

Supplementary Material for MultiFi: Multi Fidelity Interaction with Displays On and Around the Body

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This document presents an extended version of the user study description and detailed statistical test results for the locator and select task presented in the main document. The depicted tables were generated with SPSS.

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User Study – Extended Description

We conducted a laboratory user study to investigate if combined device interaction can be a viable alternative to established single device interaction for mobile tasks.

Experimental Design

We designed a within-subjects study to compare the performance and user experience aspects of MultiFi interaction to single device interaction for two information browsing tasks. The independent variable for both tasks was an interface with five levels:

Handheld (HHD): The Samsung Galaxy SIII was used as only input and output device. This serves as the baseline condition for a handheld device with high input and output fidelity.

Smartwatch (SW): The wrist-worn Sony Xperia Z1 compact was used as only an input and output device. The input and output area was 40x35 mm and highlighted by a yellow border, as shown in Figure 1, left. Participants were notified by vibration if they touched outside the input area. This condition serves as baseline for a wearable device with low input and output fidelity (high resolution, but small display space).

Head Mounted Display (HMD): The Vuzix STAR 1200XL was used as an output device. We employed indirect input as in the SW condition using a control-display ratio of 1 with the touch area limited to the central screen area of the HMD. This condition serves as the baseline for a HMD with low input and output fidelity, which can be operated with an arm-mounted controller (without the need for retrieving the controller from a pocket).

Body-referenced interaction (BodyRef): The content was displayed in front of the participant's upper body above a table, see Figure 1, left. The HMD was used to control the user's viewpoint of the virtual scene. The touch screen of the smartwatch could be used to control the position and scale of the virtual map in front of the body using the same input options as in SW, HMD, SWRef (see below). In addition, selection was achieved by aligning the smartwatch with the target visible in front of the user and touching the target rendered on the smartwatch.

Smartwatch referenced (SWRef): The information space was displayed relative to the smartwatch screen (see Figure 1, right). Outside the smartwatch screen, the virtual content was visible in the HMD employing the extended screen space metaphor. As in BodyRef, the HMD was used to control the user's viewpoint of the virtual scene. The information space could be panned and zoomed as in the other conditions.

In both tasks, dependent variables of interest were *task completion time*, *errors*, *subjective workload* as measured by NASA TLX as well as user experience measures (After Scenario Questionnaire (ASQ), *hedonic and usability aspects* as measured by AttrakDiff) and overall *preference* (ranking).

Apparatus and Data Collection

The study was conducted in a controlled laboratory environment. We employed a Samsung Galaxy SIII (resolution: 1280x720 px, 306 ppi, screen size: 107x61 mm) as smartphone a Vuzix STAR 1200 XL HMD (resolution: 852x480 px, horizontal field of view (FoV): 30.5° vertical FoV: 17.15°, focus plane distance: 3 m, resolution: 13 ppi at 3 m, weight with tracking markers: 120 g) and another smartphone (Sony Xperia Z1 compact) as smartwatch substitute (resolution: 1280x720 px, cropped extent: 550x480 px, 342 ppi, weight with tracking markers: 200 g). The HMD viewing parameters were matched with virtual cameras which rendered the test scenes used in HHD, HMD and SW. Thus all conditions operated in coordinate systems with the same metric units. The translation of virtual cameras for panning via touch in all conditions parallel to the screen was set to ensure a control-display ratio of 1. Pinch to zoom was implemented by the formula $s = s_0 * s_g$, with s being the new scale factor, s_0 the map's scale factor at gesture begin and s_g the relation between the finger distances at gesture begin and end.

While the system is intended for mobile use, here participants conducted the tasks while seated due to the strenuous nature of the repetitive tasks in the study. The participants were seated on a table (120x90 cm, height 73 cm). The chair was height adjusted for individual participants to ensure that its armrests are at the same height as the table. This should mitigate expected fatigue effects which could arise during the repetitive nature of the tasks.

We collected data for evaluation through automatic logging on the test devices, questionnaires, video recording and semi-structured interviews at the end of the study. For data analysis, we used R and SPSS. Null hypothesis significance tests were carried out at a .05 significance level, and no data was excluded, if not otherwise noted. For ANOVA, Mauchly's test was conducted. If the sphericity assumption had been violated, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity. Due to space reasons not all tests statistics are reported in detail, but are available in the appendix. For all figures, brackets indicate significant difference with a p-value <0.05 (*) and <0.01 (**). Error bars indicate standard deviation.

Procedure

After an introduction a demographic questionnaire, participants were introduced to the first task (counterbalanced) and the first condition (randomized). For each condition, a training block was conducted. For each task, participants completed a number of trials (as described in the individual experiment sections) in five blocks, each block for a different interface level. Between each block, participants filled out the After Scenario, NASA TLX and AttrakDiff questionnaires. At the end of the study, a semi-structured interview was conducted and participants filled out a separate preference questionnaire. Finally, the participants received a book voucher worth 10 Euros as compensation. Participants were free to take a break between individual blocks and tasks. Overall, the study lasted ca. 100 minutes per participant.

Participants

Twenty six participants volunteered in the study. We had to exclude three participants due to technical errors (failed tracking or logging). In total, we analyzed data from twenty three participants (1 female, average age: 26.75 years, $\sigma=5.3$, average height: 179 cm, $\sigma=6, 7$ users wore glasses, 3 contact lenses, 2 left-handed users). All but one user were smartphone owners (one less than a year). Nobody was a user of smartwatches or head-mounted displays. Twenty users had a high interest in technology and strong computer skills (three medium).

Hypotheses

One of our main interests was to investigate if combined display interaction could outperform interaction with

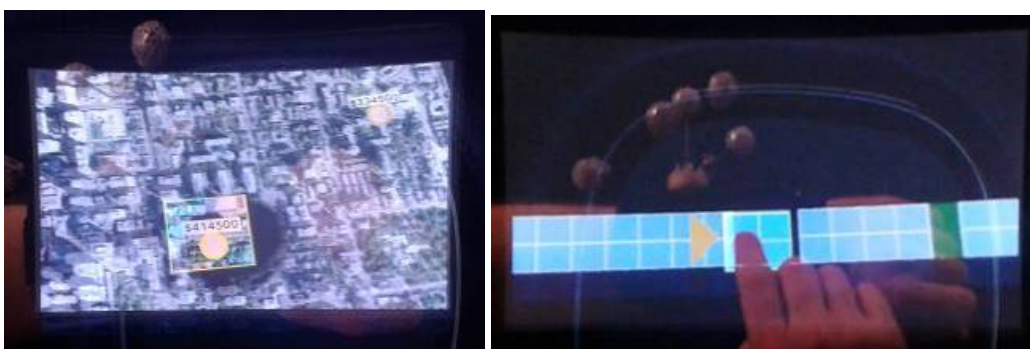


Figure 1: BodyRef (locator task) (left). SWRef (select task) (right).

individual wearable devices. We included HHD interaction as a baseline and did not expect the combined interfaces to outperform it. Hence, we had the following hypotheses: *H1*: HHD will be fastest for all tasks. *H2*: BodyRef will be faster than HMD and SW (ideally close to HHD). *H3*: BodyRef will result in fewer errors than HMD and SW. *H4*: SWRef will be faster than HMD and SW (ideally close to HHD). *H5*: SWRef will result in fewer errors than HMD and SW.

Experiment 1: Locator Task on Map

A common task on mobile mapping applications is to search for an object with certain target attributes [27]. We employed a locator task similar to previous studies involving handheld devices and multi-display environments [16][26]. Participants had to find the lowest price label (text size 12 pt) among five labels on a workspace size of 400x225 mm. We determined the workspace size empirically, to still allow direct spatial pointing for the BodyRef condition. While finding the lowest price could easily be solved with other widgets (such as a sortable list view), our task is only an instance of general locator tasks, which can encompass non-quantifiable attributes such as textual opinions of users, which cannot be sorted automatically. Users conducted ten trials per condition. With 23 participants, five interface levels and 10 trials, there was a total of $23 \times 5 \times 10 = 1150$ trials.

Task Completion Time

The task completion times (TCT, in seconds), for the individual conditions were as follows (see also Figure 2): HHD ($M=15.67, \sigma=5.45$), SW ($M=20.60, \sigma=7.62$), HMD ($M=18.68, \sigma=6.45$), BodyRef ($M=16.57, \sigma=6.16$), SWRef ($M=21.05, \sigma=10.28$). A repeated measures ANOVA indicated that there was a significant effect of interface on TCT, $F(3.10, 709.65)=42.21, p<.001$. The results of post-hoc tests with Bonferroni corrections are depicted in Table 1. Pairs are column-wise (e.g., pair HHD-SW: $t=-11.0, p<.01, d=-.72$). Significant differences are highlighted in bold. For all tests, degrees of freedom were 229. To summarize, both HHD and BodyRef were significantly faster than all remaining interfaces with medium to large effect sizes. HMD was significantly faster than both SW and SWRef. There were no significant differences between HHD-BodyRef and SW-SWRef. The smaller standard deviations of HHD, SW and HMD compared to BodyRef and SWRef could be attributed to the longer familiarity of users with touch screen interaction compared to the novel interfaces we introduced.

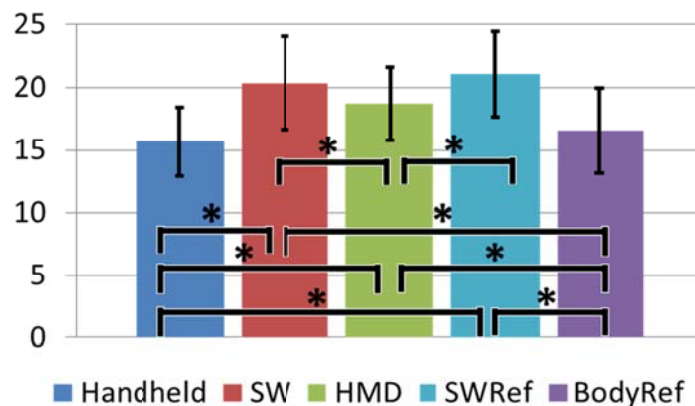


Figure 2: Task completion time (s) for the locator task.

(t, p, d)	HHD	SW	HMD	BodyRef
HHD	-			
SW	-11.0, <.01, -.72	-		
HMD	-7.4, <.01, -.49	3.6, .004, .24	-	
BodyRef	-2.3, .22, -.15	8.4, <.01, .56	5.1, <.01, .33	-
SWRef	-8.8, <.01, -.59	-1.1, 1.0, -.07	-4.1, <.01, .27	-7.3, <.01, -.48

Table 1: Test statistics (t-value, p-value, Cohen's d) (paired sample t-test with Bonferroni correction) for the map task.

Errors

From 230 selections, eight false selections were made in the HHD, HMD and BodyRef conditions. In the SW condition, 13 errors have been made, in SWRef five errors. A Friedman ANOVA indicated no significant effect of interface on errors $\chi^2(4)=4.10, p=.39$.

Subjective Workload

The subjective workload scores for individual dimensions as measured by the NASA TLX are depicted in

Figure 3. A repeated measures ANOVA indicated that there were significant effects of interface on all dimensions. The results of post-hoc tests with Bonferroni corrections indicated significant differences for the dimensions (

Figure 3). BodyRef resulted in a higher mental demand than smartwatch (albeit with a small effect size). The handheld condition resulted in lower subjective workload for all other dimension compared to most other interfaces.

User Experience

Results of the After Scenario Questionnaire (seven item Likert scale, 1: totally disagree, 7: totally agree) can be found in

Figure 4. Friedman ANOVA indicated significant effect of interface on ease of task ($\chi^2(4)=26.65, p<.001$), satisfaction with task completion time ($\chi^2(4)=9.57, p=.048$) and system support ($\chi^2(4)=12.20, p=.02$). However, Wilcoxon signed rank tests with Bonferroni corrections only indicated a significant difference between HHD and SWRef for ease of task ($Z=-3.36, p=.01$).

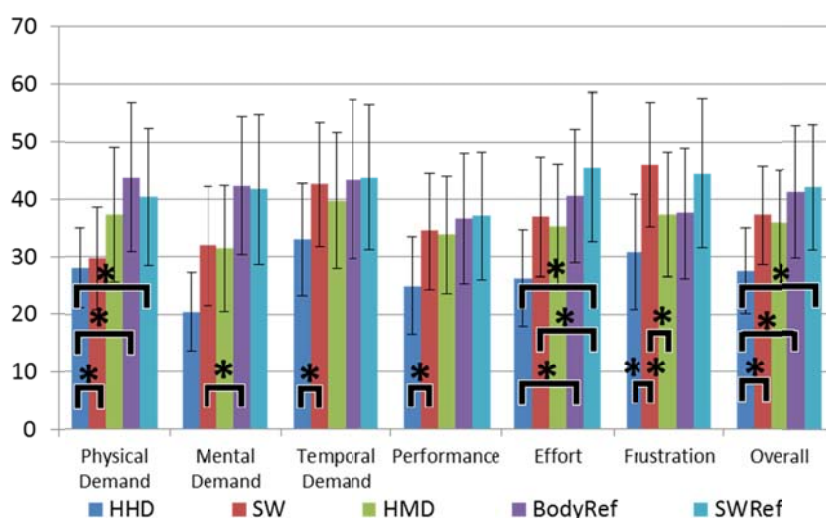


Figure 3: NASA TLX scores for the locator tasks.

