Tablet, Gestures, Remote Control? Influence of Age on Performance and User Experience with iTV Applications

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ABSTRACT
Due to recent development of TVs in the direction of highly interactive multimedia platforms, interactive TV (iTV) applications gain popularity. In terms of control possibilities a variety of input modalities have become available, though effects on performance and user experience of different age groups when controlling different iTV applications remain unclear. We present an empirical investigation comparing three input modalities (tablet, freehand gestures, remote) for controlling two iTV applications (Photo Browser, Nutrition Tracker) used by older and younger adults. Results show that all three independent variables had significant influence on performance, while we did not find influence of age or application on user experience. Overall tablet input based on a mirrored TV screen showed the best performance and was preferred by both age groups. Older adults were overall slower and showed a particularly large performance gap with the remote in comparison to younger adults.

Author Keywords
Touch; tablet; freehand gestures; remote; iTV; older adults.

ACM Classification Keywords
H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – *Evaluation, Input devices and strategies.*

INTRODUCTION
Driven by recent advancements of TVs, typical practices of using TVs have undergone many changes. Nowadays, these practices range from passive media consumption to highly interactive TV applications [32]. A variety of input modalities has been suggested to control diverse iTV applications [7,30]. Despite these developments, traditional remotes remain the preferred interaction means for TV-based media usage [27]. Nevertheless, empirical evidence exists showing that input modality influences the performance outcome for different tasks and should be chosen accordingly [23].

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By using interactive TV applications older adults can benefit from various services at home based on a familiar device [26]. With advanced age, cognitive, perceptual and motor abilities can deteriorate, while at the same time affecting the motivation in handling new technology [25]. On the interaction level, direct manipulations can reduce the effects of age-related functional decline, and on the motivational level, older adults are able to adapt to new technology if they perceive obvious benefits [13]. Thus, iTV applications might become more attractive for older adults when appropriately designed and benefits are clear. The plethora of different approaches for controlling iTV applications such as advanced remote controls [1,6], touch interactions [8,27], and various forms of gesturing [9,31] leads to the question of which input modality best matches the input requirements of a given iTV application, and which age effects apply. To our knowledge no empirical research has been conducted that directly compared performance and user experience characteristics of these input modalities for different iTV applications.

In this paper, we present an empirical study that compared a standard remote, freehand gestures, and a tablet showing the mirrored TV screen used by older and younger adults controlling two different iTV applications. The two iTV applications differed in terms of data and required input information: a list-based photo browser and a dialog-based nutrition tracker. The goal of this study was to assess performance and user experience of the input modalities with these applications to better support design of iTV applications, especially for older adults. Before describing our study in detail, we present related work that influenced its setup and the development of the prototypes.

RELATED WORK

Input devices for TV control
Various techniques have been developed to control TV applications over a distance. With regard to our study, we focus on touch-based interaction and freehand gestures.

Touch-based interaction
Preliminary work providing a concept for touch-based interaction on a remote control was suggested by Enns and MacKenzie [10], who attached a touchpad to a remote device. Choi et al. [6] adopted this idea and tracked the

users thumb on and above the surface of an optical touchpad. In their approach, a shadow representing the user's thumb is presented on the TV and used for pressing a button or drawing simple strokes. With the emergence of touchscreens, the concept of using a second screen was embraced, either for parallel usage such as sharing or transferring content, or for controlling iTV applications [4]. One of the first such systems was a PDA application to manipulate interactive content on a TV [29]. Cruickshank et al. [8] developed a PDA application to control various iTV functionalities and showed significant improvement in interacting with iTV interfaces. More recent application areas for touch-based remote control are e.g. to participate in interactive TV shows [20] or to track meals [30].

