was to schedule what programs the group wished to record for a given 3-hour time period (once per condition), using an Electronic Programme Guide (EPG). For each condition, they were assigned a three hour block in which they were to pick and choose programs to record for viewing.

The program listing was generated from scraped listings of UK and New Zealand television, and randomly assigned into hour long or half hour long blocks. Conditions were assigned pseudo-randomly to time-periods, with no condition using the same time period more than once. The EPG used for this task was Windows Media Center (WMC)[3]. This was done primarily to ensure ecological validity using an interface comparable with home media systems.

In terms of the virtualized management of control, Android phones with a basic remote interface were used (see Figure 4). These devices provided users with the ability to browse through the EPG, confirm recordings and manage control through two "special" buttons whose function changed depending on the mediation of control scheme being used.

For example, in the passing control conditions, these two buttons would refer to the other two participants by name, allowing the user to select to whom to pass control. Additionally, the devices gave feedback as to who was in control and an overview of the main display (the WMC interface). The WMC EPG itself was presented on a projector display, with participants arranged sociopetally around the display in a mock living room (see Figure 5).

For implementation details for each condition, see Table 1. Task duration was enforced through the use of 3 hour blocks in the EPG (which took from ~3min to schedule, with an additional unlimited time for training that usually lasted for around ~3 min). As such each control scheme was typically used for ~6min (so ~30min per session, ~25min for questions, ~5 for briefing). There was no time pressure; participants carried out the task to completion at their own pace.

This task duration was deemed acceptable because people interact with EPG interfaces often, but for short intervals; it is the nature of both the time-series data, the narrow range of time they are interested in, and the aim of the task. The task

[3] `http://windows.microsoft.com/en-GB/windows7/products/features/windows-media-center`

Figure 4. The user interface for controlling the system, and managing control. Three Android devices were used as remote controls to a Windows Media Center interface (pictured right). The bottom left/right buttons change function depending on the condition being evaluated.

Condition	Description	Implementation Details
		One user at a time
A: Control condition	One person in control	*A single device placed on the table with participants instructed to use it as they would a normal remote*
B: Lending	Ability to lend control and take it back	*Two buttons were used to explicitly lend/retrieve control*
C: Passing	Control can be passed around	*Two buttons were used to explicitly pass control to the other participants*
D: Taking	Control can be taken off them	*Two buttons were used to explicitly take control from the other participants*
E: Turn-taking		*Control was passed every 10 seconds*
		Multiple users (Everyone contributes to control)
F: Everyone	Everyone has control	*All devices in control at all times*
G: Plurality	Majority rules voting for selections	*When a selection was made participants were blocked from browsing, and would have 5 seconds to respond positively to confirm the selection or it would be denied*
H: Hierarchy	Designated individual outranks the others and can override their control	*One participant was randomly selected to outrank the others, when they used the system the others were blocked from control*
I: Subsets	Everyone has a subset of control	
J: Blocking	Can block other people temporarily	*Two buttons were used to selectively block participants for periods of 4 seconds*

Table 1. Experimental conditions by category. "One user at a time" denotes one person in control at any one time, while "Multiple Users" denotes everyone being in control simultaneously.

itself is well understood by users, short to conduct, and provided motivation for multiple users to interact concurrently (conflicting media interests), suiting our usage as a novel and ecologically valid task.

For the purposes of this experiment, ecological validity was strived for in a number of ways: the use of WMC ensured an ecologically valid single-user EPG interface, representative of media systems used in the home currently. A laboratory room was mocked up to resemble a living room, with natural lighting, comfortable sociopetal seating and a large display.

Figure 5. Living-room-like space used for conducting evaluations. Left: sociopetal seating arrangement. Right: Projector display with WMC.

Measures

Participants were recorded for the duration of the experiment, while instrumented system usage metrics (action counts: number of button presses per user) were also captured to measure intra-group dominance: the disparity between users within their groups i.e. to what extent did one user dominate usage of the system.

