Usability Testing of a Prototype Personal Digital Assistant (PDA)-based Decision Support System for the Management of Obesity

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Introduction

The use of handheld computers has been rapidly increasing in a variety of health care settings since the early 1990s. Generally, handheld computers are inexpensive, lightweight and highly portable, but they still have some limitations, such as a small screen, a limited network connection, minimal processing power, and inconvenient pen-based input(Grasso, 2004). According to one qualitative study exploring physicians' non-usage pattern of personal digital assistant(PDA)s, usability barriers such as screen size, handwriting recognition problems, data entry mechanism, short battery life, perceived delicacy of the device, and additional need of accessories, are some of the big barriers that decrease physicians' use(Lu et al., 2003). In a systemic review of user interface issues in PDA-based decision support systems(Lee, Starren, & Bakken, 2005), usability issues of PDA-based decision support systems were classified into five categories: display, security, memory, Web browser, and communication. In physicians' attitudes toward Handheld Decision Support Software(H-DSS), Ray and associates specifically measure perceptions of limitations including display issues(Ray et al., 2006). These usability issues may be a major impediment to the acceptance of handheld-based information systems in health care settings and can result in limitations in the design or development of handheld-based information systems.

While the potential of handheld device-based information systems has been recognized at the point-of-care for decision making and documentation, relatively few usability studies have been performed for handheld device-based decision support systems(Lee et al., 2005). Healthcare professionals tend to determine the usability of systems in the field, not through laboratory testing prior to deployment, because of lack of time. Consequently, if a system is not useful in the field, it is easily abandoned and a new system is sought out(Andon, 2004). As a contrast to such approaches, the purpose of this study was to evaluate the usability of a prototype PDA-based decision support system for the management of obesity

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through usability testing with end-users (Advanced Practice Nurses [APNs]) prior to its implementation in clinical settings.

Usability Testing

Usability testing is a process to evaluate information systems through the analysis of representative end-users interacting with the system(Weiss, 2002). Usability testing is used to 1) identify usability problems perceived by end-users, 2) measure quantitative data related to end-users' performance(e.g., time of task completion or system response), and 3) collect end-users' suggestions for improving the design or functions of system(A. Kushniruk, 2002). Usability testing should be considered as part of the design process, not as part of the evaluation of the end-product. Usability testing through iterative feedback from potential end users is an essential process to develop user-centered and effective information systems in health care. The iterative usability testing with prototypes reduces the cost of re-designing by modifying the prototypes based on evaluation more quickly and easily(Weiss, 2002). Moreover, considering that poor user interface design or suboptimal user interaction with the user interface can facilitate medical errors(Borycki & Kushniruk, 2005), usability engineering techniques have the potential to improve patient safety by identifying usability problems related to possible safety issues(e.g., technology-induced medical error) (A. Kushniruk, Triola, Stein, Borycki, & Kannry, 2004; A. W. Kushniruk, Triola, Borycki, Stein, & Kannry, 2005).

In terms of sample size for usability testing, in most cases the greater the number of participants, the greater the number of detected usability problems. However, a greater number of participants usually results in a greater cost for the evaluation (Bertini, Gabrielli, Kimani, Catarci, & Santucci, 2005). According to Nielsen and Landauer's mathematical model of identifying usability problems, the optimal number of test users is 7 in a small project, but the highest ratio of benefits to costs is achieved for 3.2 test users(Nielsen & Landauer, 1993). However, Faulkner(2003) showed that the level of computer experience in each group made a significant difference in the time required to complete a task. Also, according to Faulkner(2003), the minimum percentage of problems identified rose from 55% to 82% and the mean percentage of problems identified rose from 85% to 95% when the number of users increased from five to ten. Consequently, it is important to consider the ratio of benefits to costs in determining the sample size for end-user testing.

PDA-based Decision Support System for the Management of Obesity

The PDA-based decision support system was designed to integrate decision support functions for the screening and management of obesity into the existing clinical log system at the Columbia University School of Nursing. Nurses in APN training routinely enter de-identified data from their patient encounters in the clinical log system. The PDA-based decision support system utilizes a set of clinical practice guideline(CPG)-based decision rules and documentation templates that remind nurses to screen for obesity, assist with the screening process including calculation of body mass index (BMI), automatically generate an obesity-related diagnosis, and facilitate documentation of an evidence-based plan for obesity(Lee, Currie, John, Chen, Joyce & Bakken, 2007, Lee & Bakken, 2007). Table 1 summarizes the functions of the PDA-based decision support system. The development environment included: Palm OS 4.0–5.0 devices, Extend systems Onebridge synchronization software, Microsoft Access database software, and

AppForge, a mobile application development tool. The interface design and technical aspects of the PDA-based decision support system for the management of obesity are described in detail elsewhere(Lee & Bakken, 2007; Lee, Chen, Mendonca, Velez, & Bakken, 2007). After heuristic evaluation of a Web-based prototype of a PDA-based decision support system(Lee et al, 2007), based on the results of the heuristic evaluation, the PDA-based prototype was implemented and was the focus of the end-user testing in this paper.