A repeated measures ANOVA indicated that there was a significant effect of interface on Pragmatic Quality (PQ), $F(4, 88)=4.05, p<.001$ and on Hedonic Quality Stimulation (HQS), $F(2.84, 62.58)=58.26, p<.001$. For PQ results of post-hoc tests with Bonferroni corrections indicated significant differences as depicted in

Figure 5, left.

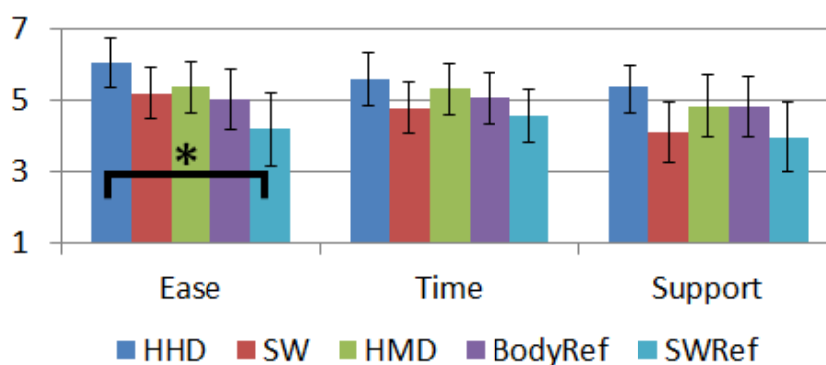


Figure 4: ASQ ratings for locator task (7-point Likert).

Preference ratings (ranking: 1: most preferred 5: least preferred) were as follows. HHD: MD=2, M=1.13, σ =1.13, SW: MD=4, M=3.87, σ =1.10, HMD: MD=2, M=2.78, σ =1.41, BodyRef: MD=4, M=3.22, σ =1.41, SWRef: MD=3, M=3.09, σ =1.38. A Friedman ANOVA indicated that there was a significant effect of interface on preference ($\chi^2(4)=19.35$, $p=.001$). Wilcoxon signed rank tests with Bonferroni corrections indicated a significant difference between HHD and SWRef ($Z=-4.25$, $p<.001$).

To summarize, for HHD the ease of task was significantly higher than for SWRef, all interfaces scored slightly below average for pragmatic quality, and only a significant difference between HMD-SWRef could be found (but with a small effect size). For hedonic quality stimulation the HHD and SW interface were rated significantly lower than the other three conditions. HHD was significantly more preferred than SW.

Experiment 2: 1D Target Acquisition

We employed a discrete 1D pointing task similar to the one used by Zhao et al. [31] (see Figure 1, right). Participants navigated to a target (green stripe) in each trial using touch input (for HHD, SW, HMD, SWRef) or spatial pointing (BodyRef). Final target selection was confirmed by a touch on the target region in all conditions. The participants were asked to use their index finger to interact with the touch surfaces. For each trial, the task was to scroll the background (HHD, SW, HMD, SWRef) or to move the smartwatch towards the target (BodyRef) until it appeared on the *selection area*. Prior to each trial, participants hit a start button at the center of the screen to ensure a consistent start position and to prevent unintended gestures before scrolling. The target was only revealed after the start button was hit. After successful selection, the target disappeared. For BodyRef, participants returned to a neutral start position centered in front of them before the next trial.

Please note that the focus of this experiment is not to derive a new target acquisition model but rather to get an initial

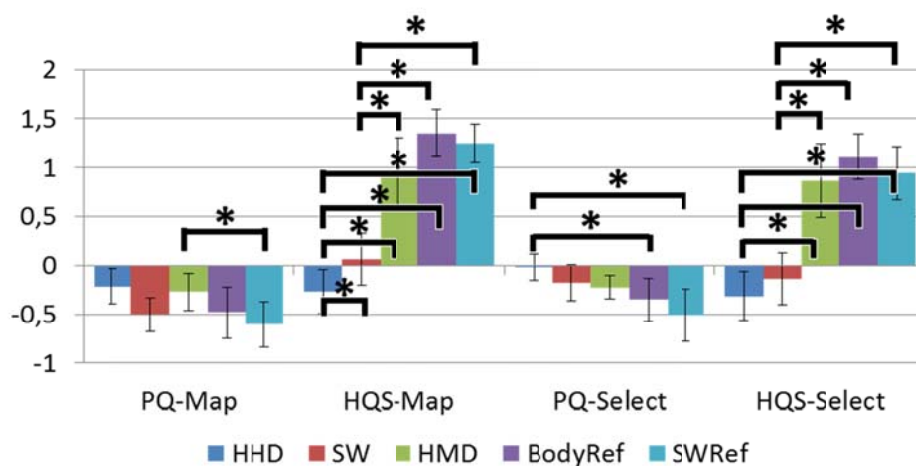


Figure 5: Pragmatic Quality (PQ) and Hedonic Quality Stimulation (HQS) measures (normalized range -2..2) for the locator task (left) and the select task (right).

insight into the potential for combined wearable device interaction compared to individual devices only. Hence, in the experiment design, we do not vary all parameters as one would need for deriving a robust model. Specifically, we fix target width to 20 mm (0.5*width of the smartwatch), use the control window and display window sizes of the individual displays and use two target distances (short: 15 cm, long: 30 cm). In addition to interface and target distance, we also introduced target direction (same side as hand carrying the smartwatch and opposite side), as independent variable as we expected performance differences in the BodyRef condition. The conditions were

blocked by interface. Per condition, each participant conducted eight trials (plus two training trials). With twenty three participants, five interface levels, two target distances, two directions and eight trials per condition a total of $23 \times 5 \times 2 \times 2 \times 8 = 3680$ trials were conducted.

Task Completion Time

Task completion times are depicted in

Figure 6. A repeated measures ANOVA indicated significant interactions between interface and length, $F(3.23, 592.25) = 89.49$, $p < .001$, interface and direction, $F(3.27, 599.15) = 5.71$, $p < .001$ and interface, length, direction, $F(2, 84, 518.73) = 4.58$, $p < .001$. Due to space constraints, we report only on the simple main effects of interface across length and direction. For short distances (15 cm), interface had a significant effect on TCT, $F(3.06, 1122.72) = 162.10$, $p < .001$, as well as for long distances (30 cm), $F(3.13, 1147.80) = 267.75$, $p < .001$. For selection on the side of the smartwatch (i.e., non-dominant hand side, left for 21 of 23 participants), interface had a significant effect on TCT, $F(3.27, 1201.05) = 316.35$, $p < .001$, as well as for selection on the opposite side of the smartwatch (i.e. dominant hand side), $F(3.12, 1145.40) = 127.57$, $p < .001$. The results of post-hoc comparisons with Bonferroni correction are depicted in

Figure 6. To summarize, HHD was the fastest interface for both directions and distances. BodyRef was significantly faster than all remaining interfaces. No other significant effects of interface on task completion time could be found.

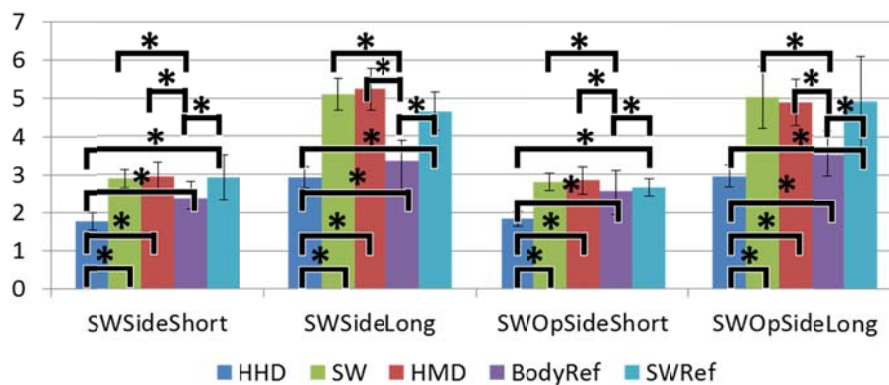


Figure 6: Task completion times (in seconds) for the select task. SWSide: side on which smartwatch was worn, SWOpSide: opposite side.

Errors

Selection errors occurred when participants tapped outside the target region. The total number of errors (M , σ) for individual interfaces were as follows: HHD: 53 ($M = .07$, $\sigma = .28$), SW: 34 ($M = .05$, $\sigma = .23$), HMD: 223 ($M = .30$, $\sigma = .77$), BodyRef: 258 ($M = .35$, $\sigma = .78$), SWRef: 37 ($M = .05$, $\sigma = .24$). A Friedman ANOVA indicated that there was a significant effect of interface on error count ($\chi^2(4) = 231.68$, $p < .001$). Wilcoxon signed rank tests with Bonferroni corrections indicated significant differences between BodyRef and all interfaces except HMD, as well as between HMD and all interfaces (except BodyRef). No significant effects of direction or length on error rate were identified. To summarize, HMD and BodyRef resulted in a significant higher error rate.

Subjective Workload

The subjective workload scores for individual dimensions as measured by the NASA TLX are depicted in Figure 7. A repeated measures ANOVA indicated that there were significant effects of interface on all dimensions but temporal demand and performance. The results of post-hoc tests with Bonferroni corrections indicated significant differences shown in Figure 7. To summarize, HHD resulted in a lower mental demand than most other conditions (except SW) and in a lower overall demand than all conditions. BodyRef and SWRef resulted in significantly higher physical demands compared to HHD and HMD (but not SW). Frustration was significantly higher for SW and SWRef compared to HHD.

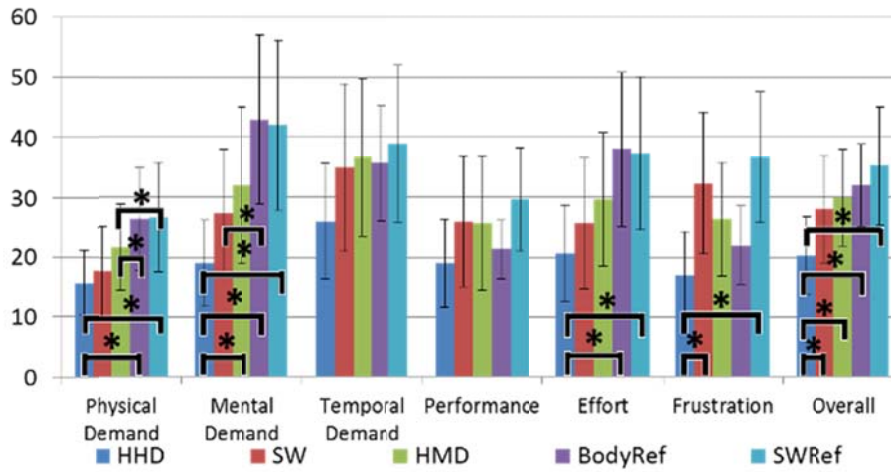


Figure 7: NASA TLX scores for the selection tasks.

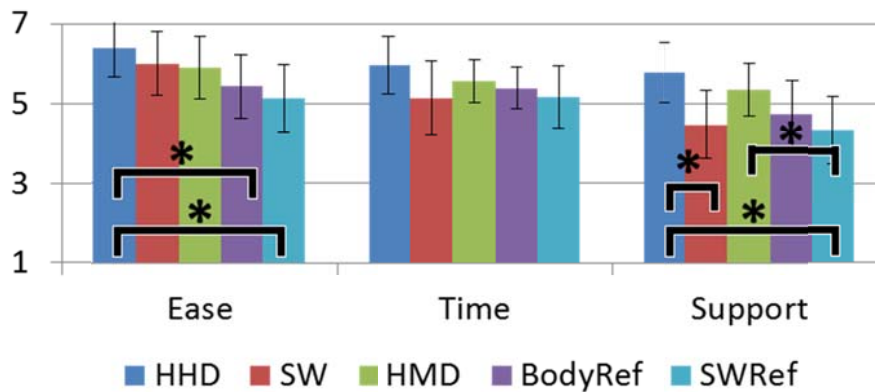


Figure 8: ASQ ratings for select task (7-point Likert).

User Experience

Results of the After Scenario Questionnaire (seven item Likert scale, 1: totally disagree, 7: totally agree) can be found in

Figure 4. Friedman ANOVAs indicated that there were significant effect of interface on ease of task ($\chi^2(4)=26.65$, $p<.001$), satisfaction with task completion time ($\chi^2(4)=9.57$, $p=.048$) and system support ($\chi^2(4)=12.20$, $p=.02$). However, Wilcoxon signed rank tests with Bonferroni corrections only indicated a significant difference between HHD and SWRef for ease of task ($Z= -3.36$, $p=.01$).

