Study of Text and Numeric Input Modalities on PDAs

by

Naomi Acosta

A thesis submitted in partial fulfillment of the requirements for the degree of

Master of Science

in

Computer Engineering

University of Puerto Rico
Mayagüez Campus
2004

Approved by:

_____	_____
Néstor J. Rodríguez, PhD. Chairperson, Graduate Committee	Date
_____	_____
Jose A. Borges, PhD. Member, Graduate Committee	Date
_____	_____
Javier A. Arroyo-Figueroa, PhD. Member, Graduate Committee	Date
_____	_____
Celia R. Colón Rivera, RN, PhD. Representative of Graduate Studies	Date
_____	_____
Fernando Vega, PhD. Director of the Department	Date

Abstract

This study is about textual and numerical input modalities on PDAs for supporting nursing tasks. Four input modalities for textual data input and four for numerical data input are compared and discussed. A total of six experiments were conducted to test these input modalities.

The methods compared in the numerical data entry experiments were an increment/decrement interface, a custom made numerical keyboard, a PDA's software keyboard, and a PDA's Graffiti. For the textual data entry experiments the methods compared were a PDA's hardware keyboard, a PDA's software keyboard, a PDA's voice recorder and Graffiti. The PDA use for the experiments was a Sony Clié PEG-NZ90.

The study revealed that for textual data input none of the method resulted clearly superior to the others. However, the voice recorder resulted the fastest method. Thus, the voice recorder should be seriously considered for nursing tasks requiring significant textual data input. However, there are issues of transcription, confidentiality and security that need to be addressed when this modality is used for clinical applications.

For numerical data input the study revealed that the custom made numeric soft-keyboard was the best method of the four. One important finding of this study was the inferior performance exhibited with Graffiti. Thus, the results of this study do not encourage adopting Graffiti for clinical tasks.

Resumen

Este estudio trata sobre modalidades de entrada de data numérica y textual en organizadores personales (PDA por sus siglas en inglés) para apoyar tareas de enfermería. Se comparan y discuten cuatro métodos para la entrada de data textual y cuatro métodos para entrada de data numérica. Un total de seis experimentos fueron conducidos para probar estas modalidades.

Los métodos comparados para entrada de data numérica fueron un método de incrementar/disminuir dígitos, un teclado numérico personalizado, un teclado en pantalla de una PDA y Graffiti de una PDA. Para entrada de data textual los métodos probados fueron, un teclado físico de una PDA, un teclado en pantalla de una PDA, una grabadora de voz de una PDA y Graffiti. La PDA utilizada para los experimentos fue la Sony Clié PEG-NZ90.

El estudio reveló que para entrada textual ninguno de los métodos resultó claramente superior a los otros. Sin embargo, la grabadora de voz resultó ser el método más rápido de todos. Este método debe ser seriamente considerado para tareas de enfermería que requieran una cantidad substancial de entrada textual. Sin embargo, existen asuntos de transcripción, confidencialidad y seguridad que necesitan ser atendidos cuando esta modalidad es utilizada para aplicaciones clínicas.

Para entrada numérica el estudio reveló que el teclado numérico personalizado resultó ser el mejor de los cuatro considerados. Un hallazgo importante del estudio fue el rendimiento inferior exhibido por el método de Graffiti. Por lo tanto los resultados del estudio no apoyan la adopción de Graffitti para aplicaciones clínicas.

To

God, my family and my friends for their understanding and support.

Acknowledgments

First of all, thanks to God for giving me this opportunity and for all his blessings. Thanks to my parents Doris A. Feliciano and Wilfredo Acosta and my sisters Aitza Ayleen Acosta and Atza Mara Acosta for their support, their love, their help and understanding. Thanks to my fiancé Luis E. Arroyo for his love and understanding, for helping me and being with me in the good and in the bad times. Thanks to my Grandmother Asunción Maldonado for her precious help, love and understanding. Thanks to Dr. Néstor J. Rodriguez, my advisor, for helping me, guiding me and giving me the privilege of working with him and being like a friend to me. Also, thanks to Dr. José Borges and Dr. Javier Arroyo members of my graduate committee, and Dr. Celia Colón Rivera for their guidance and help during the research process. I would like to give thanks to Viviam Murillo and Yajaira Soler for their help during the research and documentation process. Thanks to my friends and all the students who gave part of their time for the experiments presented in this work.