Methods

This descriptive study used observational and think aloud techniques to address the research question: what usability problems are perceived by end-users? Five recent APN graduates were invited to participate by email. The inclusion criterion was APN graduates who had completed the graduation requirements of one of Columbia University School of Nursing's APN program as of December 31, 2005. There was no exclusion criterion. The usability test was carried out in a usability laboratory at the Columbia University School of Nursing. This study was approved under Columbia University Institutional Review Board (IRB), and the consent form was waived. The PDA-based decision support system prototype was loaded on a Tungsten E2, a PDA that many nurses had used to enter their clinical log data during their APN training.

Procedures

The five APNs who agreed to participate met with the researcher who introduced the goal of this study and the functions of the application. The participants were provided with the scenarios and

< Table 1> Functions of the PDA-based Decision Support for the Management of Obesity

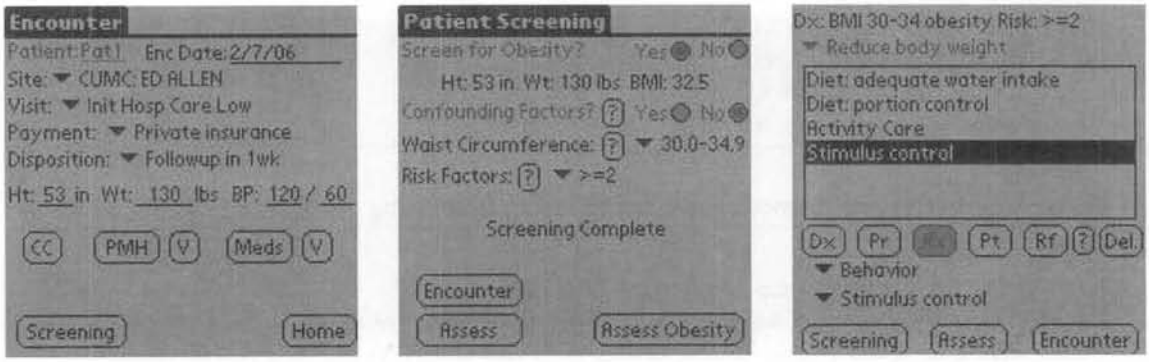
PDA-based Decision Support for the Management of Obesity
Screening
• Remind a user to screen
• Capture weight and height
• Calculate body mass index (BMI)
• Capture waist circumference (WC)
• Assess risk factors related to obesity
• Assess confounders that affect interpretation of BMI
• Provide information related to screening using infobuttons
Assessment
• Derive an obesity-related diagnosis based on the results of screening
Planning
• Set a patient goal related to the management of obesity
• Provide a guideline-based plan template that is tailored to the results of screening and a patient's weight management goal: plans of care in five categories- diagnostics (DX), procedures (PR), prescriptions (RX), patient teaching and counseling (PT), and referrals (RF)
• Provide information related to the management of obesity using infobuttons

the list of tasks(Table 2) to evaluate the application. The scenarios were developed based on the Use Cases that were developed in the functional requirement specification(Lee & Bakken, 2007; Lee, John, & Bakken, 2006). The scenarios and tasks reflected the functions of the application and were verified by one informaticist.