Pragmatic Quality (PQ) and Hedonic Quality Stimulation (HQ-S) as measured by AttrakDiff are depicted in

Figure 5, right. A repeated measures ANOVA indicated that there was a significant effect of interface on PQ, $F(2.76, 60.69)=4.05$, $p<.001$ and on HQ-S, $F(4, 88)=48.45$, $p<.001$. For PQ, results of post-hoc tests with Bonferroni corrections indicated significant differences as depicted in

Figure 5, right.

Preference ratings (ranking: 1: most preferred 5: least preferred) were as follows. HHD: MD=2, $M=2.13$, $\sigma=1.10$, SW: MD=5, $M=4.09$, $\sigma=1.16$, HMD: MD=3, $M=2.91$, $\sigma=1.24$, BodyRef: MD=3, $M=2.78$, $\sigma=1.54$, SWRef: MD=3, $M=3.09$, $\sigma=1.28$. A Friedman ANOVA indicated that there was a significant effect of interface on preference ($\chi^2(4)=17.58$, $p=.001$). Wilcoxon signed rank tests with Bonferroni corrections indicated a significant difference between HHD and SWRef task ($Z=-4.15$, $p<.001$).

To summarize, HHD scored significantly higher for ease of task and system support compared to BodyRef and SWRef (for system support also compared to SW). As in the locator task, all interfaces scored below average for pragmatic quality. BodyRef and SWRef scored significantly lower than HHD. For hedonic quality stimulation, the HHD and SW interface were rated significantly lower than the other three conditions as in the locator task. HHD was significantly more preferred than SW.

Qualitative Feedback

In semi-structured interviews participants commented on potentials and limitations of the prototypical MultiFi implementation. Most participants (21) commented on the benefits of having an extended view space compared to individual touch screens with one participant saying "Getting an overview with simple head movements is intuitive and natural". Those participants also valued the fact that precise selection was enabled through the smartwatch with one typical comment being "The HMD gives you the overview, and the SW lets you be precise in your selection". Three participants highlighted the potentially lower access costs of MultiFi over smartphones, with one comment being "I don't have to constantly monitor my smartphone". In line participants felt that BodyRef interaction was fastest (even though this is not confirmed by the objective measurements). Five participants commented on the benefits of MultiFi over HMD only interaction highlighting the direct interaction or that they could "take advantage of proprioception and motion control". Many participants (15) commented on the limitations of the hardware, specifically the quality of the employed HMD with a typical comment being "The combined interfaces [SWRef, BodyRef] gave me trouble because of display quality". Specifically, the employed HMD obscured parts of the users' field of view "preventing the ability of glancing down (on the SW) without moving your head". Another issue highlighted by 6 participants was the cost of focus switching which refers to the accommodation to different focus depths of the touch screen and the virtual HMD screen with a typical comment being: "I have to focus on three layers, which is overwhelming: SW, HMD and real world". This also led to coordination problems across devices as mentioned by 9 participants. Hence, some participants suggested not to concurrently use HMD and SW as output: "Pairing the two devices is good, but use one as input, the other as output, not both as output, it's confusing". Also, social concerns of spatial pointing were raised, "I could not imagine this in a packed bus".

Detailed Statistics for Experiment 1: LOCATOR TASK ON MAP

Task Completion Time

Mauchly's Test of Sphericity^b

Measure:TCT

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon ^a		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
interface	,617	109,837	9	,000	,775	,787	,250

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b. Design: Intercept
Within Subjects Design: interface

Tests of Within-Subjects Effects

Measure:TCT

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power ^a
interface	Sphericity Assumed	4978,603	4	1244,651	42,206	,000	,156	168,824	1,000
	Greenhouse-Geisser	4978,603	3,099	1606,578	42,206	,000	,156	130,792	1,000
	Huynh-Feldt	4978,603	3,146	1582,387	42,206	,000	,156	132,791	1,000
	Lower-bound	4978,603	1,000	4978,603	42,206	,000	,156	42,206	1,000
Error(interface)	Sphericity Assumed	27012,729	916	29,490					
	Greenhouse-Geisser	27012,729	709,645	38,065					
	Huynh-Feldt	27012,729	720,494	37,492					
	Lower-bound	27012,729	229,000	117,960					

a. Computed using alpha = ,05

The p-values in the following table are not Bonferroni corrected. Bonferroni corrected values are p-value*0.1.

Paired Samples Test

		Paired Differences				t	df	Sig. (2-tailed)	
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower				Upper
Pair 1	HHD - SW	-4,66661	6,43000	,42398	-5,50201	-3,83120	-11,007	229	,000
Pair 2	HHD - HMD	-3,00882	6,16431	,40646	-3,80970	-2,20793	-7,402	229	,000
Pair 3	HHD - BodyRef	-,89360	5,87902	,38765	-1,65742	-,12979	-2,305	229	,022
Pair 4	HHD - SWRef	-5,37769	9,18462	,60562	-6,57098	-4,18440	-8,880	229	,000
Pair 5	SW - HMD	1,65779	6,99779	,46142	,74862	2,56696	3,593	229	,000
Pair 6	SW - BodyRef	3,77300	6,77863	,44697	2,89231	4,65370	8,441	229	,000
Pair 7	SW - SWRef	-,71108	9,68903	,63888	-1,96991	,54774	-1,113	229	,267
Pair 8	HMD - BodyRef	2,11521	6,32419	,41700	1,29356	2,93687	5,072	229	,000
Pair 9	HMD - SWRef	-2,36887	8,71125	,57440	-3,50066	-1,23708	-4,124	229	,000
Pair 10	BodyRef - SWRef	-4,48409	9,31967	,61452	-5,69492	-3,27325	-7,297	229	,000

Errors

Ranks

	Mean Rank
HHD	3,00
SW	2,95
HMD	3,00
BodyRef	3,00
SWRef	3,04

Test Statistics^a

N	230
Chi-Square	4,099
df	4
Asymp. Sig.	,393

a. Friedman Test

The p-values in the following table are not Bonferroni corrected. Bonferroni corrected values are p-value*0.1.

Test Statistics^d

	SW - HHD	HMD - HHD	BodyRef - HHD	SWRef - HHD	HMD - SW	BodyRef - SW	SWRef - SW	BodyRef - HMD	SWRef - HMD	SWRef - BodyRef
Z	-1,147 ^a	,000 ^b	,000 ^b	-,832 ^c	-1,091 ^c	-1,091 ^c	-2,000 ^c	,000 ^b	-,832 ^c	-,832 ^c
Asymp. Sig. (2-tailed)	,251	1,000	1,000	,405	,275	,275	,046	1,000	,405	,405

- a. Based on positive ranks.
- b. The sum of negative ranks equals the sum of positive ranks.
- c. Based on negative ranks.
- d. Wilcoxon Signed Ranks Test

Subjective Workload

interfaces: 1: HHD, 2:SW, 3: HMD, 4: BodyRef, 5: SWRef

md: mental demand, pd: physical demand, td: temporal demand, p: performance, e: effort, f: frustration, o: overall.

Mauchly's Test of Sphericity^b

Within Subjects Effect	Measure	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon ^a		
						Greenhouse-Geisser	Huynh-Feldt	Lower-bound
interface	md	,222	30,728	9	,000	,543	,605	,250
	pd	,504	14,000	9	,123	,790	,939	,250
	td	,428	17,334	9	,044	,697	,808	,250
	p	,423	17,578	9	,041	,756	,890	,250
	e	,241	29,094	9	,001	,574	,644	,250
	f	,452	16,218	9	,063	,734	,860	,250
	o	,459	15,888	9	,070	,718	,837	,250

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b. Design: Intercept
Within Subjects Design: interface

Univariate Tests

Source	Measure	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power ^a	
interface	md	Sphericity Assumed	4281,304	4	1070,326	5,854	,000	,210	23,417	,979
		Greenhouse-Geisser	4281,304	2,173	1969,900	5,854	,004	,210	12,724	,872
		Huynh-Feldt	4281,304	2,420	1768,882	5,854	,003	,210	14,170	,899
		Lower-bound	4281,304	1,000	4281,304	5,854	,024	,210	5,854	,638
	pd	Sphericity Assumed	7449,130	4	1862,283	7,879	,000	,264	31,514	,997
		Greenhouse-Geisser	7449,130	3,162	2356,019	7,879	,000	,264	24,910	,989
		Huynh-Feldt	7449,130	3,754	1984,282	7,879	,000	,264	29,577	,996
		Lower-bound	7449,130	1,000	7449,130	7,879	,010	,264	7,879	,765
	td	Sphericity Assumed	1864,348	4	466,087	3,087	,020	,123	12,349	,791
		Greenhouse-Geisser	1864,348	2,786	669,079	3,087	,037	,123	8,602	,672
		Huynh-Feldt	1864,348	3,231	576,934	3,087	,029	,123	9,976	,721
		Lower-bound	1864,348	1,000	1864,348	3,087	,093	,123	3,087	,390
	p	Sphericity Assumed	2243,478	4	560,870	3,074	,020	,123	12,296	,789
		Greenhouse-Geisser	2243,478	3,024	741,915	3,074	,033	,123	9,295	,697
		Huynh-Feldt	2243,478	3,560	630,239	3,074	,025	,123	10,942	,751
		Lower-bound	2243,478	1,000	2243,478	3,074	,093	,123	3,074	,389
	e	Sphericity Assumed	4732,609	4	1183,152	6,217	,000	,220	24,868	,985
		Greenhouse-Geisser	4732,609	2,295	2061,883	6,217	,003	,220	14,270	,905
		Huynh-Feldt	4732,609	2,578	1836,028	6,217	,002	,220	16,025	,929
		Lower-bound	4732,609	1,000	4732,609	6,217	,021	,220	6,217	,664
f	Sphericity Assumed	3481,304	4	870,326	4,036	,005	,155	16,142	,898	
	Greenhouse-Geisser	3481,304	2,937	1185,316	4,036	,011	,155	11,852	,813	
	Huynh-Feldt	3481,304	3,439	1012,393	4,036	,007	,155	13,877	,859	
	Lower-bound	3481,304	1,000	3481,304	4,036	,057	,155	4,036	,484	
o	Sphericity Assumed	3100,085	4	775,021	7,476	,000	,254	29,905	,996	
	Greenhouse-Geisser	3100,085	2,872	1079,264	7,476	,000	,254	21,475	,978	
	Huynh-Feldt	3100,085	3,349	925,573	7,476	,000	,254	25,040	,989	
	Lower-bound	3100,085	1,000	3100,085	7,476	,012	,254	7,476	,743	
Error(interface)	md	Sphericity Assumed	16088,696	88	182,826					
		Greenhouse-Geisser	16088,696	47,814	336,485					
		Huynh-Feldt	16088,696	53,248	302,149					
		Lower-bound	16088,696	22,000	731,304					
	pd	Sphericity Assumed	20800,870	88	236,374					
		Greenhouse-Geisser	20800,870	69,558	299,042					
		Huynh-Feldt	20800,870	82,590	251,858					
		Lower-bound	20800,870	22,000	945,494					
	td	Sphericity Assumed	13285,652	88	150,973					
		Greenhouse-Geisser	13285,652	61,302	216,726					
		Huynh-Feldt	13285,652	71,092	186,879					
		Lower-bound	13285,652	22,000	603,893					
	p	Sphericity Assumed	16056,522	88	182,460					
		Greenhouse-Geisser	16056,522	66,526	241,358					
		Huynh-Feldt	16056,522	78,314	205,028					
		Lower-bound	16056,522	22,000	729,842					
	e	Sphericity Assumed	16747,391	88	190,311					
		Greenhouse-Geisser	16747,391	50,496	331,656					
		Huynh-Feldt	16747,391	56,708	295,327					
		Lower-bound	16747,391	22,000	761,245					
	f	Sphericity Assumed	18978,696	88	215,667					
		Greenhouse-Geisser	18978,696	64,615	293,722					
		Huynh-Feldt	18978,696	75,651	250,871					
		Lower-bound	18978,696	22,000	862,668					
	o	Sphericity Assumed	9122,549	88	103,665					
		Greenhouse-Geisser	9122,549	63,193	144,360					
		Huynh-Feldt	9122,549	73,686	123,803					
		Lower-bound	9122,549	22,000	414,661					

