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Abstract. After eliciting 129 potential task-gesture combinations for 23 Smart TV tasks with a Canadian sample (N=22), we then conducted studies that collected participant preference scores on mid-air bare-hand gestures for TV control in both Canada (N=747) and China (N=300), and we analyzed the effect of characteristics of individual participants on gesture preference scores. The results showed that age and cultural differences are important in determining task-gesture preferences. While exploratory, the present results indicate a need for more research in this area and suggest that one of two possible strategies may need to be adopted in designing future gesture interactions: 1) develop customized task-gesture combinations for different cultures and different age groups; 2) develop a core set of task-gesture combination possibilities and let users choose which gesture they want to use for each task.

Keywords: Mid-air/bare-hand gesture design, preference rating, individual characteristics.

1 Background

Early work on gesture-based interaction focused on table-top interfaces [1]. Gesture interaction with a TV was also considered, but it still required a hand-held controller [2]. Other contexts considered for gestural interaction have included driving [3] and gesturing with wearable devices [4]. In this paper we focus on mid-air gesturing, a natural interaction method that lets users control a system remotely without needing a special input device. With embedded cameras on Smart TVs, designers of electronic devices are considering the use of mid-air free hand interactions to control some of the major commands on devices such as Huawei's X65, the Hisense U7, and the Samsung F-series. While several researchers have proposed mid-air gesture designs for TV control [5][6][7][8][9], the input method is relatively new to most people and there is as yet no "standard" vocabulary of gestures. Thus it is difficult for UI designers to design gestures which will be widely accepted by users, and design recommendations are needed that will help UI designers choose the right gesture for different combinations of people and tasks.

2 Objective

Our objective in this research is to understand how the characteristics of individual users affect preference for gestures, focusing on cultural, age, and sex differences. This is a first step towards the development of evidence-based design recommendations concerning how to choose gestures for different groups of people to use when carrying out a particular interaction task.

3 Methodology

We ran two studies, one in Canada and one in China. The gestures used in the preference evaluation study were based on an earlier gesture elicitation study conducted in Canada (N=22) using 23 TV control tasks (see Table 3 in appendix). The gesture elicitation identified 129 salient gesture-task combinations, or approximately six gestures per task on average. The Canadian study participants (N=747) then used the same 23 tasks and 87 gestures, with gestures mapped to each task based on the suitability of the gesture for the task, as identified in the elicitation study, resulting in 129 task-gesture combinations. The participants in China (N=300) rated their preference for a subset of 36 of the gestures matching with 12 of the tasks. Both the Chinese and Canadian participants used a 7-point Likert scale to rate how suitable each gesture was for carrying out/controlling the task that it was assigned to (Figure 1). There were a total of 40 gesture-task combinations in the Chinese study, or a little over three gestures per task on average.

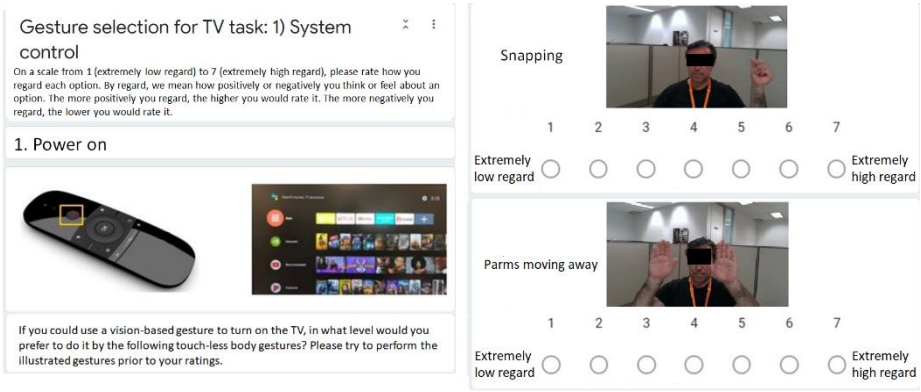


Figure 1. Example of question and rating screen. The gesture image in this figure is an example frame from a GIF animation presented in the online questionnaire.

