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Research Article

Activity-Oriented Design of Health Pal: A Smart Phone for Elders' Healthcare Support

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Wireless telephones and personal digital assistants are emerging, as the *information hubs* connect their human users with assorted electronic devices and the World Wide Web. As such, they quickly become the de facto basis for *personalized information services*. The *Kannon* project team at the National Chiao Tung University (NCTU) in Taiwan is developing a ubiquitous service infrastructure for elders' healthcare support. Among their deliverables, there is a PDA Phone, christened *Health Pal*, which can communicate with Bluetooth/ZigBee devices, universal plug-and-play (UPnP) e-home service platforms, and online healthcare providers to offer 24/7 healthcare services to elderly people. This paper presents the early results of this effort including the functional and operational concepts of *Health Pal* as well as the activity-oriented approach of its design. Preliminary results of its usefulness and usability evaluations are reported. A comparison of this platform against several similar prototypes was also included to illustrate the advantage of applying activity-oriented design approach to human-computer interactions.

1. INTRODUCTION

Telephones, especially their wireless decedents, are perhaps the most widely used, the most influential, and the most rapidly evolving technology in the modern history. Visionaries predict that these compact, affordable, untethered communication/information processing devices will culminate endless uses as camcorders, game consoles, navigation aids, tour guides, house keys, remote controls, burglar alarms, health monitors, electronic wallets, passports, and so on [1]. Economists credited them as the most effective means to bridge the "digital divide" [2]. We see them as a promising way to connect elderly people with their lives and their world. To convince yourselves with the potential value of cellular telephones in enriching and safeguarding elders' lives, you may simply consider the following scenarios and imagine the difference that a "smart phone" can make in these situations.

(1) Many old people have the need of long-term medication, and they often take several kinds of medicine at the same time. Almost every elder knows the frustration of missing doses and the concern about potential drug interactions. How much would they like to have a smart phone that can manage their dosage to avoid dangerous side effects, remind them of their medicine schedules, and adjust the schedules to compensate for missing doses?

(2) Increasing number of affluent elders pay close attention to their health conditions. They want to monitor their pulse rates, blood pressure, and oxygen and sucrose levels regularly, and use these data to plan their diet and exercise routines. Besides, the value of home-based health monitoring has also been recognized. Studies showed that home-based blood pressure monitoring can be as accurate as 24-hour ambulatory procedure in diagnosing hypertension [3]. The US Joint National Committee thus recommends self-monitoring of blood pressure, before considering ambulatory monitoring, to improve hypertension management [4]. A PDA phone with Bluetooth biosensors will be an ideal instrument for performing these home-based health monitoring tasks.

(3) Another value-added service for health conscious elders will be to keep track of the amount of carbohydrates, fat, protein, and sodium they consume as well as the amount of aerobic exercises they have on daily/weekly basis. Again, a cell phone with an embedded bar-code/RFID reader and a wireless pedometer will go a long way to offer this desirable service.

(4) Old people are also concerned with the possibility of having medical emergencies while they are unattended. They worry whether the emergency response team can find them and diagnose their conditions in time. A cell phone can be a life safer in those situations if it can transmit the elder's location, his/her medical data, and the audio-visual feed of the situations to a hospital with the flip of a safety switch.

Figure 1: Physical appearance of *Health Pal*.

Figure 1 shows the physical appearance of *Health Pal*. The device was designed by researchers from the human engineering, the applied arts, and the computer science departments of National Chiao Tung University (NCTU) in Hsinchu, Taiwan. Besides, being a PDA phone, *Health Pal* also aims at helping affluent elders to take care of the following three aspects of their healthcare needs.

(1) *Health monitoring: Health Pal* can measure pulse rate, blood pressure, and oxygen or sucrose levels by connecting itself to wearable biosensors; these physiological data can be collected on regular/need basis, and may be stored in the device or uploaded to online databases for continuous monitoring and in-time diagnosis.

(2) *Treatment support: Health Pal* can remind its user of his/her doctors' appointments, medical tests, exercise routines, and medicine intakes; the schedules of these events can be entered via email, short messages (SMS) or wired/wireless database synchronization. They can also be generated by resident software based on user's needs and preferences.

(3) *Lifestyle (diet and exercise) management: Health Pal* can help health-conscious people to regulate their diet by keeping track of their carbohydrate, protein, fat, and sodium intakes based on meticulous accounting of food ingredients using product barcodes and nutrition labels. The device can also estimate the amounts and rates of protein/fat/calorie depletion by recording and analyzing biosensor data collected by *Health Pal*.

To ensure market acceptance and user satisfaction, *Health Pal* was designed to be *comprehensible*, *versatile*, and *fashionable* in its appearance and functions. Being *comprehensible* means that it can be used by people with limited computer proficiency. Being *versatile* means that the device can provide ever more services by associating itself with add-on devices. Being *fashionable* means that the device will have an elegant design so that it may be adopted as a status symbol or a personal decor.