a. Computed using alpha = ,05

Pairwise Comparisons

Measure	(I) interface	(J) interface	Mean Difference (I-J)	Std. Error	Sig. ^a	95% Confidence Interval for Difference ^a	
						Lower Bound	Upper Bound
md	1	2	-1,739	3,137	1,000	-11,524	8,046
		3	-9,348	4,348	,428	-22,908	4,212
		4	-15,870	5,594	,096	-33,315	1,576
		5	-12,391	5,097	,236	-28,287	3,504
	2	1	1,739	3,137	1,000	-8,046	11,524
		3	-7,609	2,963	,176	-16,851	1,634
		4	-14,130 [*]	4,318	,035	-27,596	-,665
		5	-10,652	4,382	,237	-24,318	3,014
	3	1	9,348	4,348	,428	-4,212	22,908
		2	7,609	2,963	,176	-1,634	16,851
		4	-6,522	3,006	,411	-15,896	2,853
		5	-3,043	2,944	1,000	-12,227	6,140
	4	1	15,870	5,594	,096	-1,576	33,315
		2	14,130 [*]	4,318	,035	,665	27,596
		3	6,522	3,006	,411	-2,853	15,896
		5	3,478	2,939	1,000	-5,689	12,646
	5	1	12,391	5,097	,236	-3,504	28,287
		2	10,652	4,382	,237	-3,014	24,318
		3	3,043	2,944	1,000	-6,140	12,227
		4	-3,478	2,939	1,000	-12,646	5,689
pd	1	2	-11,522 [*]	3,631	,044	-22,847	-,197
		3	-11,087	3,837	,085	-23,052	,879
		4	-21,957 [*]	5,314	,004	-38,529	-5,384
		5	-21,304 [*]	4,852	,002	-36,436	-6,173
	2	1	11,522 [*]	3,631	,044	,197	22,847
		3	,435	3,250	1,000	-9,702	10,572
		4	-10,435	4,746	,387	-25,236	4,366
		5	-9,783	4,200	,294	-22,880	3,315
	3	1	11,087	3,837	,085	-,879	23,052
		2	-,435	3,250	1,000	-10,572	9,702
		4	-10,870	4,453	,232	-24,757	3,018
		5	-10,217	5,476	,755	-27,296	6,862
	4	1	21,957 [*]	5,314	,004	5,384	38,529
		2	10,435	4,746	,387	-4,366	25,236
		3	10,870	4,453	,232	-3,018	24,757
		5	,652	5,033	1,000	-15,043	16,348

	5	1	21,304 ⁺	4,852	,002	6,173	36,436
		2	9,783	4,200	,294	-3,315	22,880
		3	10,217	5,476	,755	-6,862	27,296
		4	-,652	5,033	1,000	-16,348	15,043
td	1	2	-9,565 ⁺	2,571	,012	-17,585	-1,546
		3	-6,739	3,754	,864	-18,447	4,969
		4	-10,435	4,869	,434	-25,620	4,751
		5	-10,870	4,142	,155	-23,789	2,050
	2	1	9,565 ⁺	2,571	,012	1,546	17,585
		3	2,826	3,172	1,000	-7,067	12,719
		4	-,870	4,094	1,000	-13,639	11,900
		5	-1,304	2,969	1,000	-10,565	7,956
	3	1	6,739	3,754	,864	-4,969	18,447
		2	-2,826	3,172	1,000	-12,719	7,067
		4	-3,696	3,628	1,000	-15,011	7,620
		5	-4,130	3,185	1,000	-14,064	5,803
	4	1	10,435	4,869	,434	-4,751	25,620
		2	,870	4,094	1,000	-11,900	13,639
		3	3,696	3,628	1,000	-7,620	15,011
		5	-,435	3,281	1,000	-10,666	9,797
	5	1	10,870	4,142	,155	-2,050	23,789
		2	1,304	2,969	1,000	-7,956	10,565
		3	4,130	3,185	1,000	-5,803	14,064
		4	,435	3,281	1,000	-9,797	10,666
p	1	2	-9,565 ⁺	2,684	,017	-17,937	-1,194
		3	-8,913	3,556	,201	-20,003	2,177
		4	-11,739	4,213	,108	-24,878	1,400
		5	-12,174	3,949	,054	-24,490	,143
	2	1	9,565 ⁺	2,684	,017	1,194	17,937
		3	,652	4,348	1,000	-12,908	14,212
		4	-2,174	3,848	1,000	-14,174	9,826
		5	-2,609	5,009	1,000	-18,230	13,012
	3	1	8,913	3,556	,201	-2,177	20,003
		2	-,652	4,348	1,000	-14,212	12,908
		4	-2,826	3,999	1,000	-15,298	9,646
		5	-3,261	3,523	1,000	-14,249	7,727
	4	1	11,739	4,213	,108	-1,400	24,878
		2	2,174	3,848	1,000	-9,826	14,174
		3	2,826	3,999	1,000	-9,646	15,298
		5	-,435	4,275	1,000	-13,766	12,897
	5	1	12,174	3,949	,054	-,143	24,490
		2	2,609	5,009	1,000	-13,012	18,230
		3	3,261	3,523	1,000	-7,727	14,249

		4	,435	4,275	1,000	-12,897	13,766	
e	1	2	-10,652	3,505	,060	-21,583	,278	
		3	-8,913	3,414	,160	-19,561	1,735	
		4	-14,348 ⁺	4,279	,029	-27,694	-1,002	
		5	-19,348 ⁺	4,438	,003	-33,189	-5,507	
		2	1	10,652	3,505	,060	-,278	21,583
	2	3	1,739	4,452	1,000	-12,147	15,625	
		4	-3,696	3,255	1,000	-13,847	6,456	
		5	-8,696 ⁺	2,480	,020	-16,429	-,963	
		3	1	8,913	3,414	,160	-1,735	19,561
	3	2	-1,739	4,452	1,000	-15,625	12,147	
		4	-5,435	4,959	1,000	-20,902	10,033	
		5	-10,435	5,701	,808	-28,215	7,346	
		4	1	14,348 ⁺	4,279	,029	1,002	27,694
	4	2	3,696	3,255	1,000	-6,456	13,847	
		3	5,435	4,959	1,000	-10,033	20,902	
		5	-5,000	3,143	1,000	-14,804	4,804	
		5	1	19,348 ⁺	4,438	,003	5,507	33,189
		2	8,696 ⁺	2,480	,020	,963	16,429	
	f	1	3	10,435	5,701	,808	-7,346	28,215
			4	5,000	3,143	1,000	-4,804	14,804
2			1	15,217 ⁺	2,855	,000	6,314	24,121
3			8,696 ⁺	2,780	,049	,025	17,366	
4			8,478	4,473	,712	-5,471	22,427	
2		5	1,522	4,874	1,000	-13,680	16,724	
		3	1	6,522	3,590	,829	-4,675	17,719
		2	-8,696 ⁺	2,780	,049	-17,366	-,025	
		4	-,217	5,015	1,000	-15,857	15,422	
3		5	-7,174	5,125	1,000	-23,158	8,811	
		4	1	6,739	4,441	1,000	-7,112	20,590
		2	-8,478	4,473	,712	-22,427	5,471	
		3	,217	5,015	1,000	-15,422	15,857	
		5	-6,957	4,509	1,000	-21,019	7,106	
4		5	1	13,696	4,852	,099	-1,436	28,827
		2	-1,522	4,874	1,000	-16,724	13,680	
		3	7,174	5,125	1,000	-8,811	23,158	
		4	6,957	4,509	1,000	-7,106	21,019	
5		1	1	-9,696 ⁺	2,361	,005	-17,060	-2,331
		3	-8,449	2,745	,055	-17,010	,111	
	o	1	2					

	4		-13,746*	4,090	,028	-26,504	-,989
	5		-14,558*	3,519	,004	-25,532	-3,584
2	1		9,696*	2,361	,005	2,331	17,060
	3		1,246	2,215	1,000	-5,660	8,153
	4		-4,051	2,833	1,000	-12,887	4,785
	5		-4,862	2,564	,711	-12,859	3,135
3	1		8,449	2,745	,055	-,111	17,010
	2		-1,246	2,215	1,000	-8,153	5,660
	4		-5,297	3,240	1,000	-15,401	4,807
	5		-6,109	3,039	,568	-15,586	3,369
4	1		13,746*	4,090	,028	,989	26,504
	2		4,051	2,833	1,000	-4,785	12,887
	3		5,297	3,240	1,000	-4,807	15,401
	5		-,812	2,947	1,000	-10,003	8,380
5	1		14,558*	3,519	,004	3,584	25,532
	2		4,862	2,564	,711	-3,135	12,859
	3		6,109	3,039	,568	-3,369	15,586
	4		,812	2,947	1,000	-8,380	10,003

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

*. The mean difference is significant at the ,05 level.

User Experience

After Scenario Questionnaire

Ease of Use

Ranks		Test Statistics ^a	
	Mean Rank		
easeHHD	3,91	N	23
easeSW	2,93	Chi-Square	25,649
easeHMD	3,30	df	4
easeBodyRef	2,91	Asymp. Sig.	,000
easeSWRef	1,93		

a. Friedman Test

The p-values in the following table are not Bonferroni corrected. Bonferroni corrected values are p-value*0.1.

		Test Statistics ^c									
		easeSW - easeHHD	easeHMD - easeHHD	easeBodyRef - easeHHD	easeSWRef - easeHHD	easeHMD - easeSW	easeBodyRef - easeSW	easeSWRef - easeSW	easeBodyRef - easeHMD	easeSWRef - easeHMD	easeSWRef - easeBodyRef
Z		-2,391 ^a	-1,843 ^a	-2,515 ^a	-3,356 ^a	-,674 ^b	-,679 ^a	-2,527 ^a	-1,137 ^a	-2,734 ^a	-2,614 ^a
Asymp. Sig. (2-tailed)		,017	,065	,012	,001	,500	,497	,012	,256	,006	,009

a. Based on positive ranks.
b. Based on negative ranks.
c. Wilcoxon Signed Ranks Test

Satisfaction with Task Completion Time

Ranks

	Mean Rank	Test Statistics ^a	
timeHHD	3,54	N	23
timeSW	2,59	Chi-Square	9,570
timeHMD	3,30	df	4
timeBodyRef	3,04	Asymp. Sig.	,048
timeSWRef	2,52	a. Friedman Test	

The p-values in the following table are not Bonferroni corrected. Bonferroni corrected values are p-value*0.1.

Test Statistics^c

	timeSW - timeHHD	timeHMD - timeHHD	timeBodyRef - timeHHD	timeSWRef - timeHHD	timeHMD - timeSW	timeBodyRef - timeSW	timeSWRef - timeSW	timeBodyRef - timeHMD	timeSWRef - timeHMD	timeSWRef - timeBodyRef
Z	-2,738 ^a	-,700 ^a	-1,930 ^a	-2,680 ^a	-1,395 ^b	-1,052 ^b	-,611 ^a	-,956 ^a	-1,929 ^a	-1,977 ^a
Asymp. Sig. (2-tailed)	,006	,484	,054	,007	,163	,293	,541	,339	,054	,048

- a. Based on positive ranks.
- b. Based on negative ranks.
- c. Wilcoxon Signed Ranks Test

Satisfaction with System Support

Ranks

	Mean Rank	Test Statistics ^a	
supportHHD	3,70	N	23
supportSW	2,50	Chi-Square	12,203
supportHMD	3,26	df	4
supportBodyRef	3,07	Asymp. Sig.	,016
supportSWRef	2,48	a. Friedman Test	

The p-values in the following table are not Bonferroni corrected. Bonferroni corrected values are p-value*0.1.

Test Statistics^c

	supportSW - supportHHD	supportHMD - supportHHD	supportBodyRef - supportHHD	supportSWRef - supportHHD	supportHMD - supportSW	supportBodyRef - supportSW	supportSWRef - supportSW	supportBodyRef - supportHMD	supportSWRef - supportHMD	supportSWRef - supportBodyRef
Z	-2,654 ^a	-1,290 ^a	-1,930 ^a	-2,783 ^a	-1,766 ^b	-1,747 ^b	-,152 ^a	-,058 ^b	-1,904 ^a	-1,897 ^a
Asymp. Sig. (2-tailed)	,008	,197	,054	,005	,077	,081	,879	,954	,057	,058

- a. Based on positive ranks.
- b. Based on negative ranks.
- c. Wilcoxon Signed Ranks Test

Pragmatic Quality (PQ) and Hedonic Quality Stimulation (HQS)

interfaces: 1: HHD, 2:SW, 3: HMD, 4: BodyRef, 5: SWRef

Mauchly's Test of Sphericity^b

Within Subjects Effect	Measure	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon ^a		
						Greenhouse-Geisser	Huynh-Feldt	Lower-bound
interface	pq	,472	15,321	9	,083	,721	,842	,250
	hqs	,354	21,218	9	,012	,711	,828	,250

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

- a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.
- b. Design: Intercept
Within Subjects Design: interface

Univariate Tests

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power ^a
interface	pq	Sphericity Assumed	2,458	4	,614	4,052	,005	,156	16,206	,899
		Greenhouse-Geisser	2,458	2,885	,852	4,052	,012	,156	11,689	,809
		Huynh-Feldt	2,458	3,367	,730	4,052	,008	,156	13,641	,855
		Lower-bound	2,458	1,000	2,458	4,052	,057	,156	4,052	,486
	hqs	Sphericity Assumed	48,727	4	12,182	58,260	,000	,726	233,040	1,000
		Greenhouse-Geisser	48,727	2,844	17,131	58,260	,000	,726	165,711	1,000
		Huynh-Feldt	48,727	3,311	14,718	58,260	,000	,726	192,885	1,000
		Lower-bound	48,727	1,000	48,727	58,260	,000	,726	58,260	1,000
Error(interface)	pq	Sphericity Assumed	13,346	88	,152					
		Greenhouse-Geisser	13,346	63,471	,210					
		Huynh-Feldt	13,346	74,070	,180					
		Lower-bound	13,346	22,000	,607					
	hqs	Sphericity Assumed	18,400	88	,209					
		Greenhouse-Geisser	18,400	62,575	,294					
		Huynh-Feldt	18,400	72,837	,253					
		Lower-bound	18,400	22,000	,836					

a. Computed using alpha = ,05

The p-values in the following table are not Bonferroni corrected. Bonferroni corrected values are p-value*0.1.