Freehand gestures

Early work on freehand gestures for TV control [15] transferred the point and click experience known from the computer mouse to the TV by tracking hand movements to control a cursor. Stenger et al. [31] enhanced this approach by adapting the trigger and the execution command (e.g. a grab gesture). Chen et al. [5] dispensed with the visible cursor and controlled TV channel and volume settings by moving the left or the right arm upwards or downwards. Dezfuli et al. [9] assigned interactions to specific regions of the users´ non-dominant hand, triggered when tapped with the dominant hand which facilitates to control the TV blindly. The system of Freeman et al. [14] interprets eight static hand postures and allows to control iTV applications like photo browsing in laid-back situations.

Comparative studies on input devices

In the context of interactive TV an early comparison found that the mouse interaction outperformed two different remote controls and was strongly preferred by users [21]. Comparing a standard remote with a same-shaped touch-enabled remote (arrow keys vs. swipe gestures) Pirker et al. [27] found that the touch-based interaction provided a better overall user experience although performance was worse. Rashid et al. [28] studied the costs of display switching by comparing the control of a large display with a touchpad, a hybrid approach (with content parts displayed on a mobile device) and a pure mobile device interaction. Although participants performed worse with the hybrid approach they preferred it. A previous study with a similar setup using a movie search application showed that users preferred a remote over a hybrid tablet interface [18]. Regarding gesture-based interaction a recent study compared motion gestures and freehand gestures for home entertainment and showed that familiar point and click as well as drag and drop techniques are naturally reused in this domain [32].

Age effects and input devices

When comparing the performance during the interaction with different input devices, task completion time has been shown to be significantly lower for older than for younger adults (e.g. [11,16]). In contrast, error rates often do not differ between younger and older users [13]. Findlater et al. [11] revealed that older users in particular benefit from touch screens compared to mouse usage: touch interaction reduces the performance gap between older and younger adults. In contrast, Ng et al. [24] found that older adults preferred a trackball over mouse and touch interaction, and that the latter could moderate only parts of age-related performance differences. In a multi-dimensional analysis comparing three input modalities (direct touch, a remote touchpad and gesture input) and two age groups for wall-sized displays Heidrich et al. [17] found the highest scores in performance and hedonic quality for touch input. In a study on motion-based game controllers [16] older adults performed worse than younger adults in motion-based games without age-related differences in device comfort or enjoyment. Bobeth et al. [3] compared four approaches for using freehand gestures to navigate TV menus. Results showed that directly transferring hand movements to control a cursor achieved the best performance and was preferred by older adults.

Given the growing popularity of iTV applications and the quantity of available input modalities, more research is needed to understand the specific needs of older adults in order to support designers in creating usable and enjoyable iTV applications for this audience. In contrast to existing research, our study compared the input modalities remote, tablet, and freehand gesturing for controlling two different navigation concepts of iTV applications. We examined performance and user experience differences between these applications and the three input modalities, and which age effects apply. Because of the commercial success of tablets and gesture-based interactions, we omitted other input modalities for interactive TVs such as touchpad [6] or motion-recognizing remotes [1].

METHOD

Research Questions

The following two research questions and accordant hypotheses formed the basis of our study.

Q1: How does the performance of older and younger adults differ when controlling two interactive TV applications with different input modalities (tablet, freehand gestures, remote control)?

We expect a low number of errors with the remote for both age groups, as they are already well acquainted with this form of interaction. We expect shorter task completion times for the interaction with tablet and gestures; especially older adults should benefit of direct manipulation means. Because of different functionalities we expect performance differences between the two iTV applications.

Q2: Is there a difference in the user experience of older and younger adults when using different input modalities, in terms of usability, effectiveness, satisfaction, and efficiency?

With respect to age effects in user experience we do not expect significant differences following previous findings [16]. Due to the novelty and direct-manipulation aspect of touch interaction and freehand gestures we expect higher satisfaction rates for these means compared to the remote. We expect positive ratings for the remote in terms of usability, as both age groups are accustomed to it.