This paper reports the design philosophy and process of *Health Pal* (Section 2) as well as introduces its functions and user interfaces (Section 3). In order to differentiate our device from similar devices in terms of their intended uses and features, we offered a comparison before making the conclusions.

2. DEVICE DESIGN

2.1. Operational framework

Although *Health Pal* can be used alone as a PDA phone with value-added healthcare features, it was designed to be a key component of the *Kannon* ubiquitous service infrastructure. Figure 2 shows the operational framework of *Health Pal*.The phone can work within three distinct *service circles* in order to offer three different levels (personalized, e-home oriented, and Internet-based) healthcare services.

Health Pal offers *personalized healthcare services* by bundling itself with wireless biosensors that communicate through Bluetooth [5] or ZigBee [6] radios. Kannon project developed a Bluetooth EEG headband and an ECG wristband that use MEMS dry electrodes to provide stable contacts [7, 8]. The project has also designed a ZigBee medicine bottle cap and a "Diet Cup" that will help users to keep track of their medicine schedules and dietary intakes. These novel accessories and commercial gadgets such as the bodybugg activity monitoring armbands [9] can turn *Health Pal* into a personal health monitor and biofeedback coach. It will help its users to become aware of the changes in their body conditions and devise plans to best maintain their physical and psychological well-being.

Distinct from existing health monitors, *Health Pal* can also work with e-home infrastructures, most notably the de facto standard technology of universal plug-and-play (UPnP) [10], to offer *e-home-oriented healthcare services*. These novel services will adapt specific aspects of a user's dwelling such as its lighting or acoustic effects according to his/her physical or psychological state. For example, the lighting of a living room may be synchronized with the circadian cycles of its inhabitants to enhance their energy and comfort levels. Likewise, a messaging armchair and a nearby

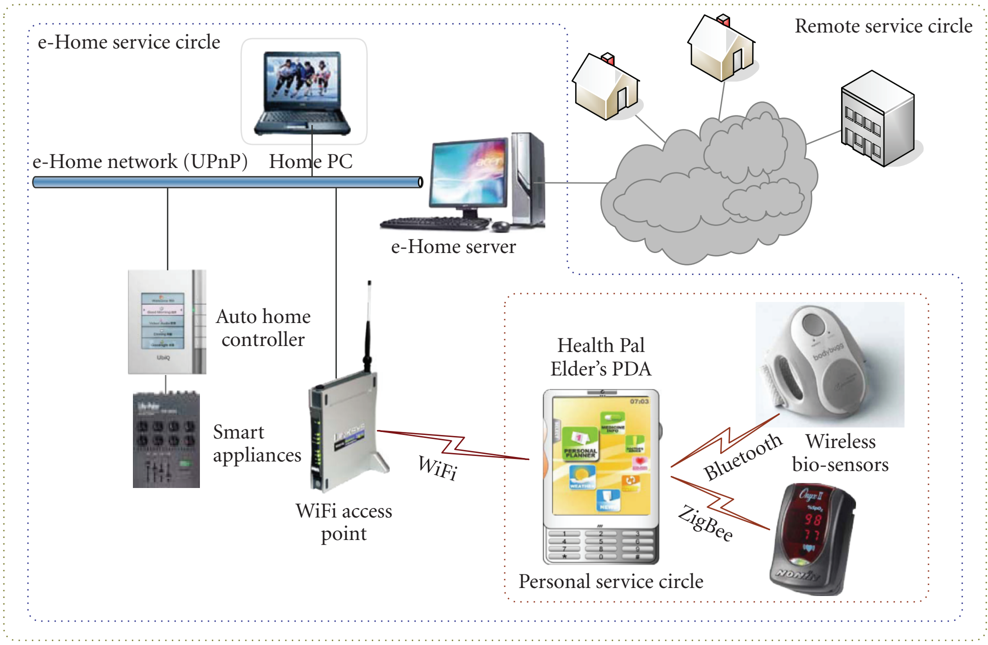

Figure 2: Operational framework of *Health Pal*.

stereo sound system may respond to the changing pulse rate and the finger temperature of their user in order to help him/her to meditate and relax. These e-home-oriented healthcare services may also have promising applications in psychological group therapy. *Health Pals* may be used to relay individual responses to the therapist so that he/she can conduct the session far more effectively than it is ever possible.

Finally, by connecting to mobile telephone networks, *Health Pal* can function naturally as the wireless data relay in *remote health monitoring* and *telemedicine* applications. The device can not merely be used in emergency situations to locate the patients and gather medical data. It can also be used to keep track of patients' food and medicine intake throughout their daily lives. Moreover, with online medicine scheduling and reminder, *Health Pal* will allow physicians to adjust medicine dosage in response to patients' changing health conditions and lifestyles. These applications will save millions of lives and billions of dollars when they become common practices.

It is our firm belief that ubiquitous Internet-based services will be a powerful means in meeting the mounting challenges of elders' healthcare needs, and smart phones such as *Health Pal* will be the natural user interface to offer these services. In the remaining parts of this section, we explain how a new design approach helped us to create this user-friendly device.

