Supportive home health care technology for older adults: Attitudes and implementation

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Healthcare delivered at home via telehealth technology may save on both individual and societal healthcare costs. Three studies investigated potential attitudinal barriers to home healthcare adoption. Results from the first concerning adults' privacy concerns and mobile device preferences showed that attitudes clustered into 4 factors and that older adults, particularly males, showed less concern than younger adults about privacy. The second and third studies explored comfort with a wearable device and the role of aesthetics over 2-week and 6-month intervals. Results showed that older adults had stable ratings for comfort while wearing a watch device designed to collect data in real time and that aspects of physical comfort predicted use over a six-month time period. Taken together, the studies provide evidence that attitudes about privacy and comfort for wearable health devices are unlikely to be significant barriers to adoption, though first impressions are important for all age groups.

Keywords: home health monitoring, telehealth, attitudes, aging in place, privacy

Many countries face the challenge of managing an aging population with a high prevalence of chronic disease. Chronic disease conditions in the US currently account for 86% of all healthcare expenditures[1]. The long-term trend of constantly increasing healthcare costs potentially jeopardizes other social support needs. Recent data from the US indicate that 86% of adults aged 65 or older suffer from one or more chronic health conditions[2], including hypertension, coronary heart disease, stroke, diabetes, cancer, arthritis, hepatitis, weak or failing kidneys, asthma and chronic obstructive pulmonary disease. Chronic conditions need to be monitored carefully to prevent complications from developing. For instance, very low or very high blood sugar can lead to diabetic coma. Thus, chronic disease can interfere with aging in place if additional health problems develop resulting in transfer to a facility where symptoms are managed by healthcare professionals[3].

Healthcare to support chronic conditions, given the expense associated with providing it in hospital settings (*Figure 1*), will inevitably migrate into the home as health monitoring technology improves. Telehealth, the remote provision of healthcare services and education by means of information and communications technology[4], can play an important role in this transition process.

The topic of this special edition is 'Suitable and Healthy Housing' and the focus of this paper is to discuss the barriers and challenges that exist for older adults, particularly willingness to use telehealth devices that can support aging in place.

Home health monitoring strategies

The role of in-home health monitoring is evolving in terms of the roles of the human (patient and provider) and technology (hardware and software) components. Until recently, healthcare has been seen as a partnership between a patient and a primary care provider, though technology is increasingly involved and both human and technology components can be part of a system that promotes safety by reducing the onset of preventable chronic health problems and emergencies[5]. Telehealth systems can be characterized, from the point of view of the human user as a mix of passive (implanted or worn sensors) and active components[6,7]. Common active devices are blood pressure cuffs and weight scales that require the patient to actively engage in self-monitoring. Each device transmits data from the residence to an offsite database. Data can be automatically analyzed to set alerts when parameters move out of range, and also viewed by a primary care provider[6,8-10].

The first partner, the patient who has agreed to take the readings regularly, provides data to the second partner, a primary care provider, who can look for trends that require attention and recommend in-person, telephonic, or virtual visits and change the treatment regimen prior to worsening symptoms.

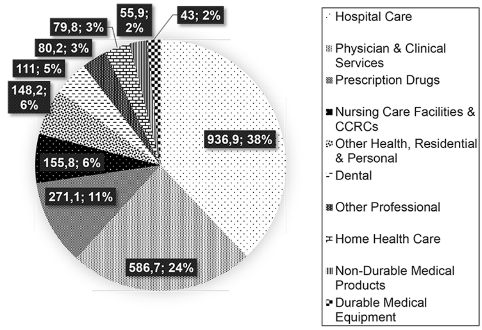

Figure 1. US healthcare expenditures in 2013 in billions of US dollars and percentages by sector. hospital care (38%) and physician & clinical services (24%) comprise over 60% of the total[29]

Barriers to adoption

Despite recent advances in technology supporting independence, older adults may be reluctant to adopt, and can be non-adherent using the active devices described above[8]. Elders often have difficulty taking medicines as prescribed[11] even with technology support. There are potential barriers to adoption that may explain the reluctance: concerns about data privacy and how well the wearable system components appear, feel, and function over time.