Thanks to the National Science Foundation and the Center for Computing Research and Development (CECORD) at the University of Puerto Rico at Mayagüez for the support of this project.

Table of Contents

List of Tables

List of Figures

List of Acronyms

HIPPA	Health Insurance Portability and Accountability Act
PDA	Personal Digital Assistant
PalmOs	Palm Operating System
PC	Personal Computer
HR	Hearth Rate
B/P	Blood Pressure
RR	Respiration Rate
O_2Sat	Oxygen Saturation
F	Fahrenheit
SD	Standard Deviation

Chapter 1

Introduction

1.1 Justification

Personal Digital Assistants (PDA's) can be very useful, especially in the health field. Because of their portability, they can be used by health professionals to enter and view information in the patient's record at the bed side. However, portability comes with a price. The small size of PDAs results in a small screen, which reduces the area available for entering and viewing information. These limitations affect user's performance and satisfaction.

Some studies demonstrate the need for improving numeric and textual data entry on PDA. A study to investigate why a digital resident diagnosis log on PDA was poorly accepted is described in [Jao03]. The authors concluded that one of the reasons was the slowness of the devices. Users complained about the complexity of the user interface and the long time needed to enter a single patient entry. They stated that in order to convince physicians to use PDA's for patient care, the devices have to be more time efficient. PDA performance, user interface and data entry issues have to be addressed and improved.

In [Young01] the authors reported an evaluation made by nurses on a hand-held device for data entry on nursing record simulations. Nurses considered that the pen-based interface was less desirable for entering textual data than the keyboard based interface.

They thought that the data was less accurate and the data entry process was difficult. These findings are consistent with the findings of the study describe in [Rodríguez03]. In this study a comparison was made between two versions of a nursing documentation application, one running on a PDA and the other running on a Laptop. The study revealed that entering textual data on a PDA was difficult for the nurses in comparison with the laptop. This fact was one of the factors that caused nurses to prefer the laptop for textual data entry.

The problems described on the previously mentioned studies evidence the need for improving input modalities for clinical applications. The study described in this thesis is a step toward this goal. The main objective of this thesis was to compare PDA input modalities to find the input methods that suit better nurse's tasks that require text and numeric data input. Six input modalities on a PDA running the PalmOS operating system were compared. These input modalities were the Palm's hardware keyboard, software keyboard, voice recorder and Graffiti, and two custom-made input modalities. The criteria for the comparison were the time to complete the tasks and user satisfaction. The findings of this study will provide valuable information to clinical application developers for selecting suitable input modalities for textual and numeric data entry.

1.2 Outline of the Thesis

This document consists of six chapters. Chapter 2 presents a literature review of non-medical and medical literature concerning PDA input methods performance. Chapter 3 describes the development of the interfaces used for the study. The Chapter 4 describes the methodology, the test subjects, the input methods and the test design and results of

the tests conducted. Chapter 5 presents a discussion of the results of the tests described in Chapter 4. Finally, the conclusions of the study and some recommendations for future work are presented in Chapter 6.

Chapter 2

Literature Review

2.1 Introduction

Not many usability studies have been conducted to test data input modalities for PDAs, specifically, in the health care area. This literature review describes primarily, various usability studies on PDA input modalities. In addition various studies that are pertinent to usability on data input methods used in medical computerized systems for PDAs are discussed.

2.2 Non-Medical Usability Studies

A psychophysical comparison of two stylus-driven soft keyboards is discussed in [Bohan99]. This study compared text entry performance on two stylus-driven soft keyboards for PDA's. The first was a miniaturized QWERTY style, and the other was the T9 that resembles a touchtone telephone keypad without the numbers. The results were that transcription rates were higher for the QWERTY keyboard than for the T9. Other experiment demonstrated that the poorer performance of the T9 may have resulted from an increase of visual scanning due to perceptual grouping of the letters on the keys.