2.2. *Design principle*

The design of *Health Pal* was conducted according to the activity-oriented design (AOD) approach first proposed by Engeström in 1987 [11]. In his approach, Engeström used activitiesas the linchpins to bind the entities that are relevant to a design task. Figure 3 shows the triangular relations among the eight components of an activity: *subjects*, *objects*, *tools*, *rules*, *community*, *division of labor*, *transformation process*, and *outcomes*. According to this model, an activity is bounded to its *subjects* and *objects*. The relations between subjects and objects are mediated by the *tools*. Tools, in turn, can enable the subject to transform objects into *outcomes*. Furthermore, an activity is conducted in an environment that defines the social and cultural *context* of the activity. A *community* is a group of shareholders in an activity who share the same objective. *Rules* and *regulations* govern how an activity may be carried out in a community. Finally, members of a community may assume different *roles* in an activity. In recent years, Nardi [12] and Kuutti [13] adopted or expanded Engeström's activity model into a design framework for human-computer interaction (HCI) that takes interpersonal cooperation and social interactions into design considerations.

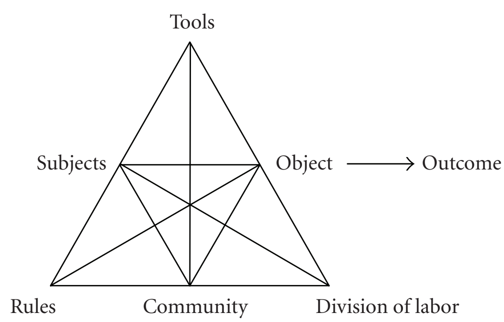

Figure 3: Model of activity theory [11].

By following AOD-HCI approach, we divided the design of *Health Pal* into five distinct steps: (1) selection of target user group, (2) analysis of healthcare activities within the target user group, (3) identification of user's needs among healthcare activities, (4) identification of necessary functions to meet the user's needs, and (5) design of physical appearance and user interfaces. The following paragraphs provide a detail account of these steps.

2.3. User group identification

The World Health Organization (WHO) divides elderly people according to their health conditions and living dependency into three categories: the Recent Old, who remain active and undertake normal activities without support, the Old, who can only afford reduced amount of activities and work, and the Very Old, who have difficulty to take care of themselves [14]. We chose the categories of the Recent Old and the Old as the target user groups of *Health Pal*.

2.4. Need and requirement analyses

In order to study elders' life patterns and understand their healthcare needs, we conducted a week-long ethnographic observation on the daily routines and healthcare-related activities of ten elders in the Recent Old and Old categories. We also interviewed our subjects after conducting our observation in order to understand the difficulties they might encounter in undertaking those activities. The questions we raised in our interviews focused on the health conditions of our *subjects*, their *processes* of healthcare activities, and the relationship among the *tools*, the *situation*, and the *community* involved in these activities.

Our ethnographic observation found that our elderly subjects have regular lifestyles. Most of them rise early and follow rigid daily routines. They rarely change the arrangements of their activities such as the choices of their family doctors and exercise places. Yet, the elders we interviewed are eager to acquire knowledge about health maintenance and care. They often apply the knowledge they learned onto themselves. The sources of their knowledge are television reports, newspaper articles, and word-of-mouth among relatives and friends. By sharing news, gossip, and knowledge, the elders remain somewhat connected with the society.

Based on the data we collected through our observation and interviews, we created eight fictitious *personas* including "David" who was described in the inset [15].

These personas provide our designers with more vivid images of the target users of *Health Pal*.

Our interviews revealed a common set of hardships encountered by most of our subjects in four specific healthcare activities: (1) *physician visits*, (2) *medicine intakes*, (3) *health monitoring and checkup*, and (4) *diet and exercise regulations*. Table 1 lists the problems, the example instances, and their ad hoc versus long-term solutions.

2.5. Function analysis

After learning the needs of our target users, the next design step was to transform user needs into system functions. To offer long-term solutions to the problems listed in Table 1, we proposed to implement the following four sets of functions.

2.5.1. Healthcare activity management

Function (1): medicine reminder

This function provides audio-visual prompts to remind users to take their medicine. If the user has taken the pills, he/she can reset the reminder by pressing a stop button on the screen; otherwise, intermittent prompts will appear repetitively. The frequency of their appearance will be proportional to the significance of the events. If the user delays his/her medicine intakes for too long, *Health Pal* will reschedule the intakes according to the usage directions of the medicine.

Function (2): diet and exercises planner

Health Pal will plan users' diet and exercies based on the instructions given by their physicians. Pop-out advices will appear according to the automatically generated diet and exercise plans.

Function (3): medical appointment manager

Health Pal can be connected to the online registry of medical clinics and hospitals through the web. It can thus handle online booking of medical appointments and schedule pop-up reminders of pending appointments. It can also alert its user of the estimated waiting time for the appointments if the online registry provides information about the length of the queue.