Participants were asked to think aloud as they completed the study tasks. Their verbalizations were recorded through Morae usability software

< Table 2 > Scenarios and Tasks for Usability Testing

	Scenarios and Tasks	
1	Follow the processes of screening and planning treatment for obesity	Normal flow of screening and planning for obesity Enter weight/height on the Encounter Screen Screen for obesity on the Screening Screen • Check BMI • Enter waist circumference • Assess risk factors • Use of infobuttons related to screening Document plans for obesity on the Planning Screen • Enter a patient's goal • Document plans of care in five categories • Use the infobuttons related to planning Document assessment and plans for other diagnoses
2	Document a reason not to screen	When a patient is coma and a user does not enter height or weight
3	Check a warning message for a wrong height or weight value	When a user enters a wrong height or weight, When a patient has a normal BMI or is underweight
4	Check questionable BMI	When the BMI is not appropriate based on clinical judgment
5	Create an encounter and complete screening and documenting plans for obesity	Create a patient and an encounter Screen for obesity Document plans for obesity



a) Encounter Screen b) Screening Screen c) Planning Screen

Figure1. Screen Shots of the PDA-based Decision Support System

which also captured time for tasks. If a participant was silent for a long time, the researcher reminded her to think out loud. When a user identified issues or the researcher found critical incidents that were characterized by comments, silence, looks of puzzlement, etc., the researcher took notes describing that person's activities to provide additional feedback that can help to highlight problems that otherwise would not be identified. After the participants finished the task, they were asked to complete a brief survey that included questions about their demographics and their computer experience and as well as open-ended questions about system, including positive characteristics, negative characteristics, problems, and recommendations.

Data Analysis

The data analysis was based on the data captured through Morae software, transcriptions, notes, and the end-user survey. The mean task performance time was calculated. The researcher searched for critical incidents, which were characterized by comments, silence, repetitive actions, etc., and reviewed these incidents in detail using Morae software. The incidents identified and the users' written comments were summarized, and content analysis, a technique for making replicable and valid inferences from data, was performed. The comments were categorized according to positive characteristics, negative characteristics, and recommendations. Users' demographics, level of computer experience, and task performance time were analyzed using Statistical Package for the Social Sciences (SPSS); frequencies, percentages, means and standard deviations were calculated.

Results

Four of the end-users graduated from the Pediatric-NP program, and one graduated in a dual program of Pediatric-NP and Neonatal-NP. The evaluation session ranged from 50 – 90 minutes. Table 3 shows the end-users' demographic information and experience with handheld devices. All the end-users had used computers for more than 2 years and currently used computers several times every day. Two of the participants considered themselves as very sophisticated or sophisticated in computer use, and the rest considered their computer use to be average. Regarding handheld device experience, all participants had a PDA, and the average number of years experience with a PDA was 2.8 years (SD=1.30, Range 1.5-5 years). The frequency of use and the level of sophistication in handheld device use varied.

All end-users completed their tasks based on the four scenarios that were provided. The mean performance time was 4.62 minutes(SD=1.30, Range 2.40-5.50 minutes). While performing the last scenario, two participants confused 'confounding factor' with 'risk factor.' In selecting two or more plan items in the same plan type, participants sometimes selected the 'plan type button' (e.g., Dx, Pr, Rx) again even though the plan button had already been selected. One participant selected the 'Assess' button instead of the 'Assess Obesity' to go to the planning template for documenting plan items for obesity.

In terms of general evaluation of the system, the end-users stated that the system was easy to use, clear, concise, and useful. Table 4 shows a summary of the end-users' evaluation statements for each screen. For positive characteristics of the Encounter screen, three participants stated that it was easy to enter weight and height values. Three

participants mentioned that they could catch their errors easily and correct them through warning messages when they entered a wrong value or did not enter necessary information. One participant stated as a negative characteristic that she could not override height or weight values after all the screening processes were finished and she went back to the Encounter screen.

In terms of the Screening screen, all participants liked the fast, simple, and automatic BMI calculation. While executing the first scenario, some participants were confused about 'confounding factors.' In the PDA-based decision support system the 'confounding factor' means a patient-related factor that affects interpretation of the BMI(e.g., the presence of edema and high muscularity). One participant stated that she was not familiar with the confounding factors for adult patients, so she needed a more specific list. Two participants wanted to see the list of confounding factors before selecting 'No' in the question asking whether a patient has any confounding

< Table 3 > Demographics Information and Handheld Device Usage of End-Users

	Category	N (%)
Age	0-19	.
	20-29	1 (20)
	30-39	1 (20)
	40-49	2 (40)
	50-64	1 (20)
	> 65	.
Gender	Female	5 (100)
	Male	.
Years of RN Experience	Less than 1 year	.
	1-2 years	1 (20)
	3-5 years	2 (20)
	6-10 years	.
	11-20 years	2 (40)
	> 20 years	.
Frequency of Use of a Handheld Device	Several times a day	2 (40)
	Once a day	1 (20)
	Several times a week	.
	Once a week	1 (20)
	Several times a month	.
	Once a month or less than	1 (20)
	Never	.
Level of Sophistication in Use of Handheld Device	Very sophisticated	.
	Sophisticated	2 (40)
	Average	2 (40)
	Unsophisticated	1 (20)
	Very unsophisticated	.