On [Ayan01] the authors compared Graffiti and soft-keyboard tapping with the task that involved entering alphanumeric characters and special symbols. The purpose of this experiment was to see which input entry method is faster and more accurate and to

observe the pattern of learning for both methods. The test subjects were inexperienced with PDA usage. The authors found that, at first, text entry on Graffiti was slower, but with usage the level of words per minute increased. But, with the keyboards, the level of words per minute remains practically the same with usage. The authors suggest that experienced users may perform faster with Graffiti.

In addition, a comparison of Graffiti vs. the on-screen soft-keyboard for experienced Palm users was presented in [Giambalvo01]. This experiment tested speed to correct completion of four tasks involving alphanumeric characters. The subjects were experienced palm pilot users. Their tests revealed no statistical significance between completion times for Graffiti and keyboard input methods.

2.3 Medical Usability Studies

An evaluation to find the reasons for the poor acceptance by neurologists of a resident diagnosis log was presented by [Jao03]. The Resident Diagnosis Assistant was a PDA based program which allows neurology residents to collect diagnostic information about patients and upload the data into a departmental computer. Palm m105 PDAs with the diagnosis assistant program were distributed to 10 physicians. The diagnosis data entry form consists of 4 fields including medical record number, date of examination, procedure types, and diagnosis types. Both procedure and diagnosis were in check-box format. The authors used a user survey to evaluate the program's usefulness and interface. Preliminary results showed low user acceptance (60%) for the technology. The complaints of the users included the complexity of the interface and the long time needed to enter a single patient entry. The researchers concluded that the reasons for the poor

acceptance included: slowness of the devices, a cumbersome user interface and the need to enter patient data manually.

In a study presented by [Lu03], they examine PDA usage and non-usage patterns among physicians. They wanted to identify the barriers that impede the physicians to use their PDA's. In this study, they wanted to record data about how physicians use their PDA's, functions and applications used, functions and applications not used, reasons and examples of why they don't use their PDAs for those functions, and recall of specific incidents with PDA usage. Twenty physicians were recruited from a major university medical center, and were interviewed face to face. All PDAs used by the physicians run the Palm operating system. On the analysis the authors identified four types of barriers: 1) organizational barriers (30% of subjects), 2) usability barriers (95%), 3) inadequate technology support or access barriers (85%), and 4) lack of need and motivations (100%). In the usability barriers area the issues included screen size, hand writing recognition problems, data entry mechanism, and navigation problems among others.

An evaluation of the use of hand-held computers for bedside nursing care was discussed in [Young01]. The study aimed to determine the usefulness of keyboard-based and pen-based hand-held devices. The authors compared the utility and efficiency of these two methods for clinical tasks. For the study they used PALMAX PD-1000 Plus Mini Notebook PC's. This is a miniaturized laptop with a keyboard and a touch screen with a stylus (pen). The PCs had Windows98 operating system. For this project 100 nurses were required from six different specialties. Each nurse was asked to complete 3 different nursing record simulations (S1, S2, S3) using a pen based and a keyboard based interface. The task S1 consisted on entering structured data using only checkboxes. Task

S2 consisted of entering data using only checkboxes and pull-down lists. And S3 consisted of entering only textual data.

In conclusion, nurses preferred the pen-based interface for entering structured data (S1, S2). They found that this interface was easier to use and more accurate and faster. On the other hand, they considered the pen based interface less desirable for entering textual data (S3). Specifically, they disliked that they had to learn to use the hand writing recognition software. They thought that the accuracy of the data was poor, and entering the data was more difficult with this interface. They concluded that the choice of an input device depends on the type of data to be input. The pen-based device is better for structured data input but not for textual data.