Study Design

Our study was based on a 3 (input modalities) x 2 (iTV applications) x 2 (age groups) mixed between-within subjects design. Our dependent variables were performance (task completion time, number of errors) and different indicators for user experience (usability, effectiveness, satisfaction, efficiency). Additionally, qualitative comments and a preference ranking of input modalities were collected.

Participants

Our study involved 30 participants of two age groups: (i) 15 older adults (8 women and 7 men) between 66 and 80 years old (M=71.3, SD=3.9), and (ii) 15 younger users (8 women and 7 men) between 19 and 38 years old (M=26.8, SD=4.4). We deliberately omitted participants between those two age groups in order to enhance differentiation of age-related effects. To avoid experience-based biases we focused on right-handed participants who frequently watch TV and who have first experiences with touch-based devices but do not own a smart phone or tablet. In a pre-study all participating older adults had gained experience with gesture-based interactions. For younger participants having first experiences with the Microsoft Kinect was a recruitment criterion. We controlled frequency of use for 16 other technical devices (ranging from TV and PC to tablet and camera) to prevent group differences in technical expertise. There was no significant difference in frequency of use between older adults (M=3.28, SD=.13) and younger participants (M=3.09, SD=.08, t_{28}=-1.24, p <.05).

Apparatus and Input Modalities

We based the comparison on two iTV applications with different navigation concepts: a Nutrition Tracker (NT) and a Photo Browser (PB).

Nutrition Tracker: This application provides a nutrition diary on TV. The start screen contains 2 large buttons: one to open the input dialog for beverages and one for tracking meals. After opening the dialog for meals users could enter the type and amount of food intake in a simple two-step procedure by selecting one or more of 6 food categories which were arranged in a 2x5 grid layout (see Figure 1 right) and then canceling or saving the input. For drinking behavior, 3 different drink categories could be selected.

Photo Browser: In this application 30 photos are presented either in an overview view, which consists of 5 pages of 6 photos and can be scrolled horizontally like a list (see Figure 2), or in a detail view (1 large photo). Switching back from detail to overview was possible via a button at the bottom of the screen. In order to prevent any emotional biases based on the photo content, we only selected pictures with a neutral rating of the IAPS (International affective picture system) [19]. Each photo could be identified clearly with a simple phrase like “the photo with the coffee cup”.

The basic interactions with the three input modalities worked the same way for both applications (see Figure 1). Interfaces and tasks were designed by taking into account and avoiding the “fat finger” problem for touch devices or fatigue for gesture-based interactions.

Tablet: Because of reported interfering effects of hybrid user interfaces [18,28] (see Related Work section), the TV interface was mirrored on the tablet which allowed users to focus only at the input device during interaction. Afterwards, focus switches back to the TV. Therewith, we also adhered to the recommendation of Nichols et al. [25] stating that the need to focus at different distances (i.e. between input and output device) should be minimized for older adults as much as possible. A selection was done by tapping on the desired element on the touch screen. Within the Photo Browser, scrolling horizontally was realized by a swipe gesture.

Freehand gestures: We used a point-and-click approach as it performed best and was preferred by older adults [3]. The user’s hand was tracked and its position was translated to screen coordinates to control a cursor. Selection was accomplished via a Wizard-of-Oz action carried out by the supervisor whenever the user performed a grab gesture.

Remote: the four arrow keys were used for changing the focus between interaction elements and the OK button was used for selecting the currently highlighted element. By this means, we followed the recommendation of Bernhaupt et al. [2] to focus only on the remote’s main buttons.