Across the two studies we addressed the following research questions:

- RQ1: Do preferred gestures, and gesture-task combinations differ according to the age of Canadian participants?
- RQ2: Do preferred gestures, and gesture-task combinations differ according to the age of Chinese participants?

- RQ3: Do Canadian and Chinese users differ in their preferred mappings of gestures to tasks?

4 Results

We began with an analysis of possible bias in use of the rating scale. Chinese participants tended to use higher ratings, and older people tended to use lower ratings. We ran one set of analyses assuming that absolute ratings were appropriate, and we used a second analysis where the ratings were transformed so as to reduce systematic differences in how participants used the rating scale (c.f.[10]). In this second analysis (reported in this paper), the rating scale data were transformed for each participant using a percentile transformation. Each person's set of rating data was converted to a uniform distribution between 0 and 1 by converting each rating point to a percentile equivalent and then dividing by 100.

Preliminary analysis showed that age effects were much stronger than sex effects in both the Canadian and Chinese samples and thus RQ1 focused on age. We used linear discriminant analysis (LDA) to identify a subset of task gesture combinations that differentiated between young (18-24) and older (65+) participants and plotted the corresponding distributions of normalized preferences as box plots (for the task gesture combinations having the highest LDA coefficients), first for the Canadian sample (Figure 2) and then for the Chinese sample (RQ2, Figure 3). Descriptions of the Task-Gesture combinations are provided in Table 1 where the first two columns refer to the Canadian sample and the rightmost two columns refer to the Chinese sample. For the Canadian sample, the medians for the older people on combinations T7G45, T22G50 and T12G58 are above the corresponding 75th percentiles for the 18-24 year olds. For the Chinese sample the medians for older people are similarly higher for T18G40, and perhaps T3G52 but are lower (the media is close to the 25th percentile for the young participants) for T22G48.

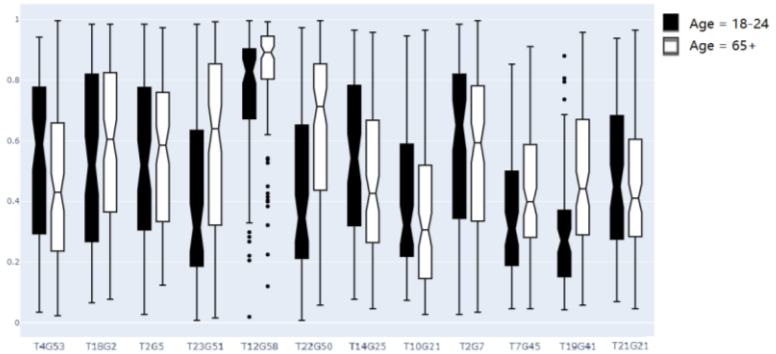


Figure 2. Boxplot for age group normalized preference comparison (18-24 vs. 65+) among Canadian task-gesture combinations. Plot shows the top 12 (10%) of task gesture combinations ranked by size of discriminating function coefficient.

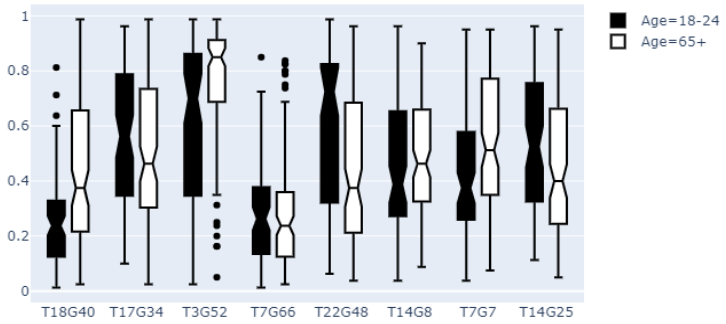
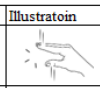
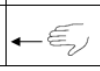


Figure 3. Boxplot for age group normalized preference comparison among Chinese task-gesture combinations. Top 8 (20%) task gesture combinations ranked by LDA coefficient.

Table 1. Task-gesture combinations that most strongly differentiate young and old participants within the Canadian (leftmost two columns) and Chinese (rightmost two columns) samples along with a description of each combination.