Prior work on privacy concerns[12-14] found that older adults were indeed concerned about data privacy, though they expressed a willingness to use remote monitoring and share data with healthcare professionals if it could identify emerging health problems or detect emergencies. These results fit well with the 'perceived usefulness' construct of the Technology Acceptance Model (TAM) posited by Davis[15] and the successor models such as UTAUT2[16]. While it is possible that older adults will use monitoring technology if privacy criteria are met, privacy concerns and attitudes found in previous work need to be addressed in addition to perceived usefulness and perceived ease of use.

Wearable monitors are designed to appear as an accessory (i.e., wristwatch or necklace) to clothing so there are other important considerations. Davis and colleagues[17] updated TAM to TAM2 when they found that social influences such as norms (people important to the user believe the device should be used) and image (use of an innovation enhances social status) were important factors for perceived usefulness. A reasonable prediction is that a wearable monitor that appears to be an assistive device is unlikely to be recommended by friends, may make someone self-conscious, so will probably not be worn. Designing for aesthetics presents a challenge to designers of wearable monitors. Recent evidence from persons with Parkinson's disease who wore two (one on each wrist) wristwatch monitors for one week that were designed to detect the changes in tremors associated with the disease shows that they wore the devices in public[18]. Successful commercial devices, such as the Fitbit (™) watch-type device designed to collect fitness data, seem to have also been able to combine form with function, enhancing one's social image.

In addition to social acceptability, physical comfort is also important. Devices that are painful to wear or feel heavy are unlikely to be worn. Comfort is particularly important for devices expected to be worn continuously for an extended period of time as any small irritant that may go unnoticed for a short period will likely become very noticeable after days or weeks. As Knight and Baber[19] noted, comfort is a multidimensional construct. These researchers developed the Comfort Rating Scale (CRS) that measures wearable device comfort on dimensions such as being securely attached, causing pain, causing harm or restricting movement, and generating feelings of social awkwardness or anxiety. Comfort measured on multiple indices can be as important for adoption as the user interface, but can often be overlooked by designers.

Hence, the goal of this project was to replicate work on the comfort of wearable monitors assessing dimensions for comfort and to extend the findings in two important ways: (i) to provide an update on elders' concerns for data privacy that Wild and colleagues[12] indicated was of less importance than expected, and (ii) to ask participants to wear a monitor for longer periods of time (2 weeks and 6 months) while assessing comfort and acceptability of the device.

Study 1

A questionnaire-based study was conducted to investigate age differences in preferences related to the collection, management, and dissemination of health data collected by mobile health-monitoring technologies.

Methods

Participants

30 Younger adult (20 female, 10 male, age M=19.8, SD=1.45), 27 middle aged adults (15 female, 12 male, age M=56.1, SD=7.56), and 35 older adults (23 female, 12 male, age M=75.7, SD=6.35) participated in the questionnaire-based study. Young adult participants were recruited from Florida State University psychology classes and compensated for participation with course credit. Middle and older adults were re-

cruited from the Tallahassee, FL metro area and compensated US$10 for their participation.

Materials and procedure

All participants were asked to complete two paper-based questionnaire measures, created for this study at Florida State University, addressing personal preferences related to a hypothetical wrist-worn health monitoring device. The first questionnaire, the Physiological Monitoring Privacy Scale (PMPS), consisted of 15 items measuring preferences related to privacy and accessibility of data collected by the device (e.g., I would want to be able to control which information is being sent to others). The second measure, the Mobile Device Feedback Preferences Scale (MDFPS), consisted of 17 items used to gauge individual preferences related to device functionality, design, and communication of information to the user (e.g., I would want to have health-related information displayed on the device). Responses for both scales were provided on a 7-point Likert scale ranging from 'Disagree' to 'Agree'. Additionally, an image of a wrist-worn health monitoring device was presented at the top of each scale.

Results and conclusions

The questionnaire items from both measures were first analyzed at a scale level. Individual items were reverse scored as needed so higher scores indicated positive ratings of comfort and acceptance of privacy issues (PMPS) and positive ratings for device feedback preferences (MDFPS). Overall scale values were calculated using the mean of all items in each scale.