Users were presented with questionnaires on the completion of each condition, including workload (NASA TLX [7]), usability (System Usability Scale (SUS) [4]), and 5-item Likert-scale questions covering the acceptability of control schemes and preferences regarding their use.

Additionally, users were asked to rank the conditions in order of preference at the end of the study, with post-condition and post-experiment interviews used in order to further understand user preferences and dislikes regarding control schemes.

Results

Unless otherwise stated, a repeated measures ANOVA (conducted using linear mixed-effects model fit by maximum likelihood (*lme()* in R) was performed with a *post hoc* Dunnett's test (comparison of every condition with the control, which was analogous to a single physical remote control). Conditions found as significantly different ($p<0.05$) from the control in the Dunnetts test are listed in each Figure. Boxplots show quartiles (25th, 50th, 75th), with means indicated by the dark circles.

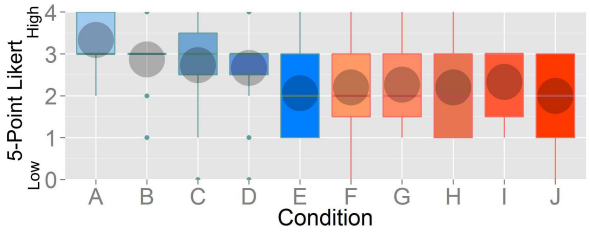

Figure 6. "I was satisfied with my experience using the system to accomplish the task" - $\chi^2(9) = 24.0994, p < 0.01, \eta^2 = 0.143$ Dunnetts: E, F, G, H, I J (letters refer to conditions in Table 1). Blue shades: "one user" conditions. Red shades: "everyone" conditions.

"One User" Schemes Are Functionally Equivalent

The "one user" schemes appeared to be functionally equivalent across a variety of metrics, with comparable SUS scores (see Figure 9), TLX scores (see Figure 8), and action counts (a measure of how much effort was required in order to use the system, see Figures 7 and 10).

Additionally, Conditions B, C, and E all achieved superior mean rankings than A (see Figure 11). Indeed, these Conditions could rarely be separated from the control.

"Everyone In Control" Fared Poorly

Conversely, the "everyone in control" conditions were broadly found to be significantly worse than the Control in SUS scores, TLX mental demand, temporal demand, effort, frustration, and self-rated satisfaction with using the system.

Additionally, the "everyone" schemes were rated poorly in terms of acceptability as a means of sharing control with others, fairness, and the extent to which users felt "in control". This trend continued in the instrumented metrics, with higher

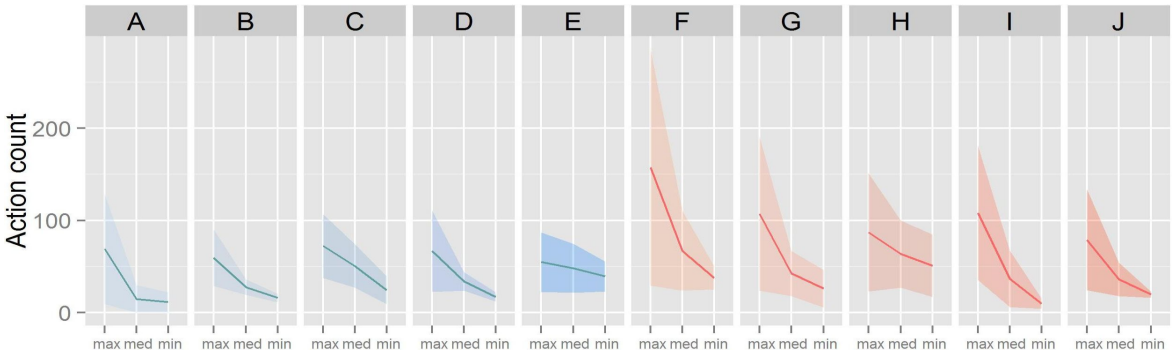

Figure 7. Dominance by actions - Plot of three values per condition: mean of (max / median / min) action counts across groups, with shaded standard deviation - $\chi^2(9) = 21.11, p < 0.01, \eta^2 = 0.233$ Dunnetts: F. Blue shades: "one user" conditions. Red shades: "everyone" conditions.