2.5.2. Audio-visual communication and emergency calls

Function (4): audio-visual communication

As a PDA phone, *Health Pal* can be used to make video and voice calls to user's friends, family members, and care providers. Nevertheless, only essential communication functions are installed so that elderly users will not feel lost in complex menu structure.

Function (5): emergency (911) calls

When a user pulls the sliding keyboard up with a hard jerk, *Health Pal* will make an emergency phone call or contact user's health care provider. User's medical data and current biosensory data will be transmitted through the phone call. Built-in camera and microphone may also be activated to relay an audio-visual feed of the current situation to healthcare professionals.

2.5.3. Health monitoring and information management

Function (6): health data gathering

Bluetooth-based biosensors can monitor pulse rate, body temperature, and blood pressure. These data will be stored in *Health Pal* and can be uploaded to user's personal computers and/or healthcare provider's databases.

Table 1: Hardships encountered by elderly patients and their expected solutions.

Hardships	Cases	Adhoc solutions	Expected solutions
Memory degeneration	Miss medicine doses Forget appointment schedules Take blood pressure readings irregularly	Use means of reminders: notes, calendar, medicine boxes, and so on. Get help from friend and family members	Scheduling aids Activity reminders
Information shortage	Ignorant about personal ailment Lack of medicine, diet, or exercise information Unsure of appointment wait time	Acquire "knowledge" from television, newspapers, or word of mouths Attempt to contact doctors or nurses in hospitals Make adhoc decisions	Reliable on-line medical and lifestyle information Easy contact with healthcare professionals
Information management	Forget doctor's advice Lose medical records	Use handwritten notes on notepads or notebooks	Personal data assistant Personal information manager and search engine
Emergency care	Lack of on-time medical help Lack of personal medical history	Wear emergency and first-aid bracelets	Cell phone emergency call feature Cell phone medical history
Health condition monitor	Unavailability of instruments Incapable of using instruments	Ignore symptoms Try to ask for help (if possible) Call for emergency service (expensive)	Handheld/Cell phone health monitors

Function (7): medical data exchanges

Health Pal can synchronize its database with those in the users' personal computers and the doctors' clinics. After data synchronization, doctors can review the user's medical records and biosensor data. Users, on the other hand, can download doctors' instructions and appointment schedules.

Function (8): medicine information retrieval

Health Pal can gather detail medication information including drug usage, potential side effects, and interactions via Internet connections. Along with its medicine reminder function, it helps to minimize the risks and maximize the benefits of medicine intake.

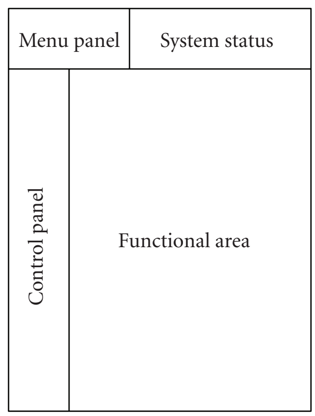

Figure 4: Screen layouts and display formats.

3. DEVICE FEATURES

Health Pal was designed to be a "constant companion" to its user. Its design process includes the following four steps: (1) the design of display screen and formats, (2) the layout of user interfaces including control buttons and menus, (3) the planning of user-device interactions, and (4) the creation of visual metaphors and symbols.

3.1. Screen layouts and display formats

Health Pal uses large legible display and simple screen layout. Texts on the screen were 14-point sizes with high contrasts.

The screen space of *Health Pal* was divided into four areas: *menu navigation*, *system stat us*, *operation guidance*, and *main activity* (see Figure 4). Menu navigation area was seated on the left top of screen space. It provided the useful information of menu (such as relative position, function category) to help users understand their current status and reduce the chance of menu missing. System status area located on the right-top side of the screen provided information such as date, time, and battery life to help users hold the system state of *Health Pal*. A control guide on the left side demonstrated the current menu situation. The central space of screen is the main active area. All the functions of *Health Pal* were displayed in this area; users can interact with these functions via the two hard buttons.

3.2. Interaction design

Elders interact with *Health Pal* by three components: a circular menu for display options, a mouse wheel for choosing options, and two hard buttons for selecting options (see Figure 5). A circular menu disclosed the menu

Figure 5: (a) Screen saver, (b) main menu, (c) pull-down keypad, (d) pull-up emergency calling pad.

options. A fish-eye method was presented in the menu. The combination of circular menu and fish-eye display let users understand where they are in the menu tree and help them preview the neighboring options besides their current selection. A mouse wheel was used to select menu options; this was because the interaction style of mouse wheel was similar to elders' previous experience such as interacting with the channel selecting of radio. Afterwards, the user can select an option through pressing the hard button.

In addition, the sequence of menu options was ranked based on the elders' activities focus. Also, the sequence of menu options was adapted according to the elders' use frequency of each option. Therefore, the user can find the functions quickly and decrease the possibility of getting lost in the menu.

