User-Defined Game Control with Smart Glasses in Public Space

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ABSTRACT
Without specific game controller and direct-touch, game control on Smart Glasses differs with existing console and mobile games. Although current game control set on Smart Glasses is explored by developers based on system limitation, the set is not reflective of user behavior. To create better game control, we presented an user-defined game control study in public space to collect user behavior. In all, 2448 game control from 24 participants were logged, analyzed, and paired with think-aloud data for 17 commands performed with 3 interaction methods (On-Body, In-Air and Phone) and 2 glasses forms (Google Glass and Epson BT-100). Our findings indicate that users choose area relatively unobtrusive to perform the game control, and glasses form does influence how users creates game control. We also present a complete user-defined game control set with agreement scores and taxonomy. Our results will help designers create better game control sets informed by user behavior.

Author Keywords
Guides; instructions; author's kit; conference publications; keywords should be separated by a semi-colon.
Optional section to be included in your final version, but strongly encouraged.

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INTRODUCTION

RELATED WORK

Game Control

Glass Input

Gaming in Public Space

User-Defined Gesture

DEVELOPING A USER-DEFINED GAME CONTROL SET

Overview and Rationale
Playing game is a *user-computer dialogue*[6], a conversation mediated by language of inputs and outputs. As in any dialogue, feedback is essential to conducting this conversation. When something is misunderstood between humans, it may be rephrased. The same is true for user-computer dialogues. Feedback, or lack thereof, either endorses or deters a player's action, causing the player to revise his or her mental model and possibly take a new action.

In Developing a user-defined game control set, we did not want the limitation of input technology to influence users' behavior. Hence, we sought to remove the *gulf of execution*[9] from the dialogue, creating, in seence, a monologue in which the player's behavior is always acceptable. This enables us to observe users' unrevised behavior, and drive system design to accommodate it.

In view of this, we developed a user-defined game control set by having 24 participants perform game control with 2 Smart Glasses (Google Glass and Epson BT-100) in a public cafe. To avoid bias from visual hint[3], no elements specific to Mobile, Console, PC games were shown. Similarly, no specific game title was assumed. Instead, participants acted in a simple blocks world of geometry shapes or basic human avatar. Each participant saw the effect of a game control (e.g., an object moving left and right) and was asked to perform the game control he or she though would cause that effect(e.g. moving the finger tip left and right in front of their chest). In another word, the effect of a game control is the *game task* to which the game control try to complete.

Seven-teen game tasks were presented, and game controls were elicited for three different interaction methods (in-air

#	Task	Used in Famous Game
1	Single select	Clash of Clans, Plague Inc.
2	Vertical menu	Puzzle&Dragon, PeggleHD
3	Horizontal menu	Clash of Clans, PeggleHD
4	Move left and right	Temple Run, Super Mario
5	Move in 4 directions	1943, RaidenX
6	Switch 2 objects	Candy Crush, Bejeweled
7	Move object to position	World of Goo, The Sim
8	Draw a path	Draw Something, P&D
9	Throw an object (in-2D)	Angry Birds, PeggleHD
10	Note highway	RockSmith, Deemo
11	Rotate an object (Z-axis)	Zuma, PeggleHD
12	Rotate an object (Y-axis)	Spore, The Sim
13	Avatar jump	Temple Run, Super Mario
14	Avatar 3D move	Spore, Tintin
15	Avatar attack	Minecraft, Terraria
16	Avatar squat	Temple Run, Minecraft
17	3D Viewport control	The Sim, Spore

Table 1. Summary of our general casual game task set. We named several famous games which uses these tasks.

gesture, on-body input, mobile phone interaction). The system did not attempt to sense the users' control input, but we use camera to record the whole control process. Participants used the think-aloud protocol and been interviewed about the control detail. They also supplied subjective preference ratings.

The final user-defined game control set was developed in light of the *agreement* participants exhibited in choosing game control for each command[15]. The more participants that used the same gesture for a given command, the more likely that gesture would be assigned to that command. In the end, our user-defined game control set emerged as a consistent collection founded on actual user behavior.

Game Tasks

Casual game is one of the game categories with most players[5], and it is shown high potential in public gaming[10, 11, 2]. We choosed top 90 casual games[13] from existing platforms, including PCs, consoles and mobile games (30 games for each) by crawling and analyzing the sale and download count data from famous gaming websites[1, 14, 12, 7]. We invited 3 experienced game developers to review these top 90 casual games. They found out 26 game tasks in total, and removed 9 tasks which were only used once in specific games. At last, we got a set of general casual game task(shown in Table 1) with 17 tasks, which can completely support 90% of our top casual games.

Participants

We recruited twenty-four participants from the mass population with equal sex ratio for our study. Their average age are 23.2 (*sd* = 2.72). All participants are right-handed and none of them had past experience with Smart Glasses usage. About their gaming experience, according to our investigation, 14 users were daily game players, 9 were weekly and 1 was monthly. Participants spent 1.36 hours (*sd* = 0.89) in average to play games one time. Moreover, 58% of them indicated that their main gaming platforms were on mobile phones, 38% were on PCs, and only 4% were on consoles. Another important factor of gaming experience is the familiarity of game controllers. The result showed that, compared with joysticks, most of them were more familiar with keyboards, mouses and touch screens (see Figure 1).