< Table 4 > Usability Evaluation of End-Users and Design Solutions

Encounter Screen			
Positive Characteristics	**Negative Characteristics**	**Recommendation**	**Design Solutions**
Easy to enter height and weight Easy to catch a mistake through warning messages while entering height and weight Can move to Patient Screening screen without full data entering	Cannot override height or weight after finishing screening	Can enter weight and height in kg/Cm	Trained users to enter different height and weight by creating a different encounter. Use of the manual for training
Screening Screen			
Positive Characteristics	**Negative Characteristics**	**Recommendation**	**Design Solutions**
Fast, automatic BMI calculation Capturing a waist circumference Good information • Clear explanation about confounding • Good to see the list of risk factors Comprehensive tool to evaluate and assess risk factors and calculate BMI	Cannot undo • Cannot change to 'yes' after selecting 'no' for confounding factor • No ability to completely clear screen when a mistake is made Ambiguous information • Need a subjective judgment in confounding factors (e.g., Muscularity) • Confounding factor is confused with Risk factors	Training about confounding factors	Not changed for the system's speed; because the confounding factor includes only two lists, users could be familiarized with the lists through user training Used clearer information and instruction in the infobutton related to the confounding factors
	Less specified list of confounding factors	Specify the list of confounding factors Allow to write free text for other in response to the confounding factor option	Not changed because the CPG does not include more specific factors, and the list of confounding factor was verified by NPs
	Can select only one confounding factor		Not changed because two items are not associated with each other
	Confounding factor list is not visible without selecting 'yes'		

< Table 4 > Usability Evaluation of End-Users and Design Solutions(continued)

Screening Screen			
Positive Characteristics	**Negative Characteristics**	**Recommendation**	**Design Solutions**
	Capture only the number of risk factors	Link risk factor to medical diagnosis and plans	Not changed for the system's speed; the only range of the risk factors affects the plan type But, these functions of the recommendation can be considered in future decision support systems
Planning Screen			
Positive Characteristics	**Negative Characteristics**	**Recommendation**	**Design Solutions**
Clear and concise	Confusion between diagnostics and procedure in the categories of plans	Put together DX and PR in one category	For consistency with the non-template CL-APN, the five plan categories were used
Comprehensive tool including a diagnosis and related to plans • Tailored plans based on a diagnosis, risk factors and a goal • Guide standard care plans • Can see list of plan selected	Cannot change a goal once it has been entered Too many drop-down options under PT		In the infobutton of the standardized plan, the full names of the abbreviations of five plan types were listed
Consistent plan categories with the existing clinical log system	Assess Obesity button is ambiguous because the screen includes plans, as well as a diagnosis		Suggested user training and use of a user manual
Allow me to delete mistake			
Separate five types of plan buttons			

factor. Due to the limitations of a small screen, the PDA-based decision support system could display only 'Confounding factor?' for the question asking if a patient has confounding factors, instead of posing a complete question. Users could see the information that explains the question, 'Confounding factors?' in detail using an infobutton on the PDA-based decision support system. One participant indicated that one factor(muscularity) on the list was subjective, and she wanted the system to direct users more instead of requiring users to use their own judgment for the confounding factors. Another participant indicated as one problem that she could not change her response to 'Yes' after selecting 'No' to the confounding factor option. In the PDA-based decision support system,

responding 'No' to the confounding factor option triggers further screening for obesity, i.e., a pop-up list related to waist circumference appears. Participants recommended training to address this concern, and agreed that training would be helpful in familiarizing them with the confounding factors. As another negative characteristic, one participant mentioned that when users make a mistake in screening for obesity or do not finish all screening processes, they cannot clear all data from the Patient Screening screen.

On the Planning screen, which displays an automatically generated diagnosis and facilitates documenting of CPG-based plan items, participants agreed that the template was visible and easy to use. In particular, they mentioned as positive characteristics that the plans are tailored, and the system guides users with standard care plans. In addition, they stated that the system has the same plan categories and separate buttons, like the existing clinical log system. However, one participant indicated two pop-up lists under teaching and counseling plan type as a negative characteristic, stating that she disliked selecting the pop-up lists several times to select a plan item. Some participants asked about abbreviations of the button names(DX, PR, RX, PT, and RF) to confirm their meaning, even though they were familiar with the plan types of the existing clinical log system. One participant indicated that the fact that she could not change a goal once it was selected as a negative characteristic.