Elders can operate *Health Pal* with only one hand using their thumb to operate the circular-menu via mouse wheel and the two flexible fingers (first and middle) to perform the two hard buttons. This interaction style could keep the quality of usability even when the elders were under the mobile environment. Moreover, a sliding part of *Health Pal* was used to support the two additional functions "number key in" and "emergency calling." When users pull the sliding part down, they can operate the numeral keypad; whereas pushing the sliding part up, the emergency model starts automatically.

3.3. User interface flows

The interface flows of *Health Pal* can be defined as four levels. Level (0) was defined as the context-aware level; in this level functions were performed automatically through sensing the conductions of use context. Level (1) was defined as the main interactive page; the relative information and options will be displayed in this level. Level (2) was defined as advanced information level; user can reach more detail information about current operating function in this level. Level (3) was defined as the system-setting level; user can set the system options in this level. For example, when *Health Pal* situates the time and then sends an alarm to remind elders to take medicine, the system now is in level (0). Then, elders confirm the remind message and enter into the main function page, the system now is in level (1). If elders want to get more information about the medicine, he/she could enter into level (2) by pressing the hard button. Furthermore, user can set the options of medicine reminding function such as alarm frequency or alarm sound volume in level (3).

3.4. User interface metaphors

In order to reduce the technological distance between the *Health Pal* and the elders, *Health Pal* used several metaphors to present the information. For example, the elders health conditions were presented as an emotional expression icon; a user could understand her/his health condition by only judging the state of icon (happy or sad). For the reminding of medicine taking function, a medicine-box metaphor was used to provide related information of medicine taking such as color/form of medicine, and times for taking medicine in a day. Moreover, two virtual avatars "Ms. Nurse" and "Mr. Weather" were used to assist elders to reach the healthcare information and the weather information.

4. USEFULNESS AND USABILITY EVALUATION

4.1. Participants

A usability evaluation was conducted to examine whether *Health Pal* satisfies the elders requirements and reduces their dependence on their caregivers. As listed in (Table 2), fifteen elders participated in the evaluation. Their average age (between 50 and 78) was 61.2 years. Nine out of the fifteen participants had been diagnosed of some chronic diseases such as diabetes, hypertensions, and hyperthyroidism. Their healthcare activities included customary physical examination, self-measurements of blood pressure and sucrose levels, regular medication, diet control, and exercises. Among our participants, 14 participants owned a cell phone. Notably, five out of these 14 participants (35%) only use the basic features of the cell phone. They dialed the telephone number using the keypad instead of looking up the contacts in the address book. The criteria of purchasing a cell

Table 2

Gender	Male	Female
	5	10
Age	>65 years	<65 years
	5	10
Chronic diseases	Yes	No
	9	6
Possession of cell phone[(1)]	Yes	No
	14	1
Self purchase of cell phone	Yes	No
	7 (4f + 3m)	7 (5f + 2m)

[(1)] Like most developing economies in the Asia Pacific region, cell phones enjoy very high market penetration in urban and suburban areas of Taiwan.

Table 3: 12 tasks in three scenarios.

Scenarios	Tasks
Search for information before working out	(1) Check today's to-do things (2) Check today's weather (3) Browse news (4) Consult doctor's instructions
Communicate with a family member and utilize vital sign monitoring	(1) Call a family member (2) View audio-visual messages (3) Look up missing phone calls
Trigger emergency alarm and receive medical treatment	(1) Activate emergency alarm (2) Update personal medical data (3) Check diet advice (4) Check medication reminders (5) Look up medicine information

phone for them included large text size, handy, and easy to use.

4.2. Test scenarios

A paper-based full-sized prototype with manually switched screens was used to conduct the usability evaluation. The participants had a first experience of how the device will work by "playing" with the mockup. With guidance from the evaluators, 15 participants "used" the mockup by following a test scenario. The persona "David" was the subject in the scenarios. The test scenarios represented activities frequently engaged in by an elder in a morning. It consisted of three scenarios: (1) *search for information before workout*, (2) *communicate with a family member and use the vital sign monitor during a workout*, and (3) *set the emergency alarm and wait for the emergency rescue team*. The test scenario consisted of twelve tasks and acquired 32 steps to complete (see Table 3).

4.3. Evaluation procedures

The evaluation sessions were organized as follows. First, the purposes of the evaluation and demographical interviews were introduced to the participants. Then, test scenarios were given to the participants. During the in-situ test, participants thought aloud every task step. After performing the tasks, performance data (task error rate and verbal protocol) were recorded. Subjects rated the usability on the perceived-of-usefulness and perceived-ease-of-use scale [16] after each scenario. The scale was twofold: subjective usefulness and ease of use. Each assessment consisted of six questions; each question was graded according to a seven-point Likert scale (one nonuseful/unusable, seven very useful/easy to use). The scale was translated into mandarin and some wordings were modified to fit the natural language of elders used in daily lives. The Chinese version of the scale was translated back into English to prevent translation errors.

Elders filled up the questionnaire based on the subjective workload assessment technique (SWAT) [17] after the usefulness and the ease-of-use test. SWAT assessed *time load, mental effort load,* and *stress load* experienced by the participants while operating the system. The questionnaire was a three-point Likert scale. With the conjoint measurement, the scores were transformed into an interval scale of workload, ranging from zero to one hundred.