Canadian Data Top 10%			**Chinese Data Top 20%**		
Code	Gestures x Task	Illustratoin	Code	Gestures x Task	Illustratoin
T4G53	Task: Unmute Gesture: Full hand pinch opening and closing ("blah blah")		T18G40	Task: Zoom in Gesture: Upright palm moving up	
T18G2	Task: Zoom in Gesture: Palms moving away.		T17G34	Task: Move backward Gesture: Upright fist moving left	
T2G5	Task: Power off Gesture: Waving		T3G52	Task: Mute Gesture: Index on lips (gesture for “shush”).	
T23G51	Task: Volume down Gesture: Covering the ear with hand		T7G66	Task: Home Gesture: Index-middle roof sign	
T12G58	Task: Confirm (Yes) Gesture: Thumb up		T22G48	Task: Volume up Gesture: Turning a knob clockwise	
T22G50	Task: Volume up Gesture: Hand behind ear (sign of "listening")		T14G8	Task: Play Gesture: Opening to palm	
T14G25	Task: Play Gesture: Palm pushing		T7G7	Task: Home Gesture: Closing to fist	
T10G21	Task: Go to first Gesture: Rotated palm flicking left		T14G25	Task: Play Gesture: Palm pushing	
T2G7	Task: Power off Gesture: Closing to fist				
T7G45	Home Gesture: Splay closing to full hand pinch				
T19G41	Task: Zoom out Gesture: Upright palm moving down				
T21G21	Task: Previous Gesture: Rotated palm flicking left				

We then carried out Linear Discriminant Analysis (LDA) comparing normalized preferences for overlapping task-gesture combinations between the Chinese and Canadian samples. We conducted LDA and selected the eight gesture-task combinations that had the highest LDA Coefficients (Table 2), presenting the distributional differences as box plots (Figure 4).

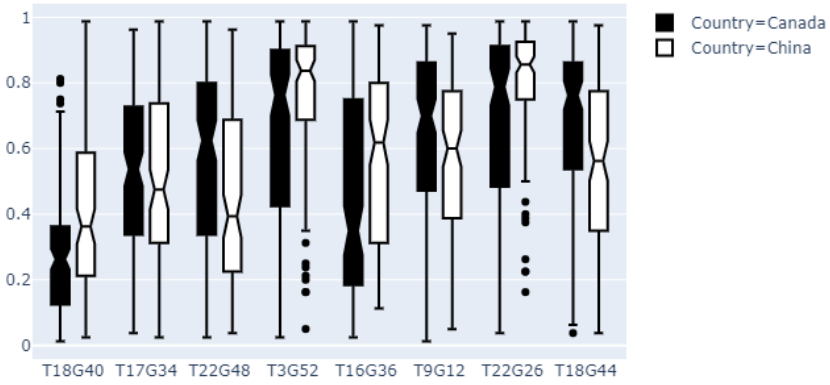
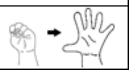


Figure 4. boxplot for age group preference comparison among Canadian and Chinese data task-gesture combinations. Plot shows the top 10% of task-gesture combinations ranked by LDA result.

As shown in Figure 4, the largest differences between the Canadian and Chinese samples were with respect to the T18G40, T22G48 and T18G44 combinations.

Table 2. Top differentiating task gesture combinations between Canadian and Chinese preferences as determined by discriminant function coefficients.

Code	Gestures x Task	Illustration
T18G40	Task: Zoom in Gesture: Upright palm moving up	
T17G34	Task: Move backward Gesture: Upright fist moving left	
T22G48	Task: Volume up Gesture: Turning a knob clockwise	
T3G52	Task: Mute Gesture: Index on lips (gesture for "shush")	
T16G36	Task: Move forward Gesture: Pointing-index rotating clockwise	
T9G12	Task: Run/Select Gesture: Index tapping	
T22G26	Task: Volume up Gesture: Upward palm moving up	
T18G44	Task: Zoom in Gesture: Full hand pinch opening to splay	