The usability problems that were identified through the user testing were discussed with the project team members, and solutions were suggested to improve the user interface of the PDA-based decision support system before the final implementation(Table 4).

Discussion

During the usability testing, end-users completed all the required tasks without encountering a severe usability problem, and agreed that the system was easy to use, clear, concise, and useful. The negative interface characteristics that were identified by the end-users provided guidance for improving the user interface. In particular, the usability testing provided valuable information for designing a user-centered interface.

Overall, end-users stated that the system was easy to use and useful. However, some negative characteristics that were identified include problems related to 'confounding factors'. Some end-users confused the confounding factors related to obesity with risk factor assessments, and wanted to be provided with more information about and specific lists of the confounding factors. One possible reason for this confusion is that confounding factors are not usually related to pediatric obesity. Because all of the participants in this evaluation had just graduated from a pediatric or neonatal program, they may not have been familiar with the content of adult obesity CPGs. However, because the researcher found that nursing processes and documentation are similar between adult care and pediatric care while the project team was developing the PDA-based decision support system for the management of pediatric obesity, the use of pediatric or neonatal graduates as end-users for user testing was otherwise not an issue.

Even though end-users were briefly trained to use the system, they used an unnecessary number of taps for the first pop-up lists or when selecting several plan items under the same plan type using the plan type buttons (e.g., to enter 'diet: food

shopping' the users tapped 'Diet' on the first level pop-up list and selected 'diet: food shopping from the second pop-up list, and then to enter 'diet: portion control' users tapped 'Diet' on the first level pop-up list or the plan type button, 'Patient Teaching (PT)' again). As a result, users cited too much tapping as a negative characteristic; excessive tapping may frustrate users and affect their acceptance of a system. Training would be useful for minimizing unnecessary behavior patterns.

Another negative characteristic that was identified by users was related to the irreversibility of some user selections as a result of functions intended to optimize the system's speed. For example, once users select a goal, a planning template is displayed and the goal cannot be changed. In addition, once users select 'yes' in response to whether they will screen a patient or not, the next step in the screening process is triggered and BMI is automatically calculated and displayed. While users liked the speed of the system, they wanted their choices to be reversible. The lack of back buttons for reversal of actions was also identified as a usability problem by users in the usability testing of another handheld device (Alexander, Hauser, Steely, Ford, & Demner-Fushman, 2004).

In the usability testing, participants' age and the number of years of experience as a registered nurse (RN) varied, in spite of the small sample size. Participants had about 2 years of experience using the existing clinical log system as a requirement of their master's APN programs. However, on their self-evaluations 3 out of 5 reported their sophistication in handheld device use to be below average. Similarly low sophistication of handheld device use was reported by nurse participants in another study that reported usability testing (Rodriguez et al., 2003). Participants' limited experience with PDAs indicates that user training is necessary for the implementation and evaluation of a PDA-based decision support system. The users' different characteristics, including demographic and level of experience as an RN, with computers, and with handheld devices, resulted in various responses in the evaluation of the PDA-based decision support system. However, their previous experience with the existing clinical log system may have affected the results of the evaluation, since no one participating in the end-user testing was unfamiliar with the clinical log system.

Several studies have shown that user interface characteristics have an effect on task performance time(Poon & Fagan, 1994; Poon, Fagan, & Shortliffe, 1996); thus, users' performance time can be another factor in the evaluation of a user interface. In the usability testing, one participant took less than three minutes to perform a task requiring normal nursing processes including screening for obesity and planning obesity management, while others took about five minutes.

Given that interface characteristics are closely associated with use and user satisfaction, usability testing is crucial to the system development process. Rodriguez et al. (2003) and Rodriguez, Borges, Soler, Murillo, and Sands(2004) showed that writing a note was the most time-consuming and difficult task for physicians and nurses using PDA-based applications, resulting in a low level of satisfaction with PDA-based applications. Usability studies comparing PDA-based applications to laptop -based applications using a touchpad found that it was easier to perform tasks that require only pointing and clicking(e.g., looking for the most recent vital signs, acknowledging a pending medication order, entering Intake/Output measurements, and entering a daily assessment) in a PDA version than a laptop