In [Rodríguez03], a comparison was made between two versions of a nursing documentation application. They used a laptop version and a PDA version to test the application in terms of efficiency and satisfaction achieved by the nurses that conducted typical tasks. The PDA used was an IPAQ3835 running Microsoft Pocket PC operating system and the laptop version was implemented on a laptop with a touchpad running the Windows2000 operating system. Eighteen nurses from a teaching hospital in Boston participated in the study. The nurses didn't have prior experience using the documentation application nor using a PDA. The participants were asked to perform 8 tasks on each version. The tasks were the same for each version (PDA and laptop). The authors concluded that in overall the participants completed the tasks in less time in the laptop version. The tasks that took less time on the PDA were looking for the most recent vital sign measurements, acknowledging a pending medication order, entering I/O measurements and entering a daily assessment. The tasks that took less time on the laptop

were reading a paragraph, entering vital sign measurements and writing a note. However, writing a note was the most time consuming task in both versions. But, the most important conclusion is, that in terms of completion time, nurses can be as effective with a PDA or a Laptop in performing typical nursing tasks at bed side with the exception of writing notes.

Chapter 3

Numeric and Textual Data Input User Interfaces

3.1 Introduction

The first step of this research consisted in selecting an appropriate PDA for the study of input modalities. Because of its wide variety of input modalities the Sony Clié PEG-NZ90 running Palm OS was selected for the study (See Figure 3.1). This PDA features a physical miniaturized keyboard, a miniaturized soft-keyboard and voice recorder. It also comes with a gesture recognition method called Graffiti. Graffiti uses an alphabet similar to the Roman alphabet that we use everyday where the letters are written with a stroke of the stylus.

Figure 3:1 Sony Clié PEG-NZ90

The next step was the implementation of the user interfaces needed for the study of input modalities. Various prototypes of a user interface that allow nurses to enter vital signs were used for the numeric data input tests described in the next chapter. Also, an

interface for entering nursing notes was used for the textual data input tests described in the next chapter. These interfaces are redesigned versions of the nursing documentation application developed by Yajaira Soler [Soler03] for a PocketPC platform. NS Basic for Palm was used for developing the user interfaces for the Palm platform.

3.2 Methods for numeric input

The first interface developed featured the up and down arrows button method shown in Figure 3.2. With this method the digits of each of the vital signs entries can be incremented or decremented by tapping with the stylus on the up and down arrows respectively.

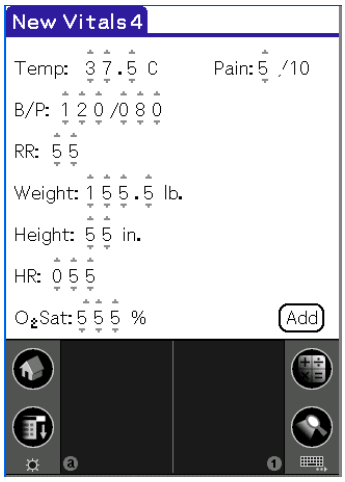


Figure 3:2 Increment/Decrement Interface for Entering Vital Sings

The second method for numeric input is presented in Figure 3.3. This interface features a custom-made numeric soft keyboard close to the vital signs entry fields. With

this method a vital sign is entered by taping with the stylus on the corresponding field and then typing the numbers on the custom-made soft keyboard.

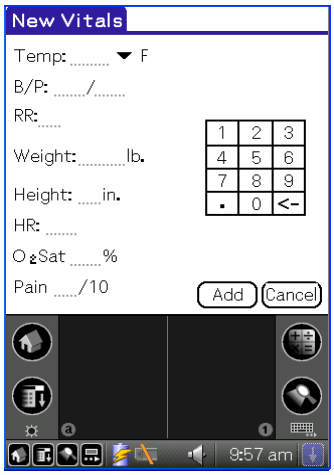


Figure 3:3 Custom Made Soft Keyboard for Entering Vital Sings

The third method used for numeric input is shown in figure 3.4. The Clié's software keyboards is a miniaturized virtual QWERTY keyboards that appear on screen and has to be typed with a stylus (See Figure 3.4)