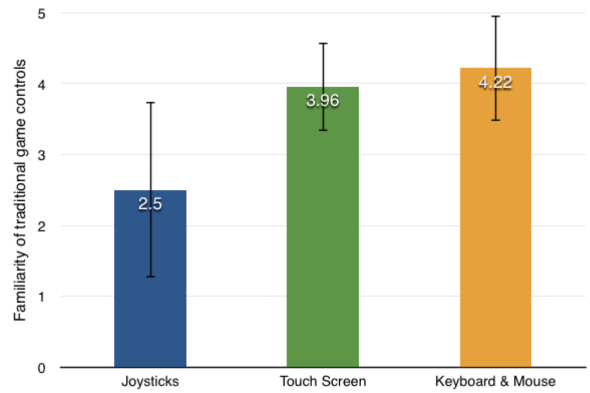

Figure 1. Users' game control familiarity.

Glass Forms

There are many Smart Glasses with different screen sizes and screen placement on the current market. To observe the effect of distinct display designs upon the study result, our study conducted on two famous Smart Glasses, Epson and Google Glass. The display of Epson BT-100 is located in front of the user's eyes with 960 $\times$ 540 resolution (equivalent of a 320" screen from 20 m away)[4]. And Google Glass locates its display above the user's right eye with 640 $\times$ 360 resolution (equivalent of a 25" screen from 2.4 m away)[8].

Interaction Methods

Procedure

Users wore two different glasses (BT-100 and Google Glass) and our software randomly presented 17 game tasks (Table 1) to participants. For each game task, participants performed a game control in 3 different interaction methods(in-air gesture, on-body input and phone interaction). And study conducted with a counterbalanced measures design with Glasses form and interaction method. After each game control, participants were shown a 5-point Likert scales concering subjective preference. With 24 participants, 17 game tasks, 2 glasses forms and 3 interaction methods, a total of 24 $\times$ 17 $\times$ 2 $\times$ 3 = 2448 game control were made. Of these, 11 were discarded due to participant confusion.

RESULTS

Our results include game control taxonomies, user-defined gesture sets, user rating, subjective responses, and qualitative observations for each interaction methods.

Preference Between Interaction Methods

Table 2 shows the average rating of 3 interaction methods. Between three interaction types had a significant difference($F_{0.05}$(2, 2445)=4.61, P = .01). We found the user

Mothod	Mean	Std.	L.Bound	U.Bound
In-Air	3.81	0.90	3.75	3.87
On-Body	3.77	0.81	3.72	3.83
Phone	3.68	0.79	3.63	3.74

Table 2. Summary of user preference between 3 different interaction methods, it provides mean value, standard deviation, 95% confidence interval for mean(Lower Bound and Upper Bound).

rating preference for in-air gesture was siginificant higher than phone interaction (P = .009). And we didn't find significant difference between in-air and on-body (P = .688). According to our interview, general reasons about why did users give phone a lower score had been found. Reason were that users had to take out their phone from packet. Users thought it was not always available and was not hands-free compared to the other interaction methods in this study. Considering the article length of this paper and user preference mentioned above, our report will focus on the finding in-air gesture and on-body input.

Behavior with Different Glasses Forms

In our study, There are 1224 game control pairs with identical user, task and interaction method. We found 119 pairs of game control (9.72% of all) were designed differently with distinct smart glasses forms. The influence of game control in each interation methods were 20.59% for in-air gesture controls, 7.35% for on-body input and 1.22% for phone interaction.

While using in-air gesture as interaction method, users who designed distictive game control mentioned that they were eager to use direct-touch in front of their face with Epson BT-100. However, it is difficult to perform same control with Google Glass because of the small screen size (an in-air fat finger problem). On the other hand, reasons to use different controls with on-body and phone interaction methods are really random and users couldn't explain by their own.

Although the form factor of smart glasses influenced the design of game control, the user preference ratings for user-defined game controls between 2 different glass forms were almost no difference($F_{0.05}$(1, 2446)=.36, P=.549).

Classification of Game Controls

As noted in related work, ???????? . However, no work has established a taxonomy of game control based on user behavior in public space to capture and describe the game design space.

Taxonomy of Game Control

The authors manually classified each gesture along four dimensions: *form*, *nature*, *binding*, and *flow*. Within each dimension are multiple categories, shown in Table 3.