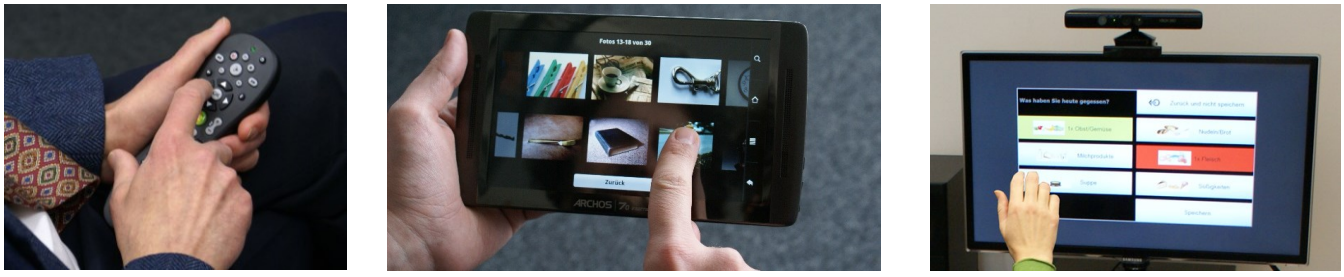

Figure 1: The three input modalities: remote (left), tablet interaction (middle), and freehand gestures (right).

The Photo Browser was developed with Adobe Flex/AIR, with communication between devices over WiFi; the Nutrition Tracker was developed using Java Swing (TV) and the Android SDK (tablet), with communication between devices via Bluetooth. Despite the differences in technologies, efforts were made to ensure that the two applications looked similarly to avoid accordant biases. The TV was a 32″, 1080p Samsung LCD TV with a refresh rate of 100 Hz. The gesture tracking was developed using the Kinect for Windows SDK. The mouse cursor was replaced with a large hand icon within both applications. The remote was a standard Windows-compatible infrared device (Hauppauge! Media Center remote). The tablet was a 7″ Archos 70 internet tablet with 800x480px resolution.

During the evaluation, participants were asked to sit in front of the TV while performing the various selection tasks. The participants sat on a firm office chair in a comfortable upright position. The Kinect sensor was placed on top of the TV and angled so that the participant's right shoulder was located in the center of its field of view. A constant shoulder-to-TV distance of 2 meters was maintained for all modalities. This standardized setup was designed to keep potential interference from positioning effects constant. The tablet and the remote were placed on a coffee table in front of the user. The supervisor took a seat to the side of the coffee table (see Figure 2). To prevent any supervisor-caused biases the same person led all study sessions.

Figure 2: Setup of the study with TV, supervisor and a participant using the tablet to control the Photo Browser.

Procedure

Before starting the actual study we asked the participants about their use of technology. Subsequently, they conducted a simple motor test measuring manual dexterity adapted from the standardized Box and Block test [22]. By this means, we wanted to better understand the performance results. The task for participants was to move as many enwrapped pralines as possible with the dominant hand out of a box and into the corresponding space in an adjacent box, while crossing a 15cm obstacle, within 60 seconds.

Next, participants received an introduction for each of the six sessions (3 input modalities x 2 applications). They should spend up to two minutes to understand how the prototype works and how they could control it with the given input modality. For practicing purposes the supervisor asked them to conduct up to five test tasks. For the actual study participants were asked to conduct 12 tasks with each input device (3x12) and both iTV applications. Thus, each participant performed 72 tasks in total. The instruction for a task with the photo browser was e.g.: "Please navigate to the photo of the train and open it in detail view." Similarly, for the nutrition tracker participants were asked: "Please enter that you had a glass of water." If an error occurred (e.g. the wrong photo has been opened) it was documented and the task was repeated.

After conducting the 12 tasks with one input modality for one iTV application, participants rated their user experience with the help of the standardized 4-item questionnaire UMUX [12]. Afterwards, the participants conducted 12 different tasks with the same application using the next input device. This procedure continued until all input devices had been tested and rated for both iTV applications. To avoid biases based on the order of input devices or applications, both independent variables (application and input modality) were counterbalanced between all participants. The tasks and the order of tasks stayed constant for each combination of input modality and application, in order to assure the same conditions for all participants. At the end of study, all participants ranked the three input devices according to their own personal preference for both iTV applications.