version with a touchpad(Rodriguez et al., 2003; Rodriguez et al., 2004). In addition, in terms of nurses' satisfaction in Rodriguez et al.'s study(2003), there was no significant difference in their satisfaction between the two nursing documentation systems except in writing notes. Due to the smaller font size and extra scrolling required for the PDA version, users could perform the task that consisted of reading a paragraph more easily using the laptop version (Rodriguez et al., 2003). Young, Leung, Ho, and McGhee(2001) found that users' acceptance of handheld computers is related to the characteristics of tasks in bedside nursing care; pen-based applications are preferred to keyboard-based devices for ease of use, accuracy, and speed in entering structured data(Young, Leung, Ho, & McGhee, 2001). These results support this study's findings that selecting from and clicking on a pop-up list is the preferred method of data entry, as opposed to directly writing text, for the PDA-based decision support system for the management of obesity, and that users were satisfied with the system and perceived the system as easy to use because the tasks of screening for obesity and documenting the obesity management plan are not complex.

Although users in these studies responded positively regarding their acceptance of PDA-based application, in some usability evaluation studies, users' acceptance of PDA-based systems was lower than for alterative systems(Chang, Tzeng, Wu, Sang, & Chen, 2003). Review of the literature indicated that limitations of the interface of a PDA are related to users' acceptance; therefore, more effective user interface designs are needed. In addition, the literature showed that another possible factor affecting user acceptance is limited experience with handheld devices and familiarity with desktop-based systems rather than PDA-based systems(Chang, Hsu, Tzeng, Sang, & Hou, 2004; Chang et al., 2003; Young et al., 2001). User training was one of the recommendations for improving users' acceptance. In this research, many participants mentioned that user training was necessary for improving minor usability problems that were identified during the previous heuristic evaluation and in the end-user usability testing.

Limitations

This research has potential limitations related to the sample size and composition and to the laboratory setting of the usability testing. Participants were recent graduates who had experience with the existing PDA-based clinical log system. Considering Rodriguez et al. (2004)'s finding that a PDA application to access an electronic patient record system required a high degree of learnability for novice users, the participants' experience with the existing PDA application may have resulted in usability problems relevant to PDA novices.

Considering the mobile nature of handheld devices, realistic simulations of the real tasks and of the real settings are considered for evaluation of mobile computing(Bertini et al., 2005). In this study, scenarios were used as a way of simulating the context. However, a laboratory setting may be different from users' clinical settings and this different environment and observation may affect the results of end-user testing.

Conclusions

Through the usability testing using end-users, usability issues that were unrecognized by the developer or usability experts were identified by APNs. This approach had an important impact on

making the system easier to use and more useful from the perspective of design and content. The results of this evaluation provided iterative feedback regarding the design and implementation of the PDA-based decision support system for the management of obesity. Considering that the limited research on handheld usability evaluation in contrast to the recent increase in use of handheld device-based applications, the usability engineering methods employed in developing and evaluating the PDA-based decision support system for the management of obesity could provide a precedent for other research on design, implementation and evaluation of handheld device-based health information systems.

Acknowledgements

This research was supported by the National Institute of Nursing Research (1R01 NR008903). The authors thank all of the project team members who worked on the mobile decision support-advanced practice nurse team at Columbia University School of Nursing.

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Abstract

Usability Testing of a Prototype Personal Digital Assistant (PDA)-based Decision Support System for the Management of Obesity

Purpose: The purpose of this study was to evaluate the usability of a prototype personal digital assistant (PDA)-based decision support system for the management of obesity through usability testing with end-users (Advanced Practice Nurses [APNs]) prior to its implementation in clinical settings.

Methods: This descriptive study used observational and think aloud techniques to address the research question: what usability problems are perceived by end-users? Five APNs were provided with the scenarios and the list of tasks to evaluate the application. Their verbalizations were recorded through Morae usability software. Data analysis was based on the data captured through Morae, transcriptions, notes, and the end-user survey.

Results: End-users completed all the required tasks without encountering a severe usability problem, and agreed that the system was easy to use, clear, concise, and useful. Usability issues that were unrecognized by the developer or usability experts were identified by APNs. The usability problems were categorized according to positive characteristics, negative characteristics, and recommendations. The usability issues were discussed with the project team members, and solutions were suggested to improve the user interface of the PDA-based decision support system before the final implementation.

Conclusions: This approach had an important impact on making the system easier to use and more useful from the perspective of design and content. The results of this evaluation provided iterative feedback regarding the design and implementation of the PDA-based decision support system for the management of obesity.

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