A multiple regression model was used to determine the predictive power of age and gender for scores on each scale. While the total sample contained a higher number of females (n=58) than males (n=34), the gender disparity was evenly distributed across age groups ($X^2(2,n=92)=0.93$, $p=0.63$). When controlling for gender, increasing age significantly predicted higher scores in the PMPS (Beta=0.21, t=2.01, p=0.047). No relationship was found between age and the MDFPS.

The results were further analyzed by introducing the interaction term between age and gender into the regression models. A significant relationship was found between the age and gender interaction term and scores on the PMPS (Beta=0.28, t=2.24, p=0.028), accounting for all of the variance explained by age in the first model. The interaction revealed that male participants accounted for the relationship between age and the PMPS ($R^2=0.22$, Beta=0.47, t=3.02, p=0.005), with no significant age differences in PMPS scores in female participants. A significant relationship was also found between the age and gender interaction term and scores on the MDFPS (Beta=0.33, t=2.61, p=0.011). Again, the significant interaction term was caused by a positive relationship between age and MDFPS scores in male participants ($R^2=0.20$, Beta=0.45, t=2.81, p=0.008), with no significant age differences in MDFPS scores in female participants.

Due to conceptual overlap in some items (e.g., who has access to private information in the PMPS and whether that information is displayed in the MDFPS), the two scales were combined and an exploratory factor analysis was conducted using principal components extraction and varimax rotation to assess underlying factors. Following an analysis of the scree plot of the Eigenvalues, it was determined that four main factors with sufficient loading from 27 of the 32 items best described the data set. In order of descending Eigenvalues, these factors were given the titles 'Factor 1: Collection and accessibility of health information - Family and medical professionals' (25.3% of variance), 'Factor 2: Leakage of health information to unauthorized recipients' (9.5% of variance), 'Factor 3: Device functionality and display' (8.0% of variance), and 'Factor 4: Accessibility of health information - Government and insurance' (6.5% of variance). Items from the MDFPS were represented across all four factors, while items from the PMPS were represented in three of the four factors (Factors 1, 2, and 3; *Table 1*).

Factor scores were then entered into a regression model including age and gender as predictors. Controlling for gender, age did not significantly predict scores on Factor 1 or Factor 3. This model predicted a small but significant portion of the variance in Factors 2 ($R^2=0.09$, $F(2,87)=4.23$, p=0.018) and 4 ($R^2=0.10$, $F(2,87)=4.90$, p=0.010). Controlling for gender, increased age was found to significantly predict larger Factor 2 scores (Beta=0.25, t=2.48, p=0.015), indicating a reduced concern that health information would be leaked to unintended recipients, and larger Factor 4 scores (Beta=0.32, t=3.13, p=0.002), indicating a higher level of comfort with health information being accessible by government and insurance institutions. The addition of the interaction term did not significantly improve model fit for any of the regression models.

Though further research is necessary to validate the novel measures used in Study 1, the results support previous findings that older adults are generally less concerned than younger cohorts about privacy related to information[20] and specifically health information[21]. In our sample, increased age significantly predicted higher scores on the PMPS, indicating greater comfort with

Table 1. Means, standard deviations (SD), and factor loadings for the Mobile Device Feedback Preferences Scale (MDFPS) and Physiological Monitoring Privacy Scale (PMPS);(r)=reverse scored item; Listed factor loadings are Varimax rotated; Factor 1=Collection and accessibility of health Information: Family and medical professionals; Factor 2=Leakage of health information to unauthorized recipients; Factor 3=Device functionality and display; Factor 4=Accessibility of health information: Government and insurance