RESULTS

The main analysis instrument was mixed ANOVA. For every analysis the assumption of sphericity was tested using Mauchly's Test; we only report the results of this test explicitly in case the assumption was violated and corrections had to be applied. For post-hoc comparisons t-tests with Bonferroni corrected alpha levels were used.

Motor test. On average, older adults had worse motor skills (M=28.67, SD=1.28) than younger participants (M=34.14, SD=1.37), t_{27}=2.93, $p<0.01$. There are significant correlations between motor skills and task completion time for all input modalities: tablet, r=-0.46, $p<0.01$, gesture, r=-0.47, $p<0.01$, and remote, r=-0.50, $p<0.01$. The better the motor skills, the lower the task completion time.

Performance:

Task completion times were analyzed using mixed ANOVA with *age* as between subjects and *input modality* and *application* as within subjects' factor (see Figure 3). For the performance measurement all task completion times where users made an error were removed. The measurements of every experimental condition (i.e. each combination of factor levels) were checked for outliers by use of boxplots. Outliers were removed in case they lay more than three times the length of the box (i.e. the interquartile range) from either end of the box. Altogether five measurements had to be removed.

The ANOVA showed significant main effects for all three independent variables. Task completion times were significantly faster for the *Nutrition Tracker* than for the *Photo Browser*, $F_{1,28}$=149.28, p<0.001. *Input modality* also had a significant influence on task completion time, $F_{2,56}$=37.27, p<0.001. Post-hoc comparisons showed that the tablet was significantly faster than both freehand gestures and remote. There was no significant difference between gesture and remote. As expected also *age* showed a significant influence on performance, $F_{1,28}$=54.32, p<0.001. Older users were slower than younger ones.

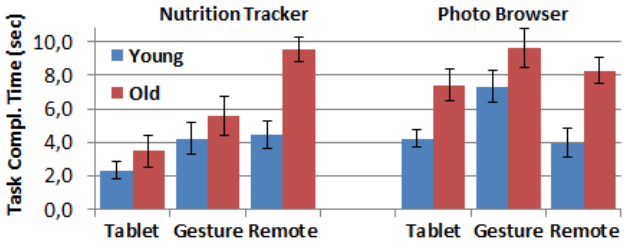

Figure 3: Task completion times for all experimental conditions. Error bars show 95% CI.

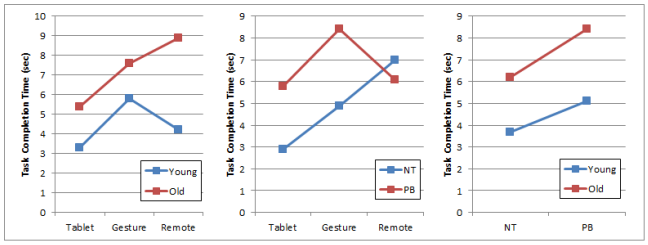

Figure 4: Interaction graph for Interaction Modality x Age (left), Interaction Modality x Application (middle) and Application x Age (right).

We also found significant interactions between the independent variables. There is a significant interaction effect between *input modality* and *age* $F_{2,56}$=13.62, p<0.001. This indicates that the used input modalities had different effects on task completion times depending on the users' age (see Figure 4 left). Whereas for tablet and gestures a similar trend in task completion time can be identified, the remote did perform well with younger users but comparatively poor for the elderlies.

The analysis also showed a significant interaction effect for *application* and *input modality,* $F_{2,56}$=53.67, p<0.001. Whereas for tablet and gestures we see a better performance in the *Nutrition Tracker*, in the case of the remote this aspect is reversed and the *Photo Browser* has the shorter task completion times (see Figure 4 middle).

We also found a significant interaction between *application* and *age*, $F_{1,28}$=5.31, p=0.029 (see Figure 4 right). Both age groups showed an increase in task completion times for the *Photo Browser*; however this increase is more distinctive for older adults.