5 DISCUSSION

Our results show that demographic variables influence which gesture will work best for a particular task. Age and cultural differences seem to be important in determining task-gesture preferences (but not sex in our study). For the Canadian sample, the older people (65+) showed higher preferences on combinations T7G45, T22G50 and T12G58 as compared to the 18-24 year olds. T22G50 (cupping the hand behind the ear for volume up) and T12G58 (the thumbs up gesture to confirm something) are gestures which occur quite frequently in in-person communication, so they may find the gesture familiar and natural. Cupping the hand behind the ear is also a strategy for effectively increasing the size of the ear and improving hearing in cases where a person (especially an older person) is having trouble hearing something. For younger people who have grown up with social media, thumbs up may more likely mean liking rather than confirmation, thus explaining their lower ratings for the task gesture combination. For T7G45 (the splayed hand closing to a pinch) may be familiar to some older people as a gesture used by orchestral conductors to signify completion, which could also be viewed as going home. One feature of all three of these combinations is that they only use one hand and thus tend to use less energy than a two-handed gesture. For the Chinese sample, T22G48 (turning a knob clockwise to volume up) may have been less preferred because it puts more strain on the hand to make the relatively fine movement. The largest differences between the Canadian and Chinese samples were with respect to the T18G40, T22G48 and T18G44 combinations. These effects may reflect cultural differences. For instance T18G40 (a gesture that moves the palm up to represent a zoom) does not seem natural to a Canadian. Interestingly the T22G48 (turning a knob clockwise to volume up) was less preferred by the Chinese sample perhaps reflecting the fact that the younger people in the Chinese sample were less familiar with that type of analogue technology. For a complete list of task-gesture combinations used in this research, see Table 3 in the appendix.

6 CONCLUSIONS

Our results show that there is unlikely to be a “one size fits all” set of gestures that can be mapped to different tasks and that will work across groups of people with different demographics. We observed, even after adjusting scoring bias, cultural differences between Chinese and Canadian participants as well as demographic differences between young and old in both the Chinese and Canadian samples. Furthermore, the gestures that differentiated between young and old in Canada differed from those that differentiated young and old in the Chinese sample. We should note that the two studies that we carried out represent exploratory research and that further research is needed to find a comprehensive set of gesture task combinations that may work for different cultures and different demographics across, and within, cultures. While the present results are not comprehensive, they demonstrate significant problems for the one size fits all approach, with the best task gesture combinations depending on the type of person who will be using the system. This makes design a common set of gestures that will suit everyone very challenging,

if not impossible (see also [11]). One strategy for future mid-air gesture design may be to let people choose, from a small set of gestures, which one they want to use for a particular task. In this approach, designers will select a promising set of gestures that map well to a particular task and will then leave the final decision of which gesture to use to the user.

Acknowledgement

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Appendix

Table 3. List of the 129 Gesture Task Combinations used in the Canadian study. The overlapping subset of 36 combinations used in the Chinese study are highlighted with grey shading.