Item	Mean±SD	Factor loading			
		1	2	3	4
Mobile Device Feedback Preferences Scale					
I would want to have health-related information displayed on the device	5.62±1.75	0.229	0.197	**0.706**	-0.092
I would prefer that the device not display health-related information but send this information to appropriate people	3.35±2.17	0.219	**-0.461**	-0.324	0.459
If the device displayed health-related information, I would like this information to be displayed digitally, for instance, as a number showing my blood pressure	6.07±1.41	0.285	-0.042	**0.600**	-0.077
Having health-related information displayed on the device would not be useful to me (r)	5.40±1.85	0.301	0.039	**0.609**	-0.006
If the device displayed health-related information, I would like for the device to signal my caregivers or healthcare professional when it detects that I have a problem (e.g., a health emergency)	5.98±1.75	**0.686**	-0.031	0.201	0.143
If the device displayed health-related information, I would prefer it to show information updated periodically, every hour or so, rather than continuously	4.24±2.11	-0.096	-0.141	-0.051	**0.446**
I would like the device to coach me about my health by sending me messages	4.77±2.04	0.338	-0.039	**0.516**	0.305
I would like the device to speak to me in addition to displaying information visually	3.39±2.31	-0.021	0.097	**0.680**	0.328
I would like the device to remind me about appointments or medication schedules	5.64±1.84	**0.574**	-0.360	0.470	0.024
I would like the device to interact with my computer system or smartphone	4.90±2.30	0.305	0.036	**0.429**	-0.258
I would like the device to charge itself automatically (e.g. solar cell)	6.05±1.62	-0.345	0.045	**0.473**	0.048
I would like the device to keep relevant health information internally so that others could access health information such as allergies, blood type, in an emergency	6.20±1.37	**0.633**	-0.084	0.388	0.051
I would like the device to restrict others from seeing the information on the device while I am viewing it (for instance, by using a polarizing filter) (r)	2.45±1.72	0.092	**0.530**	0.016	0.103
Physiological Monitoring Privacy Scale					
I would be comfortable knowing that the device shown in the photo is continuously collecting information about my physical health	5.97±1.55	**0.636**	0.298	0.312	-0.027
I would be comfortable with a trusted nurse or physician having access to this information	6.16±1.34	**0.770**	0.182	0.063	0.003
I would be comfortable with family members having access to this information	5.25±1.95	**0.550**	0.276	-0.011	0.294
I would be worried that this information could get into the wrong hands (r)	3.80±2.12	0.283	**0.675**	0.060	-0.149
I would consider the device an invasion of my privacy (r)	5.34±1.87	**0.568**	0.285	0.214	-0.204
I would be comfortable with designated family members having access to this information	6.05±1.53	**0.590**	0.017	0.185	0.225
I would be comfortable with insurance companies having access to this information	2.45±1.83	0.230	0.118	0.014	**0.681**

Table 1. (Continued)

Item	Mean±SD	Factor loading			
		1	2	3	4
I would be comfortable with the government having access to this information	2.41±1.90	0.111	0.452	0.199	**0.662**
I would be comfortable with this information being permanently available	3.06±2.24	0.289	0.228	0.133	**0.619**
I would be comfortable with this information being stored in a medical office or clinic	5.08±1.94	**0.711**	0.223	-0.014	0.245
I would be comfortable with this information being stored in my home	5.45±1.80	**0.461**	0.375	0.071	0.018
I would be worried that I might lose the watch and my information might become available to strangers (r)	3.62±2.10	0.090	**0.757**	0.017	-0.171
I would want to be able to control which information is being sent to others (r)	1.86±1.49	-0.041	**0.578**	0.101	0.285
Messages on the watch should only be visible for me (r)	2.84±2.01	0.140	**0.620**	-0.056	0.211

privacy-related issues pertaining to a health monitoring device. More specifically, increasing age significantly predicted higher scores in a factor measuring comfort with government and insurance agencies having access to health information and lower scores in a factor measuring concerns related to unauthorized access to personal health information collected by the monitoring device. An interaction of age and gender was found at the measure level, with older males indicating a higher level of comfort related to privacy than younger males. This interaction effect was not found at the factor level, indicating that the smaller number of males in the sample may have skewed the gender effects. Overall, privacy concerns are unlikely to act as a specific barrier for the adoption of health monitoring technologies in older adults as long as privacy is protected to the satisfaction of the general population.

Study 2

Using a separate sample, we also investigated age differences in comfort and aesthetics ratings related to a prototype wrist-worn health monitoring device, developed by AFrame Digital[6], closely resembling a digital watch. We investigated whether aesthetic concerns or discomfort related to the wearing of health-monitoring devices would discourage their use regardless of the potential benefits offered by the device.