Pairwise Comparisons

Measure	(I) interface	(J) interface	Mean Difference (I-J)	Std. Error	Sig. ^a	95% Confidence Interval for Difference ^a	
						Lower Bound	Upper Bound
pq	1	2	,286	,096	,071	-,015	,586
		3	,056	,126	1,000	-,336	,448
		4	,267	,145	,799	-,187	,721
		5	,385	,135	,095	-,037	,808
	2	1	-,286	,096	,071	-,586	,015
		3	-,230	,110	,476	-,571	,112
		4	-,019	,117	1,000	-,383	,346
		5	,099	,112	1,000	-,249	,447
	3	1	-,056	,126	1,000	-,448	,336
		2	,230	,110	,476	-,112	,571
		4	,211	,118	,884	-,158	,581
		5	,329*	,093	,018	,040	,618
	4	1	-,267	,145	,799	-,721	,187
		2	,019	,117	1,000	-,346	,383
		3	-,211	,118	,884	-,581	,158
		5	,118	,081	1,000	-,135	,371
	5	1	-,385	,135	,095	-,808	,037
		2	-,099	,112	1,000	-,447	,249
		3	-,329*	,093	,018	-,618	-,040
		4	-,118	,081	1,000	-,371	,135
hqs	1	2	-,329*	,090	,014	-,611	-,047
		3	-,199*	,165	,000	-,714	-,684
		4	-,621*	,132	,000	-,2031	-,1211
		5	-,516*	,122	,000	-,1897	-,1134
	2	1	,329*	,090	,014	,047	,611
		3	-,870*	,146	,000	-,1325	-,414
		4	-,1292*	,132	,000	-,1705	-,879
		5	-,186*	,139	,000	-,1619	-,754
	3	1	1,199*	,165	,000	,684	1,714
		2	,870*	,146	,000	,414	1,325
		4	-,422	,144	,078	-,873	,028
		5	-,317	,167	,708	-,837	,203
	4	1	1,621*	,132	,000	1,211	2,031
		2	1,292*	,132	,000	,879	1,705
		3	,422	,144	,078	-,028	,873
		5	,106	,085	1,000	-,160	,372
	5	1	1,516*	,122	,000	1,134	1,897
		2	1,186*	,139	,000	,754	1,619
		3	,317	,167	,708	-,203	,837
		4	-,106	,085	1,000	-,372	,160

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.
*. The mean difference is significant at the ,05 level.

Preference

Ranks		Test Statistics ^a	
	Mean Rank		
PrefMapHHD	2,11	N	23
PrefMapSW	4,11	Chi-Square	19,354
PrefMapHMD	2,89	df	4
PrefMapSWRef	3,11	Asymp. Sig.	,001
PrefMapBodyRef	2,78		

a. Friedman Test

The p-values in the following table are not Bonferroni corrected. Bonferroni corrected values are p-value*0.1.

Test Statistics^c

	PrefMapSW - PrefMapHHD	PrefMapHMD - PrefMapHHD	PrefMap SWRef - PrefMapHHD	PrefMapBody Ref - PrefMapHHD	PrefMapHMD - PrefMapSW	PrefMap SWRef - PrefMapSW	PrefMapBody Ref - PrefMapSW	PrefMap SWRef - PrefMapHMD	PrefMapBody Ref - PrefMapHMD	PrefMap SWRef - PrefMapBody Ref
Z	-4,250 ^a	-1,762 ^a	-2,235 ^a	-1,200 ^a	-2,537 ^b	-2,146 ^b	-2,273 ^b	-,386 ^a	-,140 ^b	-,664 ^a
Asymp. Sig. (2-tailed)	,000	,078	,025	,230	,011	,032	,023	,700	,889	,507

a. Based on negative ranks.
b. Based on positive ranks.
c. Wilcoxon Signed Ranks Test

Detailed Statistics for Experiment 2: 1D Target Acquisition

Task Completion Time

IF: interface, dir: direction

Descriptive Statistics

Estimates

Measure:TCT

IF	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	2,363	,027	2,310	2,416
2	3,952	,046	3,861	4,043
3	3,971	,053	3,866	4,075
4	2,938	,053	2,833	3,042
5	3,778	,066	3,648	3,907

Estimates

Measure:TCT

dir	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	3,409	,034	3,342	3,475
2	3,392	,042	3,309	3,474

Estimates

Measure:TCT

length	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	2,549	,027	2,497	2,602
2	4,251	,047	4,158	4,344

5. IF * dir

Measure:TCT

IF	dir	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	2,338	,031	2,278	2,399
	2	2,388	,030	2,329	2,447
2	1	3,995	,043	3,910	4,079
	2	3,909	,067	3,777	4,042
3	1	4,087	,058	3,972	4,202
	2	3,854	,063	3,729	3,979
4	1	2,844	,057	2,730	2,957
	2	3,031	,071	2,891	3,172
5	1	3,780	,064	3,653	3,907
	2	3,775	,093	3,592	3,958

6. IF * length

Measure:TCT

IF	length	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	1,798	,025	1,749	1,847
	2	2,928	,036	2,856	3,000
2	1	2,838	,028	2,783	2,894
	2	5,066	,074	4,920	5,211
3	1	2,884	,043	2,800	2,969
	2	5,057	,073	4,913	5,201
4	1	2,451	,059	2,335	2,566
	2	3,424	,068	3,290	3,559
5	1	2,776	,048	2,681	2,871
	2	4,779	,104	4,575	4,984

7. dir * length

Measure:TCT

dir	length	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	2,569	,033	2,505	2,634
	2	4,248	,043	4,163	4,333
2	1	2,530	,028	2,474	2,585
	2	4,254	,065	4,126	4,381

8. IF * dir * length

Measure:TCT

IF	dir	length	Mean	Std. Error	95% Confidence Interval	
					Lower Bound	Upper Bound
1	1	1	1,764	,033	1,699	1,829
		2	2,912	,041	2,831	2,994
	2	1	1,832	,029	1,776	1,889
		2	2,944	,041	2,863	3,025
2	1	1	2,880	,035	2,810	2,950
		2	5,109	,061	4,989	5,230
	2	1	2,797	,032	2,733	2,861
		2	5,022	,120	4,786	5,258
3	1	1	2,940	,055	2,830	3,049
		2	5,235	,082	5,074	5,396
	2	1	2,829	,053	2,724	2,935
		2	4,879	,089	4,703	5,055
4	1	1	2,358	,065	2,230	2,487
		2	3,329	,081	3,170	3,489
	2	1	2,544	,081	2,384	2,703
		2	3,519	,094	3,333	3,705
5	1	1	2,906	,085	2,737	3,074
		2	4,654	,074	4,508	4,801
	2	1	2,646	,034	2,578	2,713
		2	4,904	,175	4,559	5,250

Analysis of Variance

Mauchly's Test of Sphericity^b

Measure:TCT

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon ^a		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
IF	,591	95,513	9	,000	,829	,846	,250
dir	1,000	,000	0	.	1,000	1,000	1,000
length	1,000	,000	0	.	1,000	1,000	1,000
IF * dir	,595	94,178	9	,000	,819	,835	,250
IF * length	,550	108,294	9	,000	,809	,825	,250
dir * length	1,000	,000	0	.	1,000	1,000	1,000
IF * dir * length	,402	165,451	9	,000	,709	,721	,250

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b. Design: Intercept

Within Subjects Design: IF + dir + length + IF * dir + IF * length + dir * length + IF * dir * length

Tests of Within-Subjects Effects

Measure:TCT

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power ^a
IF	Sphericity Assumed	1517,230	4	379,308	301,017	,000	,622	1204,066	1,000
	Greenhouse-Geisser	1517,230	3,315	457,699	301,017	,000	,622	997,842	1,000
	Huynh-Feldt	1517,230	3,383	448,436	301,017	,000	,622	1018,454	1,000
	Lower-bound	1517,230	1,000	1517,230	301,017	,000	,622	301,017	1,000
Error(IF)	Sphericity Assumed	922,385	732	1,260					
	Greenhouse-Geisser	922,385	606,628	1,521					
	Huynh-Feldt	922,385	619,159	1,490					
	Lower-bound	922,385	183,000	5,040					
dir	Sphericity Assumed	,270	1	,270	,284	,595	,002	,284	,083
	Greenhouse-Geisser	,270	1,000	,270	,284	,595	,002	,284	,083
	Huynh-Feldt	,270	1,000	,270	,284	,595	,002	,284	,083
	Lower-bound	,270	1,000	,270	,284	,595	,002	,284	,083
Error(dir)	Sphericity Assumed	174,084	183	,951					
	Greenhouse-Geisser	174,084	183,000	,951					
	Huynh-Feldt	174,084	183,000	,951					
	Lower-bound	174,084	183,000	,951					
length	Sphericity Assumed	2663,011	1	2663,011	2547,226	,000	,933	2547,226	1,000
	Greenhouse-Geisser	2663,011	1,000	2663,011	2547,226	,000	,933	2547,226	1,000
	Huynh-Feldt	2663,011	1,000	2663,011	2547,226	,000	,933	2547,226	1,000
	Lower-bound	2663,011	1,000	2663,011	2547,226	,000	,933	2547,226	1,000
Error(length)	Sphericity Assumed	191,318	183	1,045					
	Greenhouse-Geisser	191,318	183,000	1,045					
	Huynh-Feldt	191,318	183,000	1,045					
	Lower-bound	191,318	183,000	1,045					
IF * dir	Sphericity Assumed	18,009	4	4,502	5,712	,000	,030	22,848	,981
	Greenhouse-Geisser	18,009	3,274	5,500	5,712	,000	,030	18,701	,961
	Huynh-Feldt	18,009	3,341	5,391	5,712	,000	,030	19,082	,963
	Lower-bound	18,009	1,000	18,009	5,712	,018	,030	5,712	,662
Error(IF*dir)	Sphericity Assumed	576,964	732	,788					
	Greenhouse-Geisser	576,964	599,149	,963					
	Huynh-Feldt	576,964	611,361	,944					
	Lower-bound	576,964	183,000	3,153					
IF * length	Sphericity Assumed	266,151	4	66,538	89,486	,000	,328	357,945	1,000
	Greenhouse-Geisser	266,151	3,236	82,240	89,486	,000	,328	289,600	1,000
	Huynh-Feldt	266,151	3,301	80,618	89,486	,000	,328	295,429	1,000
	Lower-bound	266,151	1,000	266,151	89,486	,000	,328	89,486	1,000
Error(IF*length)	Sphericity Assumed	544,280	732	,744					
	Greenhouse-Geisser	544,280	592,235	,919					
	Huynh-Feldt	544,280	604,155	,901					
	Lower-bound	544,280	183,000	2,974					
dir * length	Sphericity Assumed	,477	1	,477	,532	,467	,003	,532	,112
	Greenhouse-Geisser	,477	1,000	,477	,532	,467	,003	,532	,112
	Huynh-Feldt	,477	1,000	,477	,532	,467	,003	,532	,112
	Lower-bound	,477	1,000	,477	,532	,467	,003	,532	,112
Error(dir*length)	Sphericity Assumed	164,140	183	,897					
	Greenhouse-Geisser	164,140	183,000	,897					
	Huynh-Feldt	164,140	183,000	,897					
	Lower-bound	164,140	183,000	,897					
IF * dir * length	Sphericity Assumed	14,329	4	3,582	4,582	,001	,024	18,327	,946
	Greenhouse-Geisser	14,329	2,835	5,055	4,582	,004	,024	12,988	,874
	Huynh-Feldt	14,329	2,884	4,969	4,582	,004	,024	13,213	,878
	Lower-bound	14,329	1,000	14,329	4,582	,034	,024	4,582	,567
Error(IF*dir*length)	Sphericity Assumed	572,315	732	,782					
	Greenhouse-Geisser	572,315	518,733	1,103					
	Huynh-Feldt	572,315	527,742	1,084					
	Lower-bound	572,315	183,000	3,127					

a. Computed using alpha = ,05

Simple Main Effects

Pairwise Comparisons

Measure:TCT

(I) IF	(J) IF	Mean Difference (I-J)	Std. Error	Sig. ^a	95% Confidence Interval for Difference ^a	
					Lower Bound	Upper Bound
1	2	-1,589 [*]	,039	,000	-1,699	-1,478
	3	-1,607 [*]	,046	,000	-1,737	-1,477
	4	-,574 [*]	,052	,000	-,723	-,426
	5	-1,414 [*]	,061	,000	-1,587	-1,242
2	1	1,589 [*]	,039	,000	1,478	1,699
	3	-,019	,052	1,000	-,167	,129
	4	1,014 [*]	,059	,000	,846	1,182
	5	,174	,064	,073	-,008	,357
3	1	1,607 [*]	,046	,000	1,477	1,737
	2	,019	,052	1,000	-,129	,167
	4	1,033 [*]	,067	,000	,844	1,222
	5	,193	,068	,052	-,001	,387
4	1	,574 [*]	,052	,000	,426	,723
	2	-1,014 [*]	,059	,000	-1,182	-,846
	3	-1,033 [*]	,067	,000	-1,222	-,844
	5	-,840 [*]	,069	,000	-1,036	-,644
5	1	1,414 [*]	,061	,000	1,242	1,587
	2	-,174	,064	,073	-,357	,008
	3	-,193	,068	,052	-,387	,001
	4	,840 [*]	,069	,000	,644	1,036

Based on estimated marginal means

*. The mean difference is significant at the ,05 level.
a. Adjustment for multiple comparisons: Bonferroni.