Error rate. For every condition the number of errors was recorded. An error was counted when a participant selected an incorrect element. Overall error rates were rather small, and most tasks could be completed without errors. ANOVA shows a significant main effect for the *application*, $F_{1,28}$=19.06, p<0.001. Overall the error rate was higher for the *Nutrition Tracker* (Mean number of errors per condition i.e. 12 tasks: 1.06) than for the photo browser (0.42 errors). Also, we found a main effect for a*ge,* $F_{1,28}$=11.03, p=0.002 with older adults (Mean number of errors: 1.18) making significantly more mistakes than younger users (0.30). The analysis also showed a significant interaction between *application* and *age*, $F_{1,28}$=10.85, p=0.003. Whereas the error rate for the younger adults only shows a medium difference for the two applications (*Nutrition Tracker*: 0.38, *Photo Browser*: 0.22), the error rate for the older adults was approximately three times higher in case of the *Nutrition Tracker* (1.733) compared to the *Photo Browser* (0.622).

User Experience

All measures for user experience express a positive attitude of participants. The lowest-scoring measure of our study was efficiency (UMUX4) of gesture-based input in the *Nutrition Tracker* with a mean of 3.73, which is still slightly better than a neutral rating of 3.5 (see Table 1).

Both, the analysis for **Overall Usability** (UMUX1) and **Effectiveness** (UMUX2) does not show an effect of *application* or *age*, only *input modality* has a significant influence on the users rating of usability, $F_{2,56}$=14.98, p<0.001 and effectiveness, $F_{2,56}$=15.43, p<0.001. Post-hoc comparisons show that in both cases gesture is rated significantly lower than the two other modalities.

A similar significant influence of *input modality* was found for **Satisfaction** (UMUX3), $F_{2,56}$=8.08, p=0.001 and post-hoc test showed again that gesture-based input is rated worse than the other modalities. Also two interaction effects were found: First, the interaction of *application* with a*ge* is significant, $F_{1,28}$=11.46, p=0.002. Whereas the *Nutrition Tracker* was perceived different by the two user groups (satisfaction rating of 6.27 by the older versus 5.16 by the younger) the *Photo Browser* was rated similar (5.69 vs. 5.56). Second, there is a significant interaction between *application* and *input modality*, $F_{1.66,46.40}$=6.28, p=0.006. As Mauchly's test indicated that the assumption of sphericity has been violated ($\chi^2(2)$=6.26, p=0.04) degrees of freedom have been corrected using Greenhouse-Geisser estimates of sphericity (ε=0.829).

Analyzing the results for **Efficiency** (UMUX4) similar patterns as observed previously emerge. ANOVA shows a significant main effect for *input modality*, $F_{2,56}$=16.40, p<0.001 with the gesture-based approach rated significantly less efficient than the two other modalities. Also, the efficiency rating shows an interaction effect between *application* and *input modality* similar to the performance and satisfaction measurement, $F_{2,56}$=4.49, p=0.016.

			UMUX1	UMUX2	UMUX3	UMUX4
Nutrition Tracker	Tablet	Young	6.53	6.20	6.47	6.20
		Old	6.20	6.13	6.53	6.33
	Gesture	Young	4.93	4.20	4.33	3.73
		Old	5.53	5.00	5.87	5.00
	Remote	Young	6.07	5.27	4.67	5.40
		Old	6.00	5.60	6.40	5.80
Photo Browser	Tablet	Young	6.33	5.60	5.73	6.00
		Old	5.67	5.87	5.53	5.13
	Gesture	Young	5.13	4.27	4.80	4.27
		Old	5.00	5.00	5.27	4.53
	Remote	Young	6.53	5.93	6.13	6.00
		Old	5.93	6.07	6.27	6.20

Table 1: Mean ratings on the user experience scales ranging from 1 (bad) to 7 (good).