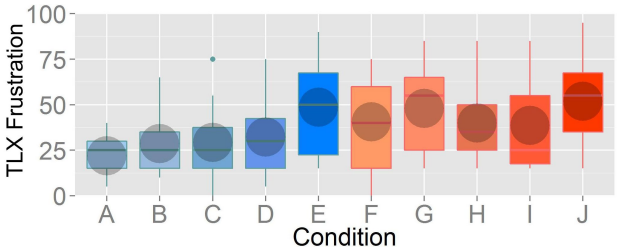

Figure 8. TLX Frustration Question by condition, lower is better - $\chi^2(9) = 33.93, p < 0.01, \eta^2 = 0.103$ Dunnetts: E, F, G, J. Blue shades: "one user" conditions. Red shades: "everyone" conditions.

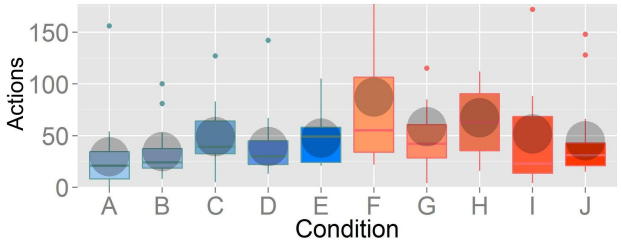

Figure 10. Mean actions across users by condition - $\chi^2(9) = 23.30725, p < 0.01, \eta^2 = 0.104$ Dunnetts: F. Blue shades: "one user" conditions. Red shades: "everyone" conditions.

mean action counts (see Figure 10), indicating that instead of self-mediation, users were having to expend greater effort in order to counteract each other's inputs.

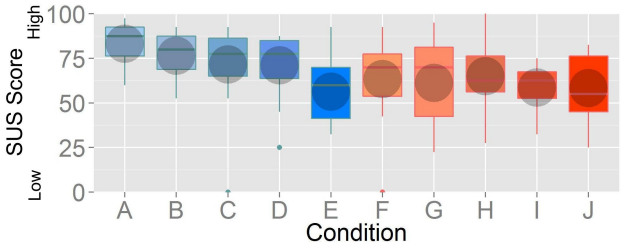

Figure 9. Overall SUS Score (a ten-item Likert-type questionnaire for assessing usability, higher is better) - $\chi^2(9) = 36.80, p < 0.01, \eta^2 = 0.181$ Dunnetts: E, F, G, H, I J. Blue shades: "one user" conditions. Red shades: "everyone" conditions.

Dominance

Dominance here refers to the disparity between users within their groups, in terms of instrumented metrics, specifically action counts (button presses). This was examined as a potential metric for measuring fairness: to what extent did one user dominate usage of the system. Shareability [8] has been shown to be important in terms of impacting equity of control [14]; barriers preventing shareability thereby foster interpersonal dominance within groups (as seen for example in [12]).

In Figure 7 we can see that by action count, condition E (turn taking) exhibited the least dominance, which is to be expected when each participant is given the same amount of time in which to operate. Compared to our control condition, the "one user" conditions exhibited lower dominance behaviour, in contrast to the "everyone" conditions.

The "one user in control" conditions by and large exhibit low dominance, a level that is perhaps socially acceptable or even necessary for a group task. The results for condition D partially confirm this: in this condition, participants were allowed to take control whenever they wished, therefore it might be reasonable to presume that if one participant was dominating to the detriment of the experience, the others might have taken control, given their familiarity with their fellow participants.