An open-ended interview was carried out regarding (1) the advantages of the system, (2) the shortcoming of the system, and (3) possible improvements for future iteration design at the end of the test.

4.4. Evaluation findings

In general, subjective values about the services, display format, and interaction style of *Health Pal* were very high. At the same time, error rate was significantly low. During the evaluation, five participants (30% of them) asked about the services provider and prospective sale price for "*Health Pal*." It showed that the needs of the elders were satisfied by the Health Pal and a desire to own it was excited.

4.4.1. Objective results

Almost all operations were error free (total error rate = 0.028). Error rates for scenarios (1), (2), and (3) were 0.00, 0.03, and 0.17, respectively. The error rate in scenario (2) using the communication features of "*Health Pal*" was the highest among all scenarios. The majority of errors (67%) committed in scenario (2) happened in the tasks of *calling a family member whose number was saved in the contacts*. Four participants made the same wrong operation by dialing the number directly on the digit keypad. In order to understand why subjects made such error, we had a debriefing interview with subjects who made the error. We found that one of the elders did not own a mobile phone. Therefore, navigation in the menu and searching for a number in the contacts was not familiar for this participant. Although another two elders own a mobile phone, dialing the number directly was a more habitual method for them. The last participant used his mobile phone more often and usually employed speed dial to call his family. Consequently, he made this error. In summary, participants had difficulties in understanding the iconographical meaning of the *contacts icon*. Next, the second most errors were committed in scenario (3). In this scenario, participants had problems in looking up the medication information in detail. Two out of 15 elders did not know that the individual pill on the screen can be rotated to show related information by operating the mouse wheel. In this case, adding operation guidelines on the screen should be considered in the next design stage. Finally, in scenario (1), all participants completed the tasks perfectly. It showed that the user-interface design for scenario (1) fitted with elders' mental model and provided an easy interaction manner for the elderly. This was confirmed with behavioral observation data which demonstrated that participants were not frustrated or confused at all.

4.4.2. *Subjective results*

Quantitative findings for workload and usability

On the whole, the feedbacks were very positive. Most participants thought that the features of *Health Pal* were useful (mean = 2.40, standard deviation = 1.04) and easy to be used (mean = 2.77, standard deviation = 1.20). Meanwhile, participants also indicated that using *Health Pal* took a bit of work as it was measured in terms of *time workload*, *mental workload*, and *stress workload* (SWAT score, mean = 23.88, standard deviation = 25.81). In all three dimensions of SWAT assessment, processing and response demands did not exceed available capacity of participants. The subjective values of all the three scenarios were reported below. Table 4 listed the mean score and standard deviations of SWAT questionnaire, the score of perceived usefulness and perceived ease of use.

Table 4: Mean score and standard deviations of SWAT, perceived usefulness and perceived ease of use.

	Means	Standard deviations
SWAT	23.89	25.82
Usefulness (Total)	2.40	1.04
Scenario (1)	2.32	0.89
Scenario (2)	2.58	1.47
Scenario (3)	2.33	0.93
Ease of use (Total)	2.77	1.20
Scenario (1)	2.84	1.24
Scenario (2)	2.66	1.30
Scenario (3)	2.83	1.20

In scenario (1), Health Pal provided critical information in daily live, such as news and weather information. This feature was well received by participants (perceived of usefulness, mean = 2.32, standard deviation = 0.89). Three out of 15 participants indicated that reading news in the beginning of a day was a daily routine for them. In particular, business news were considered necessary when they managed their retire funds, and a stock watch feature was desired. General consensus was that users had access to essential information in an effortless manner via Health Pal (perceived of ease of use, mean = 2.84, standard deviation = 1.24).

In scenario (2), participants placed high values on communication features (perceived usefulness, mean = 2.58, standard deviation = 1.46). Because thirty five percent of participants only use a mobile phone to make and receive calls, the four existed communication features on Health Pal satisfied their needs already. Further, they thought more communication features will increase the complexity of the system but will not make it more usable. Also, participants mentioned "Health Pal" was easier to work when, *Health Pal* was compared to regular mobile phone (perceived ease of use, mean = 2.67, standard deviation = 1.30), specific comments such as "pull-down" keypad significantly decreased the size of Health Pal, and it is very handy.

In scenario (3), almost all participants found that the system was an ideal tool to enhance their health management (perceived usefulness, mean = 2.40, standard deviation = 1.04), especially for those participants older than sixty-five years (perceived ease of use, mean = 1.97, standard deviation = 0.82). Five participants are greater than sixty-five years and they were required to adhere to medication regimens. For that reason, they believed the context sensitive medication reminder feature was very helpful. Detailed medicine information can be looked up in the system. If elderly people had doubts on prescriptions and would like to consult their friends or relatives, this information can be showed to their friends and relatives. Participants whose age was under sixty-five years also pointed out that *Health Pal* could play a significant role in taking care of their elder parents (perceived ease of use, mean = 2.63, standard deviation = 1.18). Regarding ease of use, opinions from most evaluators were positive. Evaluators thought that synchronizing personal medical data with health care providers was so easy that they would not be bothered by inputting data by themselves.