User Preferences

Asked to rank the input modalities older adults and younger adults put for both applications the tablet on rank 1, the remote on rank 2 and gesture on rank 3 (see Figure 5). None of the older adults ranked the modality gesture first. Many participants could imagine to use more than one input modality to control iTV applications which is in line with the findings of Coelho et al. [7].

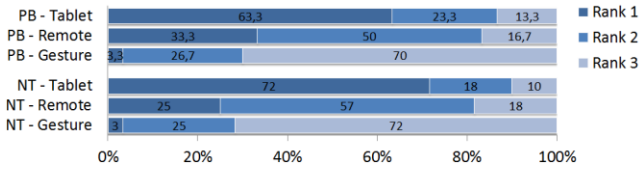

Figure 5: Ranking of the input modalities in percentage for Photo Browser (PB) and Nutrition Tracker (NT).

DISCUSSION

The discussion first focuses on the performance measurements and then analyses the user experience results.

Task completion time. The observation that older adults needed significantly more time to complete tasks was expected and confirmed findings of previous research (e.g. [11]). Lower task completion times with the Nutrition Tracker could be explained by the fact that tasks in the Photo Browser application required the navigation between several pages, while the Nutrition Tracker was based on one page and dialogues. The better performance of the tablet might be caused by the higher motor costs of moving the upper limb for gesture-based interactions and the necessity of numerous button presses in combination with button switches at the remote.

The effect of *age* on *input modality* is in particular interesting for the remote as the performance gap between older and younger adults was greatest and not in line with the trends for tablet and freehand gestures. One reason for this effect might be the different usage patterns of the remote. While younger adults used the remote mostly with one hand and without looking at it, the majority of older adults used both hands (see Figure 1 left) and looked at the remote for each button switch. Various explanations for this behavior difference are possible [13]: (i) Age-related decline of fine motor control leads to problems when using buttons on the remote. Thus, the buttons were too small for blind usage. (ii) Age-related loss of dexterity might lead to a higher expenditure of time per button press, which adds up with every button press. (iii) Older adults seem to be more anxious about making errors and want to be sure to press the correct button. The tablet is able to mitigate all of these age-related differences as it features larger targets, a lower number of needed interactions and direct feedback about whether the correct picture is being opened. Freehand gestures, meanwhile, require good motor abilities but not the same degree of precision as pressing small buttons on a standard remote. In addition, the cost of display switching between devices is avoided.

The measured interaction effect between *application* and *input modality* emphasizes the influence of the interaction concept for iTV applications. While navigating linearly through a two-row list of photos worked well with the remote, the dialog-based navigation concept of the Nutrition Tracker led to problems. This unusual interaction concept for controlling TVs was possibly more cognitively demanding for participants when using an indirect input device. In contrast to the repetitive button presses needed when using the Photo Browser, the Nutrition Tracker required users to switch between buttons more often, which also cost more time. The direct manipulation approaches of tablet and freehand gestures seem to be better candidates for the control of two-level dialog-based iTV applications. In summary, our hypothesis on shorter task completion times for tablet and gestures was only true for the tablet, while our hypothesis on performance differences between the applications could be verified.

Error rate. The number of errors was low in general and no significant influence of input modalities was measured. Therewith, our expectations on a low number of errors with the remote were confirmed. The identified impact of *application* might be caused by the unusual dialog-based user interface of the Nutrition Tracker. The more complex two-level selection approach seemed to be more error-prone and cognitively demanding than the more linear user interface of the Photo Browser. The higher general error rate of older adults in comparison with younger ones may be attributed to the slightly reduced motor skills that impact all three input modalities. With the remote two buttons were occasionally pressed at the same time, while with the tablet the swipe gesture led occasionally to accidently performed taps, and with the freehand gestures the tendency to overshoot targets occurred more often. Nevertheless, the low overall number of errors suggests that the applications could be controlled without major problems with all three input modalities.