Methods

Participants

26 Younger adults (15 female, 11 male, age M=20.8, SD=3.51), 25 middle (20 female, 5 male, age M=58.0, SD=3.43) and 31 older adults (22 female, 9 male, age M=71.7, SD=5.36) participated and completed the study over two sessions separated by two weeks. The initial lab session lasted approximately 30 minutes, where participants were assigned a device and introduced to the phone-based data collection system. The watch was returned to the experimenters in the second session. Young adults were recruited from Florida State University undergraduate psychology courses and received course credit for their participation. Middle and older adults were recruited from the Tallahassee, FL metro area and received US$30 in compensation for their participation.

Materials and procedure

Data on comfort and aesthetic ratings were collected using a modified Comfort Rating Scale[19], adapted to include a number of aesthetics-related items. The adapted scale comprised 12 individual items (*Table 2*) scored on a 7-point Likert-scale, ranging from 1 (Disagree) to 7 (Agree).

Participants were asked to wear a non-functional prototype of a wrist-worn health monitoring device equipped with a colored plastic watch-like casing and an adjustable, rubber wrist-strap for two weeks, removing it only if it was going to be immersed in water. The CRS ratings were collected daily using a telephone-based survey with automated prompts answered with a telephone's numeric keypad.

In an initial in-lab session, participants were introduced to the study, assigned the device, and trained how to use the Precision Polling call-in system. Over the course of two weeks, the participants wore the watch and were instructed to call Precision Polling daily to complete the adapted CRS. If participants did not call in two days in a row, they were contacted by phone reminding them to participate. After 14 days, the participants came back to the lab to return the watch and receive final compensation.

Table 2. Factor analysis for watch comfort scale; Listed factor loadings are Varimax rotated; Factor 1=Negative affect, Factor 2= Aesthetics, Factor 3=Positive affect

Item	Study 2, Factor			Study 3, Factor		
	1	2	3	1	2	3
I am worried about how I look when I am wearing the device	0.135	**0.757**	0.022	0.139	**0.930**	0.025
The device feels securely attached to my body (r)	0.186	-0.425	**0.628**	0.080	0.020	**0.713**
The device in painful to wear	**0.555**	-0.093	0.373	**0.706**	0.028	0.364
Wearing the device makes me feel strange	0.402	**0.734**	0.065	0.268	**0.844**	0.271
The device inhibits or restricts my movement	**0.717**	0.302	0.040	**0.606**	**0.543**	0.017
I feel secure when wearing the device (r)	-0.188	0.335	**0.760**	0.075	0.119	**0.724**
The device feels abrasive or irritating to my skin	**0.771**	0.221	0.208	**0.809**	0.413	0.143
The device is unpleasantly warm	**0.843**	0.087	0.012	**0.617**	0.257	0.337
The device is unpleasantly cold	**0.774**	0.089	0.030	**0.898**	0.045	-0.109
The device feels heavy	**0.509**	0.410	0.058	**0.637**	0.132	0.225
The device is as comfortable to wear as a watch (r)	0.279	0.068	**0.683**	**0.603**	0.235	**0.533**
The device is too tight on my wrist	**0.483**	0.308	0.153	**0.728**	0.309	0.005

Results and conclusions

Data from the Day 1 adapted CRS responses were entered into an exploratory factor analysis using principal components extraction and Varimax rotation (*Table 2*: individual factor loading). Three factors emerged from the data set, entitled as 'Factor 1: Negative affect' (35.8% of variance), 'Factor 2: Aesthetics' (12.7% of variance), and 'Factor 3: Positive affect' (10.1% of variance). For the purposes of this study, the titles positive and negative affect are interpreted in terms of the Positive and Negative Affect Schedule (PANAS)[22], where they are two distinct, but moderately negatively correlated, factors[23]. These factor loadings were used to compute mean time 1 and time 2 composite scores for each of the three factors at the beginning and end of the study. Due to study adherence issues resulting in missing data clustered towards the end of the study, time 2 factor values were calculated at Day 10, to retain as much data as possible while having the largest possible temporal separation from Day 1. The final sample included in the analyses contained 73 participants including 22 younger adults (age M=21.1, SD=3.73), 23 middle aged adults (age M=58.0, SD=3.37), and 28 older adults (age M=71.5, SD=5.45).