Qualitative findings for interaction behavior

Some interesting comments on the user-interface feature of Health Pal were brought up in the evaluation. First, participants showed a clear preference for *activity-oriented interactive flow and personalized presentation sequence*, for example, comments such as "it is nice to see what you need at the first glance," "it saves a lot of time spent on searching a name in the telephone directory," and "it is a smart design." These opinions implied that using personal preferences as an agent to construct information retrieval was welcomed by the elders, compared to the traditional hierarchical menu structure. Second, four participants adored the combination of mouse wheel and two hard buttons because the control feedback was firm there were positive comments such as "the control style is very logical" and "I can use it by one hand. Good job." It showed that Health Pal gave an intuitive and engaging experience for the user. Third, evaluators noted the constant companion metaphor in the system and they liked it. For example, they said "how interesting to have a personal nurse who reminds you to take pills every day" and "I can tell what to wear just by looking at the weatherman's dressing." This reflected that Health Pal represented a comforting caregiver for the elderly and met their needs for safety.

4.4.3. *Next design iteration*

Suggestions made by participants included three aspects: intensified emergency alarm, automatic take-me-along reminder, and secured personal information. Two participants proposed that light and sound alarms should be incorporated so that a stranger on the street will notice the urgent situation. Also, special diagnosis and contact person information should be enlarged and more standout. Meanwhile, most female evaluators called for reminders to take Health Pal along before leaving home. Interestingly, seventy percent of female participants do not carry a mobile phone when they go out with their husbands. Consequently, they constantly forget to bring a mobile phone when they go out by themselves. Therefore, our system should provide an active but not annoying reminder for users in the future. Finally, two out of fifteen participants are worried about the privacy of their personal data. A Work on data security should be carried in the next design stage.

5. DEVICE COMPARISON

The currently existing researches of providing elders with health care services include four ways: reminding systems, telecoms, and emergency contacts or medical service systems. The reminding systems include PEAT system [18], autominder system [19]; the emergency system includes AGAPE service [13], and examples of medical service systems are MIThril [14] and wearable context aware system for ubiquitous healthcare [15].

PEAT system is the first one to use AI planning technique. It is mainly used on portable configurations. When the project proceeds, PEAT system provides vision and acoustic clues. It has a model to memorize users' detailed schedule, and alarm users with this model. But when the user installs some specific information, the system will accommodate automatically. When a new activity is added, PEAT will use PROPEL (planning and execution system) to simulate the plan to solve the contradictions between plans.

Autominder system can precisely update user's daily program, monitor these activities, and provide adequate reminding. The system has three main components: (1) the Plan Manager, which maintains user's daily schedules, updates event information, and resolves potential timetable conflicts; (2) the Client Modeler, which enables the user to look up his/her daily schedules and keep track of the progress of his/her work; (3) the Intelligent Reminder Generator (IRG), which sends reminding messages to the user based upon the To-Do list maintained by the Plan Manager and the Current Event list kept in the Client Modeler. It is more reliable than PEAT system because it enhances the ability to evaluate plans and alarms under a more reasonable surrounding. Autominder is now manipulated upon three platforms: Pearl robots, IMP intelligent walker, and PDAs which are based upon wireless communication.

The scheduling function puts an emphasis on the reminding timers of hospital appointments and medicine taking. Further, the inputting events in *Health Pal* are automatically inputted through external peripherals. Users do not need to arrange their schedules and enter them in *Health Pal* by themselves. *Health Pal* emphasizes simple operations, reduces complicated functions, automatically receives necessary medical care events, and gives reminding in advance. *Health Pal* makes it as simple as possible for the elders.

AGAPE service helps elders by tracking their locations and monitoring their health to provide information to the helping crew. AGAPE sets up a framework of seeable location information and the information of elders, doctors, and the emergent medical crew to help dealing with the emergent events. AGAPE connects elders' portable configurations with wireless internet. The monitor system is ECG, which supervises diseases like arrhythmia. When the user feels ill, the system will establish an emergent medical crew according to the documents.

Health Pal emergency system does not automatically realize users' emergent situations, but provides an easy way for users to contact in emergency. Furthermore, *Health Pal* performs users' personal medical records on the portable configurations so as to make passengers or emergency medical technicians understand patients' previous medical system and to prevent inappropriate medical treatments or first aid.

MIThril system embeds the physical medical sensors into cell phones or PDAs to provide input/output and common calculating functions. MIThril system also subsupports wide-range physical examinations. Its software is object oriented; therefore, it follows the requirements of some specific users to install particular sensors. The system supports configurations like accelerometer, GPS navigator, voice-activated devices, thermo sensors, and so on. Meanwhile, MIThril connects via RS-232 links to biosensors that monitor user's breathing rate, blood pressure, oxygen, and sucrose levels.