Task	Gesture	Code
Power on	Snapping	T1G1
	Palms moving away	T1G2
	Waving	T1G5
	Clapping	T1G4
	Index-middle knocking	T1G6
	Pointing-index poking	T1G13
Power off	Palms getting closer	T2G3
	Snapping	T2G1
	Clapping	T2G4
	Waving	T2G5
	Index-middle knocking	T2G6
	Closing to fist	T2G7
	Pointing-index poking	T2G13
Mute	Index on lips (gesture for "shush")	T3G52
	Timeout sign (both hands)	T3G28
	Covering the ear with hand	T3G51
	Full hand pinch opening and closing (gesture for "blah blah")	T3G53
Unmute	Index on lips (gesture for "shush")	T4G52
	Full hand pinch opening and closing (gesture for "blah blah")	T4G53
	Hand behind ear (sign of "listening")	T4G50
	Timeout sign (both hands)	T4G28
Back	Forehand slapping	T5G14
	Thumb left moving left	T5G20
	Upright palm rotating left	T5G35
	Pointing-index swiping left	T5G54
	Index-middle knocking	T5G6
	Pointing-index rotating counter-clockwise	T5G37
Activate menu	Opening to palm	T6G8
	Waving	T6G5
	Full hand pinch opening to splay (hololenz gesture)	T6G44
	Thumb up	T6G58
	Clapping	T6G4
	Index pinching	T6G11
	Victory sign	T6G24
	Upright palm moving up	T6G40
	Closing to fist and hold it long	T6G55
	Flat four fingers (folded thumb)	T6G64
	Closing to fist	T6G7
Home	Make a triangle with thumb and index finger with both hands	T7G56
	Make a triangle with all fingers	T7G57
	Closing to fist	T7G7
	Splay closing to full hand pinch	T7G45
	Closing to fist and hold it long	T7G55
	Index-middle roof sign	T7G66
Navigate	Index pointing	T8G9
	Upright index moving	T8G10
Run (Select)	Index pinching	T9G11
	Index tapping	T9G12
	Pointing-index poking	T9G13
	Thumb up	T9G58
	Closing to fist	T9G7
	Index trigger	T9G65
Go to first	Forehand slapping	T10G14
	Forehand slapping wide	T10G15
	Long forehand slapping	T10G16
	Rotated palm flicking left	T10G21
Go to last	Backhand slapping	T11G17
	Backhand slapping wide	T11G18
	Long backhand slapping	T11G19
	Rotated palm flicking right	T11G22
Confirm (Yes)	Thumb up	T12G58
	Nodding the head	T12G61
	Index-middle knocking	T12G6
Reject (No)	Thumb down	T13G59
	Shaking the head	T13G60
	Waving	T13G5

Task	Gesture	Code
Play	Scissors sign	T14G23
	Snapping	T14G1
	Closing to fist	T14G7
	Palm pushing	T14G25
	Thumb up	T14G58
	Clapping	T14G4
	Opening to palm	T14G8
	Upward palm moving up	T14G26
Pause	Palm pushing	T15G25
	Opening to palm	T15G8
	Victory sign	T15G24
	Timeout sign (both hands)	T15G28
	Snapping	T15G1
	Clapping	T15G4
	Closing to fist	T15G7
	Downward palm moving down	T15G27
Move forward	Pinch moving right	T16G29
	Pointing-index rotating clockwise	T16G36
	Upright palm moving right	T16G31
	Upright fist moving right	T16G33
	Index trigger moving right	T16G67
	Scissors sign moving right	T16G69
Move backward	Pinch moving left	T17G30
	Upright palm moving left	T17G32
	Upright fist moving left	T17G34
	Pointing-index rotating counter-clockwise	T17G37
	Index trigger moving left	T17G68
	Scissors sign moving left	T17G70
Zoom in	Camera fingers sign moving away	T18G46
	Opening the hook-shape pinch to open thumb-index	T18G42
	Full hand pinch opening to splay	T18G44
	Palms moving away	T18G2
	Pinch moving up	T18G38
	Upright palm moving up	T18G40
Zoom out	Camera fingers sign Getting close	T19G47
	Closing the hook-shape pinch to closed pinch	T19G43
	Splay closing to full hand pinch	T19G45
	Palms getting closer	T19G3
	Pinch moving down	T19G39
	Upright palm moving down	T19G41
Next	Backhand slapping	T20G17
	Rotated palm flicking right	T20G22
	Upright palm moving right	T20G31
Previous	Forehand slapping	T21G14
	Thumb left moving left	T21G20
	Rotated palm flicking left	T21G21
	Upright palm moving left	T21G32
Volume up	Upward palm moving up	T22G26
	Turning a knob clockwise	T22G48
	Pinch rotating clockwise	T22G62
	Pointing-index rotating clockwise	T22G36
	Pinch moving up	T22G38
	Upright palm moving up	T22G40
	Hand behind ear (sign of "listening")	T22G50
	Side pinch moving up	T22G71
Volume down	Downward palm moving down	T23G27
	Turning a knob counter-clockwise	T23G49
	Pinch rotating counter-clockwise	T23G63
	Pointing-index rotating counter-clockwise	T23G37
	Pinch moving down	T23G39
	Upright palm moving down	T23G41
	Covering the ear with hand	T23G51
	Side pinch moving down	T23G72