Pairwise Comparisons

Measure:TCT

(I) dir	(J) dir	Mean Difference (I-J)	Std. Error	Sig. ^a	95% Confidence Interval for Difference ^a	
					Lower Bound	Upper Bound
1	2	,017	,032	,595	-,046	,081
2	1	-,017	,032	,595	-,081	,046

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

Pairwise Comparisons

Measure:TCT

(I) length	(J) length	Mean Difference (I-J)	Std. Error	Sig. ^a	95% Confidence Interval for Difference ^a	
					Lower Bound	Upper Bound
1	2	-1,701 [*]	,034	,000	-1,768	-1,635
2	1	1,701 [*]	,034	,000	1,635	1,768

Based on estimated marginal means

*. The mean difference is significant at the ,05 level.
a. Adjustment for multiple comparisons: Bonferroni.

Two-Way Interactions

IFDirSS: Interface * Direction (direction fixed at level: same side of smartwatch)

Mauchly's Test of Sphericity^b

Measure:TCT

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon ^a		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
IFDirSS	,622	173,245	9	,000	,818	,826	,250

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b. Design: Intercept
Within Subjects Design: IFDirSS

Tests of Within-Subjects Effects

Measure:TCT

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power ^a
IFDirSS	Sphericity Assumed	885,533	4	221,383	316,348	,000	,463	1265,392	1,000
	Greenhouse-Geisser	885,533	3,273	270,588	316,348	,000	,463	1035,288	1,000
	Huynh-Feldt	885,533	3,306	267,891	316,348	,000	,463	1045,710	1,000
	Lower-bound	885,533	1,000	885,533	316,348	,000	,463	316,348	1,000
Error(IFDirSS)	Sphericity Assumed	1027,321	1468	,700					
	Greenhouse-Geisser	1027,321	1201,053	,855					
	Huynh-Feldt	1027,321	1213,144	,847					
	Lower-bound	1027,321	367,000	2,799					

a. Computed using alpha = ,05

Pairwise Comparisons

Measure:TCT

(I) IFDirSS	(J) IFDirSS	Mean Difference (I-J)	Std. Error	Sig. ^a	95% Confidence Interval for Difference ^a	
					Lower Bound	Upper Bound
1	2	-1,656 [*]	,046	,000	-1,788	-1,525
	3	-1,749 [*]	,058	,000	-1,913	-1,585
	4	-,505 [*]	,056	,000	-,663	-,348
	5	-1,442 [*]	,060	,000	-1,611	-1,272
2	1	1,656 [*]	,046	,000	1,525	1,788
	3	-,093	,049	,575	-,230	,045
	4	1,151 [*]	,067	,000	,961	1,341
	5	,215 [*]	,058	,003	,050	,379
3	1	1,749 [*]	,058	,000	1,585	1,913
	2	,093	,049	,575	-,045	,230
	4	1,243 [*]	,076	,000	1,030	1,457
	5	,307 [*]	,066	,000	,121	,493
4	1	,505 [*]	,056	,000	,348	,663
	2	-1,151 [*]	,067	,000	-1,341	-,961
	3	-1,243 [*]	,076	,000	-1,457	-1,030
	5	-,936 [*]	,074	,000	-1,145	-,728
5	1	1,442 [*]	,060	,000	1,272	1,611
	2	-,215 [*]	,058	,003	-,379	-,050
	3	-,307 [*]	,066	,000	-,493	-,121
	4	,936 [*]	,074	,000	,728	1,145

Based on estimated marginal means

*. The mean difference is significant at the ,05 level.

a. Adjustment for multiple comparisons: Bonferroni.

IFDirSO: Interface * Direction (direction fixed at level: opposite side of smartwatch arm)

Mauchly's Test of Sphericity^b

Measure:TCT

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon ^a		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
IFDirSO	,490	260,345	9	,000	,780	,788	,250

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b. Design: Intercept
Within Subjects Design: IFDirSO

Tests of Within-Subjects Effects

Measure:TCT

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power ^a
IFDirSO	Sphericity Assumed	649,705	4	162,426	127,570	,000	,258	510,281	1,000
	Greenhouse-Geisser	649,705	3,121	208,174	127,570	,000	,258	398,143	1,000
	Huynh-Feldt	649,705	3,151	206,202	127,570	,000	,258	401,951	1,000
	Lower-bound	649,705	1,000	649,705	127,570	,000	,258	127,570	1,000
Error(IFDirSO)	Sphericity Assumed	1869,103	1468	1,273					
	Greenhouse-Geisser	1869,103	1145,397	1,632					
	Huynh-Feldt	1869,103	1156,352	1,616					
	Lower-bound	1869,103	367,000	5,093					

a. Computed using alpha = ,05

Pairwise Comparisons

Measure:TCT

(I) IFDirSO	(J) IFDirSO	Mean Difference (I-J)	Std. Error	Sig. ^a	95% Confidence Interval for Difference ^a	
					Lower Bound	Upper Bound
1	2	-1,521 [*]	,066	,000	-1,709	-1,333
	3	-1,466 [*]	,055	,000	-1,621	-1,310
	4	-,643 [*]	,062	,000	-,819	-,467
	5	-1,387 [*]	,093	,000	-1,648	-1,125
2	1	1,521 [*]	,066	,000	1,333	1,709
	3	,055	,072	1,000	-,149	,260
	4	,878 [*]	,089	,000	,627	1,129
	5	,134	,102	1,000	-,153	,422
3	1	1,466 [*]	,055	,000	1,310	1,621
	2	-,055	,072	1,000	-,260	,149
	4	,823 [*]	,083	,000	,588	1,057
	5	,079	,097	1,000	-,194	,352
4	1	,643 [*]	,062	,000	,467	,819
	2	-,878 [*]	,089	,000	-1,129	-,627
	3	-,823 [*]	,083	,000	-1,057	-,588
	5	-,744 [*]	,098	,000	-1,020	-,468
5	1	1,387 [*]	,093	,000	1,125	1,648
	2	-,134	,102	1,000	-,422	,153
	3	-,079	,097	1,000	-,352	,194
	4	,744 [*]	,098	,000	,468	1,020

Based on estimated marginal means

*. The mean difference is significant at the ,05 level.

a. Adjustment for multiple comparisons: Bonferroni.

IFLengthShort: Interface * Length (length fixed at level: short)

Mauchly's Test of Sphericity^b

Measure:TCT

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon ^a		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
IFLengthShort	,452	290,069	9	,000	,765	,772	,250

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b. Design: Intercept
Within Subjects Design: IFLengthShort

Tests of Within-Subjects Effects

Measure:TCT

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power ^a
IFLengthShort	Sphericity Assumed	302,054	4	75,513	162,097	,000	,306	648,389	1,000
	Greenhouse-Geisser	302,054	3,059	98,736	162,097	,000	,306	495,887	1,000
	Huynh-Feldt	302,054	3,088	97,821	162,097	,000	,306	500,527	1,000
	Lower-bound	302,054	1,000	302,054	162,097	,000	,306	162,097	1,000
Error(IFLengthShort)	Sphericity Assumed	683,872	1468	,466					
	Greenhouse-Geisser	683,872	1122,723	,609					
	Huynh-Feldt	683,872	1133,229	,603					
	Lower-bound	683,872	367,000	1,863					

a. Computed using alpha = ,05

Pairwise Comparisons

Measure:TCT

(I) IFLengthShort	(J) IFLengthShort	Mean Difference (I-J)	Std. Error	Sig. ^a	95% Confidence Interval for Difference ^a	
					Lower Bound	Upper Bound
1	2	-1,040 [*]	,028	,000	-1,119	-,962
	3	-1,086 [*]	,039	,000	-1,197	-,975
	4	-,653 [*]	,052	,000	-,801	-,504
	5	-,977 [*]	,050	,000	-1,117	-,838
2	1	1,040 [*]	,028	,000	,962	1,119
	3	-,046	,039	1,000	-,156	,065
	4	,387 [*]	,054	,000	,236	,539
	5	,063	,049	1,000	-,074	,200
3	1	1,086 [*]	,039	,000	,975	1,197
	2	,046	,039	1,000	-,065	,156
	4	,433 [*]	,060	,000	,264	,603
	5	,109	,056	,536	-,050	,267
4	1	,653 [*]	,052	,000	,504	,801
	2	-,387 [*]	,054	,000	-,539	-,236
	3	-,433 [*]	,060	,000	-,603	-,264
	5	-,325 [*]	,065	,000	-,509	-,140
5	1	,977 [*]	,050	,000	,838	1,117
	2	-,063	,049	1,000	-,200	,074
	3	-,109	,056	,536	-,267	,050
	4	,325 [*]	,065	,000	,140	,509

Based on estimated marginal means

*. The mean difference is significant at the ,05 level.

a. Adjustment for multiple comparisons: Bonferroni.

IFLengthLong: Interface * Length (length fixed at level: long)

Mauchly's Test of Sphericity^b

Measure:TCT

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon ^a		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
IFLengthLong	,517	240,904	9	,000	,782	,789	,250

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b. Design: Intercept
Within Subjects Design: IFLengthLong

Tests of Within-Subjects Effects

Measure:TCT

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power ^a
IFLengthLong	Sphericity Assumed	1481,327	4	370,332	276,748	,000	,430	1106,992	1,000
	Greenhouse-Geisser	1481,327	3,128	473,642	276,748	,000	,430	865,536	1,000
	Huynh-Feldt	1481,327	3,158	469,145	276,748	,000	,430	873,833	1,000
	Lower-bound	1481,327	1,000	1481,327	276,748	,000	,430	276,748	1,000
Error(IFLengthLong)	Sphericity Assumed	1964,411	1468	1,338					
	Greenhouse-Geisser	1964,411	1147,801	1,711					
	Huynh-Feldt	1964,411	1158,803	1,695					
	Lower-bound	1964,411	367,000	5,353					

a. Computed using alpha = ,05

Pairwise Comparisons

Measure:TCT

(I) IFLengthLong	(J) IFLengthLong	Mean Difference (I-J)	Std. Error	Sig. ^a	95% Confidence Interval for Difference ^a	
					Lower Bound	Upper Bound
1	2	-2,137 [*]	,065	,000	-2,320	-1,954
	3	-2,129 [*]	,059	,000	-2,295	-1,962
	4	-,496 [*]	,065	,000	-,680	-,312
	5	-1,851 [*]	,093	,000	-2,114	-1,588
2	1	2,137 [*]	,065	,000	1,954	2,320
	3	,009	,078	1,000	-,212	,229
	4	1,641 [*]	,087	,000	1,396	1,886
	5	,286	,107	,075	-,015	,587
3	1	2,129 [*]	,059	,000	1,962	2,295
	2	-,009	,078	1,000	-,229	,212
	4	1,633 [*]	,085	,000	1,391	1,874
	5	,277	,103	,072	-,012	,567
4	1	-,496 [*]	,065	,000	-,312	,680
	2	-1,641 [*]	,087	,000	-1,886	-1,396
	3	-1,633 [*]	,085	,000	-1,874	-1,391
	5	-1,355 [*]	,097	,000	-1,628	-1,082
5	1	1,851 [*]	,093	,000	1,588	2,114
	2	-,286	,107	,075	-,587	,015
	3	-,277	,103	,072	-,567	,012
	4	1,355 [*]	,097	,000	1,082	1,628

Based on estimated marginal means

*. The mean difference is significant at the ,05 level.

a. Adjustment for multiple comparisons: Bonferroni.