Composite factor scores were created by calculating the mean of questionnaire items primarily loading on each of the three factors (*Table 2*). Time 1 scores were significantly correlated with Time 2 scores for each of the three factors (Negative affect, r=0.61, p<0.001; Aesthetics, r=0.57, p<0.001; Positive affect, r=0.26, p=0.026). A repeated measures MANOVA compared the effect of time on factor scores between age groups finding an overall significant effect of time (Wilks' Lambda=0.88, F(3,68)=3.09, p=0.033, η_p^2=0.120) and interaction of time and age group (Wilks' Lambda=0.77, F(6,138)=3.09, p=0.007, η_p^2=0.120). Univariate tests revealed that the overall time effect was driven by a significant difference in the positive affect factor F(1,70)=9.20, p=0.003, η_p^2=0.116) while the interaction effect was driven by the negative affect factor (F(2,70)=7.35, p=0.001, η_p^2=0.174). Individual contrast analyses for positive affect (*Table 3*) revealed a significant decrease in mean factor score between Time 1 and 2 in younger adults (ΔM=-0.83, p=0.026). The age group by factor score interaction in negative affect was attributed to a significant increase in younger adults (ΔM=0.63, p<0.001).

Table 3. Repeated measures MANOVA contrast analyses, mean difference in factor scores between time of measurement by age group; *=p<0.05

Factor	**Mean±SD**		**Δ Mean±*SE***	**p**
	Time 1	**Time 2**		
Negative affect				
Young	1.95±0.88	2.63±1.34	0.68±0.20	0.001*
Middle	2.22±0.90	2.42±1.22	0.20±0.19	0.327
Old	2.52±1.32	2.18±1.05	-0.34±0.18	0.060
Positive affect				
Young	5.36±0.88	4.53±1.69	-0.83±0.37	0.026*
Middle	5.07±1.40	4.41±1.62	-0.66±0.36	0.068
Old	4.96±1.17	4.62±1.54	-0.34±0.33	0.293
Aesthetics				
Young	4.52±1.69	4.61±2.11	0.09±0.34	0.792
Middle	5.61±1.47	4.98±1.74	-0.63±0.34	0.065
Old	5.16±1.77	5.41±1.71	0.25±0.31	0.415

Overall, first impressions acted as strong predictors for overall attitudes towards the wrist-worn health monitoring device, showing significant correlations between Time 1 and Time 2 measurements for all three factors: negative affect, positive affect, and aesthetics. Further analysis at the age group level revealed some significant relationships between age and factor ratings. Across the study period, a decrease in positive affect was found for younger adults, but not in the middle or older adult sample. Following the same trend of more negative attitudes towards the device, negative affect was also found to increase in younger adults. Middle-aged and older adults did not follow this trend. For middle-aged and older adults, as long as first impressions related to the comfort and aesthetics of a health monitoring device are acceptable, they are likely to adopt and continuously use the device. In the next study we examine longer-term use of telehealth technology with both a normal adult and clinical (heart failure) population, addressing weaknesses such as inability to monitor watch-wearing compliance, and norms of politeness that may dissipate when people experience serious health problems.

Study 3

Materials and procedures

Older persons with and without Heart Failure (HF) were asked to wear a working model of the watch device used in Study 2 for a period of six months as part of a larger randomized field trial[24]. Responses for the modified version of the CRS[19] were recorded at the initial session and after six months. The adapted scale items were identical to those used in Study 2, but were scored on a 5-point Likert-scale, ranging from 1 (Strongly Agree) to 5 (Strongly Disagree). Equivalent to Study 2, responses were reverse coded as necessary to result in higher numbers indicating greater agreement.

The watch device collected and automatically stored skin temperature, ambient light conditions using built-in sensors, and motion data using built-in accelerometers. The watch needed to be re-charged periodically so each user was provided with two watch devices so that one could be worn while the other was charging. The device interface consisted of a simulated analog clock, battery indicator, wireless connection status bars, and the date which were all updated automatically from the central computer using the wireless connection (*Figure 2*).