In contrast the "everyone in control" conditions exhibited greater dominance behaviour than the "one user" conditions, an indicator of their chaotic nature (reported in most post-condition interviews), with one user effectively being required to actively and continuously assert control over the system in order to counteract the discordant nature of multiple simultaneous inputs.

Caveats & Edge Cases

There were some notable exceptions to these observations. For example, Condition G (majority rules for selections) came out favourably in subjective metrics; participants indicated that although they disliked the underlying "everyone" scheme they enjoyed the fairness of voting to make a selection; this was a confound where we evaluated mediating selection, not control.

Similarly, Condition E (turn taking) frequently fared poorly (e.g. featuring the highest mean TLX temporal demand). Enforced fairness via time-slicing may have been confounded by the necessity to time-slice at small intervals in order to allow participants to experience the control scheme within the duration of the task.

Additionally, questions are raised regarding the acceptability of taking control (condition D), whose mean ranking was the only ranking of the "one user" conditions to be worse than the control.

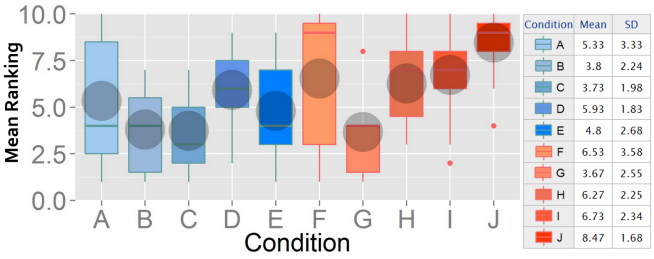

Figure 11. Ranking (lower is better) - Friedman test $\chi^2(9) = 37.20$ $p < 0.01$, Wilcox pairwise sign rank test with Bonferroni correction showed no statistically significant differences ($p > 0.05$)

Interview Feedback

Control: Some Want It, Some Don't

For some, being in control was important and not being in control disquieting (G: refers to group, C: refers to condition):

> "I liked the ones where I was in control, I liked being the one in control" G:2, C:Debrief

Conversely, in some of the groups there were participants that had no interest in being in control, for example because of a disinterest in making decisions or even a dislike in sharing viewing:

> "I don't like being in charge, so I'm happy to let someone else have the responsibility" G:2, C:F
> "I liked it because he was in control, and can watch what he wants to watch" G:2, C:A
> "I don't want to share TV with them!" G:3, C:D

"Everyone In Control" Encourages Dominance

Three groups provided similar complaints regarding the discordant nature of the everyone in control conditions, with participants explicitly noting the presence of dominance behaviour in this condition:

> "I always find this a bit annoying in computer games where you both have control and you invariably hit the wrong thing, because you both go down at the same time, so you make mistakes more trying to get to the same thing" G:2, C:F
> "One person has to take the lead because you can't all operate at the same time" G:3, C:F

"One User At A Time" Preferred

Again, most groups noted and preferred the simplicity of the "one user in control" schemes and their associated management schemes, e.g.:

> "It was good to be able to transfer the remote" G:2, C:D
> "One person in control is the best, because we can all talk to each other and just one can pick" G:4, C:Debrief

However there were concerns regarding the usefulness of some of these schemes:

> "I feel like this is just mechanising something you can do naturally" G:2, C:G
> "I think in the end everything is too tiring for me, I prefer to give control to anyone, quite a lot of things are interesting to watch." G:3, C:Debrief

SUMMARY AND DISCUSSION

"One user at a time" is superior to "everyone in control"

The "one person" conditions exhibited statistically better SUS ratings and mean rankings (aside from Condition G) confirming the view that the primary differentiator between conditions was whether they allowed concurrent inputs versus allowing one user to interact with the underlying media system at a time.

Lending, passing, and taking control are, at worst, comparable to having one physical shared remote

These conditions exhibited comparable TLX, SUS, and dominance behaviour (with no statistically significant differences) whilst mean user rankings were moderately better than that of the control (Condition A). That these schemes approach the usability of the single remote control users are familiar with suggests that we can build mediation of control schemes that are on par with, and superior to in functionality, the existing standard of a single remote control for input.