User Experience. A positive user experience was reported for all measured items (UMUX1-4). As hypothesized and analog to previous research, no significant differences were found between *age* groups [16]. Similarly, the choice of *application* did not influence user experience factors. More polarizing or personal content in the iTV applications could have had a greater impact on user experience than a Photo Browser that shows neutral photos and a Nutrition Tracker that records arbitrary non-personal meals. Together with the low error rates, these positive results suggest that the two iTV applications were designed appropriately and that both age groups enjoyed using them. All three input modalities were rated as being easy to use.

Nevertheless, *input modality* had a significant influence on all measured items (UMUX1-4). The lower rating of freehand gestures might be caused by the longer task completion times but also by technical problems related to functional issues of the prototype (see Limitations section). Although tablet interaction showed better performance results than remote both input modalities received similar results in the user experience ratings. This might be caused by the fact that participants were able to accomplish all tasks with both devices without major problems. However, when asked to rank input modalities preferences could be identified. A clear preference was found for the mirrored TV screen on the tablet, probably because of the overall best performance and the advantage of direct manipulation. In summary, our hypothesis of higher satisfaction with tablet and gestures could not be verified but the one on positive usability ratings for the remote was confirmed.

Measures for Satisfaction (UMUX3) showed *age* effects on *application* and an influence of *input modality* on *application*. While both age groups showed a similar level of satisfaction with the Photo Browser, older adults were more and younger adults less satisfied with the Nutrition Tracker. Ratings of younger adults might reflect the worse performance which occurred using the Nutrition Tracker, while older adults might have rated more with regards to its content. Nutrition tracking might be more relevant for older adults. Further, the effect of *input modality* on *application* might be explained by the different navigation concepts of the two iTV applications. The rather linear interactions with the Photo Browser could be achieved comfortably and almost blindly with the remote. For the two-level dialog-navigation of the Nutrition Tracker direct manipulations per touch seemed to be more comfortable.

LIMITATIONS

In our setup the freehand gesture recognition sometimes produced short delays of some hundreds of milliseconds. Participants needed to correct their movements and lost some time. Hence our study might not directly be applicable to gesture recognition systems that perform in real time. Occasionally more serious freezes occurred; in these cases performance for the given task was not measured, but they may have influenced the perceived user experience negatively. Interestingly, the Kinect had more problems detecting hand movements of older adults than of younger adults. Maybe the tendency of older adults to sit in more hunched or crooked postures contributed to this trend, as the Kinect software attempts to identify the full-body skeleton to be able to track individual limbs.

CONCLUSION

In this paper, we examined the influence of a*ge*, *application* and *input modality* on performance and user experience when controlling iTV applications. We observed younger and older adults using a list- and a dialog-based iTV application with the input modalities tablet, freehand gestures and remote. While all three independent variables had a significant influence on performance, user experience differences were only found for *input modality*.

The results show that a mirrored TV screen on a tablet is the most promising of the assessed alternatives to control iTV applications for both younger and older adults. Direct manipulations and the reduction of display switches for conducting selection tasks seems to be advantageous in this context, especially for older adults. Accordingly, we recommend designers targeting older adults to avoid unnecessary display switches e.g. by mirroring the TV screen on a tablet. Also, using freehand gestures seems to be a promising approach, but requires improvements on the technical side towards higher accuracy and robustness. If a system can assure accurate real-time tracking, short point-and-click gestures should provide comfortable means for selection tasks without grabbing a physical control device. The remote works well for linear tasks, while older adults had problems with the non-linear user interface and showed a particularly high performance gap compared to younger participants. For linear use cases (e.g. zapping) the remote works equally good whereas designers should keep the amount of needed button changes reduced, thus for more complex input they should design the navigation in a series of linear task or consider omitting the remote for older adults completely.

Overall, older adults are easily able to adopt alternative input modalities to control iTV applications. The presented work lays the foundation for further investigations about the control of iTV applications, e.g. including further input modalities or multimodal usage scenarios.

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