Participants

41 Older adults (22 female, 19 male, aged 53 to 92 years [M=71.8, SD=8.8]) were recruited for this study, including 14 persons with HF. Persons

Figure 2. The watch device user interface (in storage mode) as used in study 3

with and without HF were recruited through local hospitals and advertisements. Those with HF had their diagnosis verified either by providers (if recruited through hospitals) or by a registered nurse who reviewed their health histories and medication regimens during a clinical interview (if recruited through advertisements). Enrolled participants were compensated US$15 a week for using the system. Here we focus solely on reporting data on comfort ratings given at enrollment and after 6 months.

Results

An exploratory factor analysis was completed on the 12-items of the CRS for this sample using principal components analysis. The Varimax-rotated results revealed the same three components found in study 2 (negative affect, aesthetics, and positive affect) that accounted for 30.4, 20.2, and 14.9 percent of the variance, respectively (*Table 2*). The small sample size limits the number of predictors that can be reasonably analyzed. Gender failed to reach significance and subsequent analyses were collapsed across gender. Additional analyses indicated that HF and age were related to the CRS ratings so they were retained.

A repeated measures MANCOVA was conducted to assess the change over time on the CRS subscales, with HF status as the between groups variable and age included as a covariate. Neither age nor HF significantly interacted over time on any of the CRS subscales. The main effects of time and HF also failed to reach significance. Age ($F(3,21)=3.97$, $p=0.022$, $\eta^2=0.36$) had a significant main effect. Planned follow up tests for age on the positive affect, negative affect, and aesthetics subscales were not significant. Planned comparisons for the HF groups showed that positive affect ($F(1,23)=4.79$, $p=0.039$, $\eta^2=0.17$) was higher for individuals with HF while the negative affect and aesthetics subscales showed no differences (*Table 4*). These results suggest that a chronic

*Table 4. Study 3 means and standard deviations (SD) for factor scores and average device adherence time by heart failure (HF) group adjusted for age; *Participants were instructed to wear the device continuously for 180 days; the percentage of time the device was actually worn over the study period is indicated, excluding extended periods of time spent away from the home*

Factor	HF, Mean±SD		non-HF, Mean±SD	
	Time 1	Time 2	Time 1	Time 2
Negative affect	3.86±0.88)	3.59±0.65	3.83±0.77	3.74±0.84
Positive affect	3.87±0.88)	4.03±0.43	3.33±0.68	3.35±0.72
Aesthetics	4.35±0.88)	4.20±0.79	3.84±0.98	4.12±1.00
Device adherence*	-	77.64±14.57	-	83.37±19.11

condition was related to more positive affect, but in general the ratings were stable over the course of six months and did not change with age.

To provide better effect sizes and estimate the impact on actual use all variables, shown in *Table 5*, were z-scored (standardized) prior to a regression analyses. Two regression equations (subscales for Time 1 and Time 2 CRS ratings) predicted percentage of time the watch was worn (recorded skin temperatures above 24.4°C generally indicate the watch was being worn[24]), excluding times when the network was down or participants were away, by HF, age, and CRS ratings. The benchmark of 24.4°C was decided upon after extensive testing from the biomedical engineers who designed the FDA-cleared watch device. Participants wore the device as they would a normal watch so there was not an airtight seal between the watch and the participant's skin, meaning that temperatures could reflect combinations of skin and ambient conditions that varied indoors and outdoors during winter and summer months. The CRS ratings at Time 1 did not predict watch wearing. The negative affect scale at Time 2 was a significant predictor of watch wearing behavior (beta=0.7, p=0.028) over and above gender, age, HF, and the other CRS subscales (*Table 5*). For this analysis, the negative affect score was reversed meaning that participants disagreeing that the watch was uncomfortable, heavy, abrasive, or tight were more likely to wear the device.