Wearable context-aware system for ubiquitous healthcare is a service system of providing health care with Ubicomp. It connects physical monitoring sensors (heartbeats, breath, body temperature, and calories) with context sensors to predict possible context information. After calculating, the system provides health care services (location-based services, remote healthcare services). Currently, it is used on PDA systems to remote monitor users' physical information. When the physical signals are sent to the PDA through ZigBee, the PDA will provide the information to doctors through wireless internet. Furthermore, the physical information is also provided to the users. *Health Pal*, in contrast, combines medical reminders, provider communication, and self-care to provide users with integrated services.

6. CONCLUSIONS

Health Pal is still in its infancy. The design of the physical device and its user interfaces was completed according to the activity-oriented design (AOD) approach. However, its hardware prototyping and software implementation have just begun. Further evaluation of its usability will be carried out once the working prototype is ready.

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REFERENCES

[1] "The Phone of the Future," Economist, November 2006.
[2] "Phoney Finance," Economist, October 2006.
[3] G. S. Stergiou, "Ambulatory or home blood pressure monitoring for treatment adjustment?" *American Journal of Hypertension*, vol. 19, no. 5, pp. 475–476, 2006.
[4] A. V. Chobanian, G. L. Bakris, H. R. Black, et al., "Seventh report of the joint national committee on prevention, detection, evaluation, and treatment of high blood pressure," *Hypertension*, vol. 42, no. 6, pp. 1206–1252, 2003.
[5] "Bluetooth," http://www.bluetooth.com/bluetooth/.
[6] "ZigBee alliance," http://www.zigbee.org/en/index.asp.
[7] J. C. Chiou, L. W. Ko, C. T. Lin, et al., "Using novel MEMS EEG sensors in detecting drowsiness application," in *Proceedings of the IEEE Biomedical Circuits & Systems Conference (BioCAS '06)*, London, UK, November-December 2006.
[8] C. T. Lin, H. Y. Hsieh, L.-W. Ko, M. Lin, S. F. Liang, and C. T. Hong, "Development of wireless brain computer interface with embedded multi-task scheduling," in *Proceedings of the IEEE Biomedical Circuits & Systems Conference (BioCAS '06)*, London, UK, November-December 2006.
[9] Apex Fitness, "body bugg," http://www.bodybugg.com/.
[10] UPnP Forum, http://www.upnp.org/default.asp.
[11] Y. Engeström, *Learning by Expanding: an Activity Theoretical Approach to Developmental Research*, Orienta Konsultit, Helsinki, Finland, 1987.
[12] B. A. Nardi, "Activity theory and human-computer interaction," in *Context and Consciousness: Activity Theory and Human-Computer Interaction*, B. A. Nardi, Ed., pp. 7–16, MIT Press, Cambridge, Mass, USA, 1996.
[13] K. Kuutti, "Activity theory as a potential framework for human-computer interaction research," in *Context and Consciousness: Activity Theory and Human-Computer Interaction*, B. A. Nardi, Ed., pp. 17–44, MIT Press, Cambridge, Mass, USA, 1996.
[14] World Health Organization, "Men, aging and health: achieving health across the life span," http://whqlibdoc.who.int/hq/2001/WHO_NMH_NPH_01.2.pdf, 2001.
[15] A. Cooper, *The Inmates are Running the Asylum*, SAMS, Indianapolis, Ind, USA, 1999.
[16] F. D. Davis, "Perceived usefulness, perceived ease of use, and user acceptance of information technology," *MIS Quarterly*, vol. 13, no. 3, pp. 319–340, 1989.
[17] G. B. Reid and T. E. Nygren, "The subjective workload assessment technique: a scaling procedure for measuring mental workload," in *Human Mental Workload*, P. A. Hancock and N. Meshkati, Eds., pp. 185–218, North-Holland, Amsterdam, The Netherlands, 1998.
[18] R. Levinson, "The planning and execution assistant and trainer (PEAT)," *Journal of Head Trauma Rehabilitation*, vol. 12, no. 2, pp. 85–91, 1997.
[19] M. E. Pollack, L. Brown, D. Colbry, et al., "Autominder: an intelligent cognitive orthotic system for people with memory impairment," *Robotics and Autonomous Systems*, vol. 44, no. 3-4, pp. 273–282, 2003.
[20] D. Bottazzi, A. Corradi, and R. Montanari, "Context-aware middleware solutions for anytime and anywhere emergency assistance to elderly people," *IEEE Communications Magazine*, vol. 44, no. 4, pp. 82–90, 2006.
[21] A. S. Pentland, "Healthwear: medical technology becomes wearable," *Computer*, vol. 37, no. 5, pp. 42–49, 2004.
[22] D.-O. Kang, H.-J. Lee, E.-J. Ko, K. Kang, and J. Lee, "A wearable context aware system for ubiquitous healthcare," in *Proceedings of the 28th Annual International Conference of the IEEE Engineering in Medicine and Biology (EMBS '06)*, pp. 5192–5195, New York, NY, USA, August-September 2006.