"Everyone in control" is poorly suited to concurrent use

These conditions exhibited worse mean rankings, poor SUS scores, higher TLX frustration, as well as greater dominance behaviour (excluding Condition G). This suggests that single-user media systems should not be opened up to concurrent use, and places a question mark over the usability of new input mechanisms such as phones with IR support if there is no means of mediating between multiple concurrent inputs.

Design Implications

Currently, there are a number of ways in which TV media-system user interfaces can accommodate multi-user use e.g.:

- Multi-pointer/cursor UIs
- Split-screen/screen division
- Offloading interaction onto other devices or screens
- Mediating control through proximity or attention

However, these approaches may have issues regarding moving away from existing interfaces and their associated mental models and behaviours. We propose that, given the increasing range of input modalities (e.g. mobile phones with IR support or remote apps, or multiple users employing gestural controls etc.) mediation of control schemes might provide an alternative to redesigning familiar interfaces, allowing use of these new input modalities and mechanisms without coupling them to new and potentially confusing user interfaces, by retaining familiar single-user interfaces and interactions. As an example, consider a TV which can be controlled by every smart phone in the room; mediation of control would allow users to achieve concurrent use, where destructive inputs (e.g. both attempting a navigational event simultaneously) would be prevented.

Additionally, we propose an initial set of mediation of control schemes (passing/taking/lending control), based on existing control management behaviours, that can facilitate this usage.

Future Work

We foresee a number of areas in which further work would be required in order to determine both the viability and suitability of mediation of control schemes.

Appropriateness of Mediation of Control

Establishing the generalisability of this approach e.g. what tasks are suited to more simplistic single-user interactions (and thus are suited to mediation of control schemes) would aid in designing multi-user smart TVs whose more basic or ubiquitous functionality is still readily accessible to users of all ages and capabilities. Navigation, 1-dimensional controls (e.g. volume or channel switching), or contexts where the complexity of higher bandwidth input controls (such as pointer input) is unnecessary (e.g. grid-based views navigated via cursor) might all be areas where mediation of control is of use. Additionally, facilitating management of control might provide additional social benefits, for example being able to take control from children, or have parental inputs prioritised, that would be worth investigating in longitudinal studies in the home.

Further Mediation of Control Schemes

Our study looked at existing behaviours as the primary inspiration for our mediation of control schemes, suggesting thus far that there is no one scheme that should become the defacto mediation of control scheme. There are other potentially useful ways in which mediation of control could be applied, for example:

- Inferring when a user is no longer interacting
- Prioritising user inputs and modalities
- Employing timeouts to automatically relinquish control

Future work should look to examine both their acceptability, their suitability across different tasks and contexts, and appropriate feedback for communicating availability for interaction, whilst establishing what set of mediation of control schemes should be used, and when.

CONCLUSIONS

Our capability to enable shared use of TV media systems in the home has increased substantially in the last few years, with new input mechanisms (e.g. smartphones) and modalities (e.g. gestures) allowing for anyone in the living room to contribute to the input and control of a media system.

Concurrent use interfaces may be inappropriate for a number of reasons (e.g. visual complexity, undermining existing mental models regarding interaction). Additionally, we suggest that concurrent use of single-user media systems is inappropriate as users are ineffective at self-mediation of control, with inputs combining destructively. As such, we propose that single-user media systems be augmented with mediation of control schemes; this combination offers a potential alternative to concurrent use systems, allowing for users to retain the familiar interfaces and mental models they have developed over time, whilst allowing new input mechanisms and modalities to be utilized in an effective and useful way.

Finally, we offer an initial set of mediation of control behaviours (passing, taking and lending control) derived from existing behaviours for managing control that are at worst functionally equivalent to, and in some cases better than, in terms of dominance and subjective ratings, managing the single physical remote control, to serve as a baseline for examining future mediation of control schemes.

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