To control for interrater effects, an independent rater performed the same categorization using 170 trials data (random selected 10 trials for each tasks), Interrater reliability shown in table 4. The average Kappa is .897. A Kappa value of .8 and higher is considered *almost perfect.*

Taxonomy of Game Controls		
Form (In-Air)	*finger*	Using finger to perform control.
	hand	Using hand to perform control.
	head	Using head to perform control.
	voice	Using voice control.
Form (On-Body)	*palm*	Interact b.t. finger and palm.
	fingers	Interact b.t. fingers.
	leg	Interact b.t. hand and leg.
	handback	Interact b.t. finger and handback.
	forearm	Interact b.t. finger and forearm.
	face	Interact b.t. finger and face.
	wrist	Interact b.t. finger and wrist.
	ring	Interact with ring.
	watch	Interact with watch.
	glasses	Interact with glasses.
	necklace	Interact with necklace.
Binding	*direct*	Directly control with screen.
	surface	Absolute mapping screen to surface.
	independent	No binding b.t. screen and control.
Nature	*symbolic*	Control visually depicts a symbol.
	physical	Control acts physically on objects.
	metaphorical	Control indicates a metaphor.
	abstract	Control mapping is arbitrary.
Flow	*discrete*	Response occurs *after the user acts.*
	continuous	Response occurs *before the user acts.*

Table 3. Taxonomy of game controls based on 2448 gestures. The abbreviation "b.t." means "between".

The scope of the *form* dimension is applied separately to different interaction methods. There are 4 form categories with in-air gesture. *Finger* is a special case of *hand*, but it is worth distinguishing because of their similarity to mouse actions and direct-touch. There are 11 *form* categories with on-body input. Each form categories can be sensed by different techonologies. 4 of them (*palm*, *handback*, *forearm*, *wrist*) are operating with both hands. 2 of them (*leg*, *face*) are using single hand to interact with different body parts. *fingers* is specific with single hand control with just interaction between fingers. rest of them (*watch*, *glasses*, *necklace*) are interacting with gadgets.

In the *nature* dimension, *symbolic* controls are visual depictions. For example, forming the victory pose in the air for selecting menu option 2, or forming a gun pose to throw an object. *Physical* controls should ostensibly have the same effect with real world physical objects. *Metaphorical* controls occur when a control acts on, with, or like something else. Examples are tracing a finger in circle to simulate a "object ratating", using two fingers to "walk" across the palm, pretending the palm as a trackpad to perform gestures. Of course, the control itself usually not enough to reveal its metaphorical nature; the answer lies in user's mental model which can be understood by our interview. Finally, *abstract* gestures have no *symbolic*, *physical*, or *metaphorical* connection to their referents. The mapping is arbitrary, which does not necessarily mean it is poor. Touch between thumb and index finger to perform "avatar jump", for example, would be an abstract control.

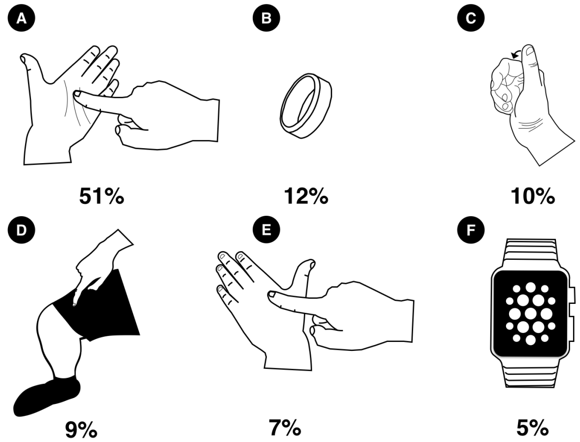

Figure 3. The top 6 on-body input forms. (A)Interact between finger and palm. (B)Interact with ring. (C)Interact between fingers.(D)Interact between finger and leg. (E)Interact between finger and hand back. (F)Interact with watch.

#	Task	Kappa Value
1	Single select	0.863
2	Vertical menu	1.000
3	Horizontal menu	0.688
4	Move left and right	0.825
5	Move in 4 directions	1.000
6	Switch 2 objects	0.804
7	Move object to position	1.000
8	Draw a path	1.000
9	Throw an object (in-2D)	1.000
10	Note highway	0.697
11	Rotate an object (Z-axis)	0.867
12	Rotate an object (Y-axis)	1.000
13	Avatar jump	0.867
14	Avatar 3D move	0.880
15	Avatar attack	1.000
16	Avatar squat	0.878
17	3D Viewport control	0.878
	Average	*0.897*

Table 4. Interrater reliability for each task.

User-Defined Game Control Sets

Agreement

Conflict and Coverage

Properties of the User-defined Gesture Sets

Taxonometric Breakdown of User-defined Game Controls

Mental Model Observations

Social Acceptance and Control Area

Metaphor from Exisiting Game Control

DISCUSSION

Users' and Designers' Gestures

Implications for In-Air Gesture Technology

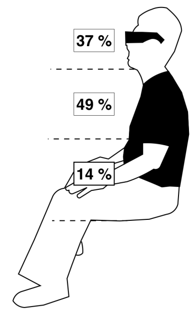

Figure 2. The control area for in-air hand gesture.

Implications for On-Body Input Technology

Implications for User Interfaces

Limitation and Next Steps

CONCLUSION

ACKNOWLEDGMENTS

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