Errors

Effect of Interface

Ranks		Test Statistics ^a	
	Mean Rank		
HHD	2,87	N	740
SW	2,81	Chi-Square	231,677
HMD	3,21	df	4
BodyRef	3,28	Asymp. Sig.	,000
SWRef	2,82		

a. Friedman Test

The p-values in the following table are not Bonferroni corrected. Bonferroni corrected values are p-value*0.1.

Test Statistics ^c										
	SW - HHD	HMD - HHD	BodyRef - HHD	SWRef - HHD	HMD - SW	BodyRef - SW	SWRef - SW	BodyRef - HMD	SWRef - HMD	SWRef - BodyRef
Z	-1,973 ^a	-7,582 ^b	-8,753 ^b	-1,637 ^a	-8,885 ^b	-9,777 ^b	-,337 ^b	-1,652 ^b	-8,624 ^a	-9,606 ^a
Asymp. Sig. (2-tailed)	,049	,000	,000	,102	,000	,000	,736	,099	,000	,000

a. Based on positive ranks.
 b. Based on negative ranks.
 c. Wilcoxon Signed Ranks Test

Effects of Direction and Length

SWOSide: opposite side of smartwatch arm

SWSide: same side as smartwatch arm

Test Statistics ^b		
	Long - Short	SWOSide - SWSide
Z	-,466 ^a	-1,365 ^a
Asymp. Sig. (2-tailed)	,641	,172

a. Based on negative ranks.
 b. Wilcoxon Signed Ranks Test

Subjective Workload

interfaces: 1: HHD, 2:SW, 3: HMD, 4: BodyRef, 5: SWRef

md: mental demand, pd: physical demand, td: temporal demand, p: performance, e: effort, f: frustration, o: overall.

Mauchly's Test of Sphericity ^b								
Within Subjects Effect	Measure	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon ^a		
						Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Interface	md	,156	36,024	9	,000	,855	,757	,250
	pd	,364	19,625	9	,021	,723	,850	,250
	td	,390	18,283	9	,033	,718	,844	,250
	p	,462	14,974	9	,093	,756	,897	,250
	e	,166	34,878	9	,000	,617	,705	,250
	f	,779	4,856	9	,847	,910	1,000	,250
	o	,551	11,588	9	,239	,798	,957	,250

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.
 b. Design: Intercept
 Within Subjects Design: Interface

Univariate Tests

Source	Measure	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power ^a	
Interface	md	Sphericity Assumed	3328,636	4	832,159	7,978	,000	,275	31,913	,997
		Greenhouse-Geisser	3328,636	2,620	1270,627	7,978	,000	,275	20,901	,977
		Huynh-Feldt	3328,636	3,027	1099,733	7,978	,000	,275	24,149	,987
		Lower-bound	3328,636	1,000	3328,636	7,978	,010	,275	7,978	,768
	pd	Sphericity Assumed	8850,909	4	2212,727	8,658	,000	,292	34,630	,999
		Greenhouse-Geisser	8850,909	2,891	3061,878	8,658	,000	,292	25,026	,990
		Huynh-Feldt	8850,909	3,401	2602,226	8,658	,000	,292	29,447	,996
		Lower-bound	8850,909	1,000	8850,909	8,658	,008	,292	8,658	,801
	td	Sphericity Assumed	1435,000	4	358,750	1,852	,127	,081	7,406	,540
		Greenhouse-Geisser	1435,000	2,873	499,464	1,852	,150	,081	5,320	,447
		Huynh-Feldt	1435,000	3,377	424,981	1,852	,139	,081	6,252	,490
		Lower-bound	1435,000	1,000	1435,000	1,852	,188	,081	1,852	,255
	p	Sphericity Assumed	1024,091	4	256,023	1,889	,120	,083	7,555	,550
		Greenhouse-Geisser	1024,091	3,023	338,758	1,889	,140	,083	5,710	,469
		Huynh-Feldt	1024,091	3,588	285,392	1,889	,128	,083	6,778	,517
		Lower-bound	1024,091	1,000	1024,091	1,889	,184	,083	1,889	,259
	e	Sphericity Assumed	5867,273	4	1466,818	6,754	,000	,243	27,016	,991
		Greenhouse-Geisser	5867,273	2,467	2378,273	6,754	,001	,243	16,663	,940
		Huynh-Feldt	5867,273	2,821	2080,128	6,754	,001	,243	19,051	,961
		Lower-bound	5867,273	1,000	5867,273	6,754	,017	,243	6,754	,698
	f	Sphericity Assumed	4266,818	4	1066,705	5,613	,000	,211	22,452	,973
		Greenhouse-Geisser	4266,818	3,642	1171,677	5,613	,001	,211	20,441	,962
		Huynh-Feldt	4266,818	4,000	1066,705	5,613	,000	,211	22,452	,973
		Lower-bound	4266,818	1,000	4266,818	5,613	,027	,211	5,613	,618
	o	Sphericity Assumed	2706,711	4	676,678	8,089	,000	,278	32,357	,998
		Greenhouse-Geisser	2706,711	3,191	848,357	8,089	,000	,278	25,809	,991
		Huynh-Feldt	2706,711	3,829	706,905	8,089	,000	,278	30,973	,997
		Lower-bound	2706,711	1,000	2706,711	8,089	,010	,278	8,089	,774
Error(Interface)	md	Sphericity Assumed	8761,364	84	104,302					
		Greenhouse-Geisser	8761,364	55,013	159,259					
		Huynh-Feldt	8761,364	63,562	137,839					
		Lower-bound	8761,364	21,000	417,208					
	pd	Sphericity Assumed	21469,091	84	255,584					
		Greenhouse-Geisser	21469,091	60,704	353,667					
		Huynh-Feldt	21469,091	71,427	300,574					
		Lower-bound	21469,091	21,000	1022,338					
	td	Sphericity Assumed	16275,000	84	193,750					
		Greenhouse-Geisser	16275,000	60,335	269,745					
		Huynh-Feldt	16275,000	70,909	229,519					
		Lower-bound	16275,000	21,000	775,000					
	p	Sphericity Assumed	11385,909	84	135,547					
		Greenhouse-Geisser	11385,909	63,485	179,349					
		Huynh-Feldt	11385,909	75,356	151,096					
		Lower-bound	11385,909	21,000	542,186					
	e	Sphericity Assumed	18242,727	84	217,175					
		Greenhouse-Geisser	18242,727	51,808	352,124					
		Huynh-Feldt	18242,727	59,233	307,981					
		Lower-bound	18242,727	21,000	868,701					
	f	Sphericity Assumed	15963,182	84	190,038					
		Greenhouse-Geisser	15963,182	76,474	208,739					
		Huynh-Feldt	15963,182	84,000	190,038					
		Lower-bound	15963,182	21,000	760,152					
	o	Sphericity Assumed	7026,822	84	83,653					
		Greenhouse-Geisser	7026,822	67,001	104,876					
		Huynh-Feldt	7026,822	80,408	87,389					
		Lower-bound	7026,822	21,000	334,611					

a. Computed using alpha = ,05

Pairwise Comparisons

Measure	(I) Interface	(J) Interface	Mean Difference (I-J)	Std. Error	Sig. ^a	95% Confidence Interval for Difference ^b		
						Lower Bound	Upper Bound	
md	1	2	-2.727	1.174	.000	-6.407	.952	
		3	-8.409 [*]	2.241	.012	-15.434	-1.384	
		4	-14.318 [*]	3.653	.008	-25.771	-2.866	
		5	-12.300 [*]	3.718	.000	-24.158	-.842	
	2	1	2.727	1.174	.000	.952	6.407	
		3	-5.682	2.262	.003	-12.775	-1.411	
		4	-11.591 [*]	3.075	.011	-21.233	-1.949	
	3	1	8.409 [*]	2.241	.012	1.384	15.434	
		2	5.682	2.262	.003	-1.411	12.775	
		4	-5.909	3.610	1.000	-17.238	5.419	
	4	1	-4.091	3.251	1.000	-14.282	6.101	
		2	14.318 [*]	3.653	.008	2.866	25.771	
		3	11.591 [*]	3.075	.011	1.949	21.233	
		5	5.909	3.610	1.000	-5.419	17.238	
	5	1	18.181 [*]	3.412	.000	11.359	25.003	
		2	12.300 [*]	3.718	.000	4.842	20.358	
		3	9.773	3.079	.087	-1.820	17.366	
		4	4.091	3.251	1.000	-6.101	14.282	
	pd	1	2	-7.045	3.902	.853	-19.278	5.187
			3	-8.182	3.696	.475	-20.366	4.002
4			-25.000 [*]	4.946	.001	-40.505	-9.495	
5			-19.091 [*]	4.690	.005	-30.700	-4.481	
2		1	7.045	3.902	.853	-5.187	19.278	
		3	-1.136	4.901	1.000	-16.502	14.229	
		4	-17.955	6.169	.084	-37.296	1.387	
		5	-12.045	4.995	.249	-27.676	-3.585	
3		1	8.182	3.696	.475	-4.002	20.366	
		2	1.136	4.901	1.000	-14.229	16.502	
		4	-16.818 [*]	4.807	.021	-31.890	-1.746	
		5	-10.909 [*]	2.954	.014	-20.171	-1.647	
4		1	25.000 [*]	4.946	.001	9.495	40.505	
		2	17.955	6.169	.084	-1.387	37.296	
		3	16.818 [*]	4.807	.021	1.746	31.890	
		5	5.909	6.099	1.000	-13.180	25.001	
5		1	19.091 [*]	4.690	.005	4.481	33.700	
		2	12.045	4.995	.249	-3.585	27.676	
		3	10.909 [*]	2.954	.014	1.647	20.171	
		4	-5.909	6.099	1.000	-25.001	13.180	
td	1	2	-7.500	4.274	.908	-20.898	5.898	
		3	-7.045	4.507	1.000	-21.175	7.084	
		4	-10.682	3.908	.130	-23.028	1.665	
		5	-8.636	5.006	1.000	-25.221	8.000	
	2	1	7.500	4.274	.908	-5.898	20.898	
		3	.455	3.905	1.000	-11.789	12.898	
		4	-3.182	3.700	1.000	-14.876	8.512	
		5	-1.136	4.498	1.000	-15.238	12.965	
	3	1	7.045	4.507	1.000	-7.084	21.175	
		2	-.455	3.905	1.000	-12.898	11.789	
		4	-3.636	4.266	1.000	-17.012	9.739	
		5	-1.591	2.381	1.000	-9.056	5.874	
	4	1	10.682	3.908	.130	-1.665	23.028	
		2	3.182	3.700	1.000	-8.512	14.876	
		3	3.636	4.266	1.000	-9.739	17.012	
		5	2.045	4.542	1.000	-12.196	16.287	
	5	1	8.636	5.006	1.000	-9.000	25.273	
		2	1.136	4.498	1.000	-12.965	15.238	
		3	1.591	2.381	1.000	-5.874	9.056	
		4	-2.045	4.542	1.000	-16.287	12.196	
p	1	2	-5.909	2.271	.166	-13.028	1.210	
		3	-8.136	3.988	1.000	-18.639	6.398	
		4	-6.591	3.213	.529	-16.684	3.492	
		5	-9.218 [*]	2.874	.039	-18.327	-.309	
	2	1	5.909	2.271	.166	-1.210	13.028	
		3	-.227	4.180	1.000	-13.334	12.879	
		4	-.682	3.808	1.000	-11.994	10.631	
		5	-3.409	2.358	1.000	-10.800	-3.984	
	3	1	8.136	3.988	1.000	-6.398	18.639	
		2	.227	4.180	1.000	-12.879	13.334	
		4	-.455	4.237	1.000	-13.740	12.831	
		5	-3.182	4.194	1.000	-16.332	9.969	
	4	1	6.591	3.213	.529	-3.492	16.684	
		2	.682	3.808	1.000	-10.631	11.994	
		3	.455	4.237	1.000	-12.831	13.740	
		5	-2.727	3.462	1.000	-13.580	8.126	
	5	1	9.218 [*]	2.874	.039	.309	18.327	
		2	3.409	2.358	1.000	-3.984	10.800	
		3	3.182	4.194	1.000	-9.969	16.332	
		4	2.727	3.462	1.000	-8.126	13.580	
e	1	2	-5.455	2.301	.274	-12.688	1.759	
		3	-6.384	3.000	.460	-15.770	3.043	
		4	-20.455 [*]	5.334	.010	-37.178	-3.731	
		5	-15.000 [*]	4.745	.047	-29.875	-.125	
	2	1	5.455	2.301	.274	-1.759	12.688	
		3	-.909	3.658	1.000	-12.378	10.559	
		4	-15.000	5.602	.141	-32.584	2.584	
		5	-9.545	4.945	.672	-25.048	5.957	
	3	1	6.384	3.000	.460	-3.043	15.770	
		2	.909	3.658	1.000	-10.559	12.378	
		4	-14.091	5.442	.171	-31.152	2.971	
		5	-8.636	3.124	.116	-18.431	-1.158	
	4	1	20.455 [*]	5.334	.010	3.731	37.178	
		2	15.000	5.602	.141	-2.584	32.584	
		3	14.091	5.442	.171	-2.971	31.152	
		5	5.455	4.896	1.000	-9.771	20.680	
	5	1	15.000 [*]	4.745	.047	.125	29.875	
		2	9.545	4.945	.672	-5.957	25.048	
		3	8.636	3.124	.116	-1.158	18.431	
		4	5.455	4.896	1.000	-9.680	9.771	

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.
 *. The mean difference is significant at the .05 level.