*Table 5. Regression summary for Time 1 and 2 variables predicting watch wearing at six months; All variables are z-scored; B1=unstandardized coefficient; SEB=standard error for B1; B2=standardized coefficient; HF=Heart failure; *=p<0.05*

Variable	B1	SEB	B2
Time 1			
Age	0.00	0.51	0.00
Heart failure (1=HF)	0.02	0.23	0.02
Negative affect	0.52	0.51	0.30
Positive affect	-0.43	0.37	-0.30
Aesthetics	-0.08	0.41	-0.05
Time 2			
Age	0.06	0.24	0.05
Heart failure (1=HF)	0.00	0.19	0.00
Negative affect	1.07	0.46	0.70*
Positive affect	-0.64	0.42	-0.40
Aesthetics	-0.35	0.31	-0.25

The structure of the CRS rating was verified for study 3 and the CRS ratings were stable over time and did not vary as a function of age or a chronic health condition. The trends on the CRS subscales were similar to those found in study 2 with older adults increasing in positive and decreasing in negative affect over time and aesthetics remaining stable. More important is that although those with HF reported higher positive affect on the CRS, only negative affect was predictive for actual watch wearing behavior over and above the presence of a known health condition or advancing age and those older adults in both groups reported less negative attitudes over time. This result is promising for the adoption of health technology as the longer the device felt comfortable the more likely it was to be worn, thereby sending vital health information to healthcare providers.

Summary

These studies show some similarities to prior ones, but also some important differences. Study 1 indicated that gender may be a moderator of privacy attitudes toward monitoring devices across the lifespan. Older males indicated greater comfort with privacy related issues compared to younger and middle-aged males and all females. There were no age or cohort trends discovered in females. Given the small unrepresentative samples, this pattern of age and gender differences needs to be replicated. However, on the whole, privacy concerns are not necessarily a strong barrier to adoption and tend to be lower in older cohorts. Privacy concerns, assessed by the MDFPS and PMPS, appear to cluster into 4 categories, representing accessibility to health care professionals, unauthorized disclosure, functionality of the device, and accessibility to government and insurance. This clustering supports the earlier finding of a differential concern for disclosing private information to family and health care professionals versus government and insurance companies[21].

Study 2, investigating comfort and aesthetics over a two-week period of continuous wearing of a watch-like monitoring device, showed few age or cohort differences in comfort over time. First impressions for the factors of positive affect, negative affect, and aesthetics held across time. If anything, older adults were more likely to rate the device less negatively over time compared to younger and middle-aged adults who were more likely to show less positive affect over time. So, as long as designers pay close attention to comfort and aesthetics, monitoring devices may prove quite acceptable to older adults.

Study 3, though based on a very small sample of normal older adults and those with heart failure, yielded a factor structure similar to that found in Study 2 for comfort ratings. Again, comfort ratings were very stable across time (here 6 months), and did not vary much by medical status. In general comfort ratings improved over time and the ratings completed at six months predicted actual use.

Taken together, the studies provide evidence that attitudes about privacy and comfort for current devices are unlikely to be a significant barrier to adoption and use of monitoring devices for older adults with chronic conditions. As long as devices make a good first impression for aesthetics, perceived comfort, and perceived usefulness, they are likely to be acceptable. Such devices may play a useful role in maintaining older adults with chronic conditions in their homes. Models of technology acceptance and use often show that attitudes play somewhat different roles for affirmations of willingness to use and actual use[25] and the studies presented here are no exception despite some evidence that comfort can be related to the actual use of wearable devices. Hence, a caveat is that we still know too little about the factors influencing adherence[24]. Finally, we have growing but still limited information about the reliability of such systems in the home[6,24], which may affect trust in their efficacy.

For health care to be integrated into home environments, beyond acceptability, it must show efficacy and cost effectiveness[26]. Efficacy is well-established for many chronic conditions but questions remain about cost effectiveness[27]. Nonetheless, with falling prices for technology and improved design principles for telehealth systems[4] it seems likely that an aging population prone to chronic health conditions will increasingly be able to stay safely and comfortably at home.

Older adults in many cultures express the desire to remain at home as long as possible as they age, though there are cultural differences in expectations about the role of families in supporting this desire (norms such as filial piety and interdependence in Eastern cultures, and independence in Western ones). The recently constructed Global AgeWatch Index[28], ranks countries on characteristics such as income security, enabling environment, health status, and capability. To the extent that technology can support aging in place, particularly for healthcare, telehealth services can play an important role in meeting AgeWatch criteria for both enabling environment and health status criteria.

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