Pairwise Comparisons

Measure	(I) Interface	(J) Interface	Mean Difference (I-J)	Std. Error	Sig. ^a	95% Confidence Interval for Difference ^a	
						Lower Bound	Upper Bound
f	1	2	-14,773 [*]	3,473	,004	-25,663	-3,883
		3	-3,409	3,898	1,000	-15,630	8,812
		4	-5,227	3,314	1,000	-15,617	5,163
		5	-15,455 [*]	4,014	,009	-28,041	-2,868
	2	1	14,773 [*]	3,473	,004	3,883	25,663
		3	11,364	4,489	,194	-2,710	25,437
		4	9,545	4,326	,386	-4,017	23,108
		5	-,682	4,113	1,000	-13,576	12,213
	3	1	3,409	3,898	1,000	-8,812	15,630
		2	-11,364	4,489	,194	-25,437	2,710
		4	-1,818	4,565	1,000	-16,130	12,494
		5	-12,045	4,763	,195	-26,980	2,889
	4	1	5,227	3,314	1,000	-5,163	15,617
		2	-9,545	4,326	,386	-23,108	4,017
		3	1,818	4,565	1,000	-12,494	16,130
		5	-10,227	4,370	,292	-23,929	3,474
	5	1	15,455 [*]	4,014	,009	2,868	28,041
		2	,682	4,113	1,000	-12,213	13,576
		3	12,045	4,763	,195	-2,889	26,980
		4	10,227	4,370	,292	-3,474	23,929
o	1	2	-7,106 [*]	2,041	,022	-13,506	-,706
		3	-6,894 [*]	2,159	,044	-13,662	-,126
		4	-13,864 [*]	2,796	,001	-22,629	-5,098
		5	-12,765 [*]	3,284	,009	-23,062	-2,469
	2	1	7,106 [*]	2,041	,022	,706	13,506
		3	,212	2,428	1,000	-7,400	7,824
		4	-6,758	2,755	,230	-15,395	1,880
		5	-5,659	2,951	,688	-14,910	3,592
	3	1	6,894 [*]	2,159	,044	,126	13,662
		2	-,212	2,428	1,000	-7,824	7,400
		4	-6,970	2,946	,277	-16,208	2,268
		5	-5,871	2,470	,270	-13,615	1,872
	4	1	13,864 [*]	2,796	,001	5,098	22,629
		2	6,758	2,755	,230	-1,880	15,395
		3	6,970	2,946	,277	-2,268	16,208
		5	1,098	3,413	1,000	-9,601	11,798
	5	1	12,765 [*]	3,284	,009	2,469	23,062
		2	5,659	2,951	,688	-3,592	14,910
		3	5,871	2,470	,270	-1,872	13,615
		4	-1,098	3,413	1,000	-11,798	9,601

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.
 *. The mean difference is significant at the ,05 level.

User Experience

After Scenario Questionnaire

C1: HHD, C2: SW, C3: HMD, C4: BodyRef, C5: SWRef

Ease of Use

Ranks		Test Statistics ^a	
	Mean Rank		
eC1	3,83	N	23
eC2	3,30	Chi-Square	24,815
eC3	3,17	df	4
eC4	2,65	Asymp. Sig.	,000
eC5	2,04	a. Friedman Test	

The p-values in the following table are not Bonferroni corrected. Bonferroni corrected values are p-value*0.1.

Test Statistics ^b										
	eC2 - eC1	eC3 - eC1	eC4 - eC1	eC5 - eC1	eC3 - eC2	eC4 - eC2	eC5 - eC2	eC4 - eC3	eC5 - eC3	eC5 - eC4
Z	-1,807 ^a	-2,496 ^a	-2,632 ^a	-3,475 ^a	-,263 ^a	-1,412 ^a	-2,630 ^a	-1,313 ^a	-2,979 ^a	-,980 ^a
Asymp. Sig. (2-tailed)	,071	,013	,008	,001	,793	,158	,009	,189	,003	,327

a. Based on positive ranks.
b. Wilcoxon Signed Ranks Test

Satisfaction with Task Completion Time

Ranks		Test Statistics ^a	
	Mean Rank		
tC1	3,78	N	23
tC2	2,74	Chi-Square	11,148
tC3	3,00	df	4
tC4	2,74	Asymp. Sig.	,025
tC5	2,74	a. Friedman Test	

The p-values in the following table are not Bonferroni corrected. Bonferroni corrected values are p-value*0.1.

Test Statistics ^c										
	tC2 - tC1	tC3 - tC1	tC4 - tC1	tC5 - tC1	tC3 - tC2	tC4 - tC2	tC5 - tC2	tC5 - tC3	tC5 - tC4	tC4 - tC3
Z	-2,694 ^a	-2,066 ^a	-2,351 ^a	-2,673 ^a	-1,469 ^b	-,964 ^b	-,182 ^b	-1,591 ^a	-,854 ^a	-,893 ^a
Asymp. Sig. (2-tailed)	,007	,039	,019	,008	,142	,335	,856	,112	,393	,372

a. Based on positive ranks.
b. Based on negative ranks.
c. Wilcoxon Signed Ranks Test

Satisfaction with System Support

Ranks		Test Statistics ^a	
	Mean Rank		
sC1	3,96	N	23
sC2	2,37	Chi-Square	24,270
sC3	3,54	df	4
sC4	2,83	Asymp. Sig.	,000
sC5	2,30	a. Friedman Test	

The p-values in the following table are not Bonferroni corrected. Bonferroni corrected values are p-value*0.1.

Test Statistics^c

	sC2 - sC1	sC3 - sC1	sC4 - sC1	sC5 - sC1	sC3 - sC2	sC4 - sC2	sC5 - sC2	sC4 - sC3	sC5 - sC3	sC5 - sC4
Z	-3,036 ^a	-1,284 ^a	-2,230 ^a	-3,237 ^a	-2,477 ^b	-1,059 ^b	-,351 ^a	-1,575 ^a	-3,206 ^a	-1,229 ^a
Asymp. Sig. (2-tailed)	,002	,199	,026	,001	,013	,289	,726	,115	,001	,219

- a. Based on positive ranks.
- b. Based on negative ranks.
- c. Wilcoxon Signed Ranks Test

Pragmatic Quality (PQ) and Hedonic Quality Stimulation (HQS)

interfaces: 1: HDD, 2:SW, 3: HMD, 4: BodyRef, 5: SWRef

Mauchly's Test of Sphericity^b

Within Subjects Effect	Measure	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon ^a		
						Greenhouse-Geisser	Huynh-Feldt	Lower-bound
interface	PQ	,336	22,271	9	,008	,690	,798	,250
	HQS	,553	12,110	9	,209	,803	,957	,250

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

- a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.
- b. Design: Intercept
- Within Subjects Design: interface

Univariate Tests

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power ^a
interface	PQ	Sphericity Assumed	3,149	4	,787	5,792	,000	,208	23,170	,977
		Greenhouse-Geisser	3,149	2,759	1,142	5,792	,002	,208	15,980	,924
		Huynh-Feldt	3,149	3,194	,986	5,792	,001	,208	18,500	,950
		Lower-bound	3,149	1,000	3,149	5,792	,025	,208	5,792	,633
	HQS	Sphericity Assumed	41,130	4	10,282	48,454	,000	,688	193,817	1,000
		Greenhouse-Geisser	41,130	3,213	12,801	48,454	,000	,688	155,686	1,000
		Huynh-Feldt	41,130	3,827	10,747	48,454	,000	,688	185,441	1,000
		Lower-bound	41,130	1,000	41,130	48,454	,000	,688	48,454	1,000
Error(interface)	PQ	Sphericity Assumed	11,961	88	,136					
		Greenhouse-Geisser	11,961	60,693	,197					
		Huynh-Feldt	11,961	70,263	,170					
		Lower-bound	11,961	22,000	,544					
	HQS	Sphericity Assumed	18,674	88	,212					
		Greenhouse-Geisser	18,674	70,687	,264					
		Huynh-Feldt	18,674	84,197	,222					
		Lower-bound	18,674	22,000	,849					

- a. Computed using alpha = ,05

Pairwise Comparisons

Measure	(I) interface	(J) interface	Mean Difference (I-J)	Std. Error	Sig. ^a	95% Confidence Interval for Difference ^a	
						Lower Bound	Upper Bound
PQ	1	2	,161	,081	,601	-,093	,416
		3	,205	,071	,087	-,017	,427
		4	,335*	,106	,047	,003	,668
		5	,491*	,127	,008	,096	,886
	2	1	-,161	,081	,601	-,416	,093
		3	,043	,105	1,000	-,285	,372
		4	,174	,136	1,000	-,251	,599
		5	,329	,136	,242	-,095	,753
	3	1	-,205	,071	,087	-,427	,017
		2	-,043	,105	1,000	-,372	,285
		4	,130	,078	1,000	-,112	,373
		5	,286	,109	,152	-,053	,624
	4	1	-,335*	,106	,047	-,668	-,003
		2	-,174	,136	1,000	-,599	,251
		3	-,130	,078	1,000	-,373	,112
		5	,155	,115	1,000	-,202	,513
	5	1	-,491*	,127	,008	-,886	-,096
		2	-,329	,136	,242	-,753	,095
		3	-,286	,109	,152	-,624	,053
		4	-,155	,115	1,000	-,513	,202
HQS	1	2	-,174	,095	,796	-,469	,121
		3	-1,186*	,133	,000	-1,601	-,771
		4	-1,429*	,119	,000	-1,799	-1,058
		5	-1,261*	,133	,000	-1,676	-,846
	2	1	,174	,095	,796	-,121	,469
		3	-1,012*	,173	,000	-1,553	-,472
		4	-1,255*	,133	,000	-1,669	-,840
		5	-1,087*	,148	,000	-1,547	-,627
	3	1	1,186*	,133	,000	,771	1,601
		2	1,012*	,173	,000	,472	1,553
		4	-,242	,139	,946	-,675	,190
		5	-,075	,147	1,000	-,534	,385
	4	1	1,429*	,119	,000	1,058	1,799
		2	1,255*	,133	,000	,840	1,669
		3	,242	,139	,946	-,190	,675
		5	,168	,125	1,000	-,223	,559
	5	1	1,261*	,133	,000	,846	1,676
		2	1,087*	,148	,000	,627	1,547
		3	,075	,147	1,000	-,385	,534
		4	-,168	,125	1,000	-,559	,223

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.
*. The mean difference is significant at the ,05 level.

Preference

Ranks

	Mean Rank
PrefSelHHD	2,00
PrefSelSW	3,89
PrefSelHMD	2,78
PrefSelSWRef	3,09
PrefSelBodyRef	3,24

Test Statistics^a

N	23
Chi-Square	17,577
df	4
Asymp. Sig.	,001

a. Friedman Test

The p-values in the following table are not Bonferroni corrected. Bonferroni corrected values are p-value*0.1.

Test Statistics^c

	PrefSelSW - PrefSelHHD	PrefSelHMD - PrefSelHHD	PrefSelSWRef - PrefSelHHD	PrefSelBody Ref - PrefSelHHD	PrefSelHMD - PrefSelSW	PrefSelSWRef - PrefSelSW	PrefSelBody Ref - PrefSelS W	PrefSelSWRef - PrefSelHMD	PrefSelBody Ref - PrefSelHMD	PrefSelBody Ref - PrefSelSWRef
Z	-4,145 ^a	-1,476 ^a	-2,291 ^a	-2,408 ^a	-2,178 ^b	-1,513 ^b	-1,393 ^b	-,632 ^a	-,925 ^a	-,309 ^a
Asymp. Sig. (2-tailed)	,000	,140	,022	,016	,029	,130	,163	,527	,355	,758

- a. Based on negative ranks.
- b. Based on positive ranks.
- c. Wilcoxon Signed Ranks Test