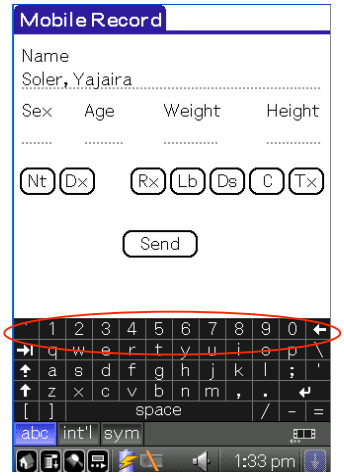


Figure 3:4 The Clié's Numerical Software Keyboard

The fourth method, the Clié's graffiti is a gesture recognition method that uses a unistroke alphabet (See Figure 3.5). Unistrokes are numbers, letters and punctuation marks made by drawing with the stylus the corresponding alphanumeric symbol with one stroke on an area provided Palm's user interface. The numbers are written on the right side of the graffiti writing area.

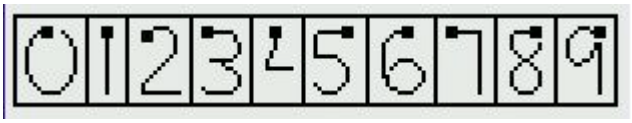


Figure 3:5 Graffiti Numeric Alphabet

3.3 Methods for Textual Input

Figure 6 shows the user interface used for entering nursing notes for the textual input tests described in the following chapter. The first input method used for entering text with this user interface was the Clie's software keyboard (See Figure 3.6). To enter the text the user simply taps on the entry field and then taps on the letters of the keyboard.

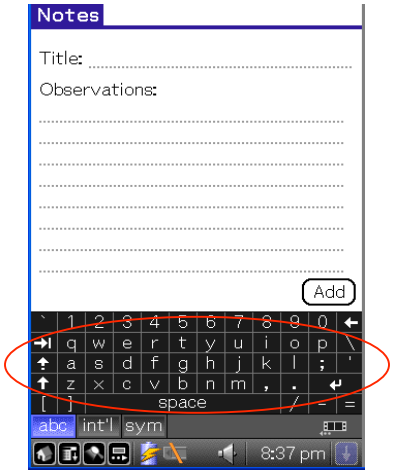


Figure 3:6 User Interface for Entering Nursing Notes with the Clié's Software Keyboard

The Clié's hardware keyboard is a miniaturized physical QWERTY keyboard that can be tipped with the fingers (See Figure 3.7.).

Figure 3:7 Clié's Hardware Keyboard

Another input method used for textual data entry was Graffiti (See Figure 3.8.). Like for the numbers and other mathematic symbols the letters are written with only one stroke of the stylus on the left side of the Graffiti Writing Area. The dot indicates the starting point on the alphabet.

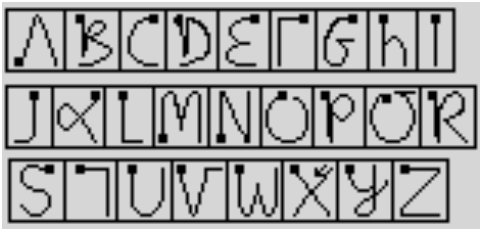


Figure 3:8 Palm's Graffiti Textual Alphabet

Graffiti is a gesture recognition method that uses a unistrokes alphabet. Unistrokes are letters similar to the ones of the alphabet but made drawing the letter with one stroke on the input area with the stylus (a pen like instrument). This method was created to accelerate the data input procedure because the system recognizes each stroke as a letter; this way the user has to lift less the stylus from the screen. This intends to reduce the data entry time because the user can write more simple letters without having to look at the writing area.

The Graffiti Writing Area is the area in which the user enters the data with Graffiti characters. In this part of the experiment the user enters the data manually and the data is displayed in the output area of the interface (See Figure 3.9.). The letters and punctuation marks have to be entered in the left side of the Graffiti Writing Area.

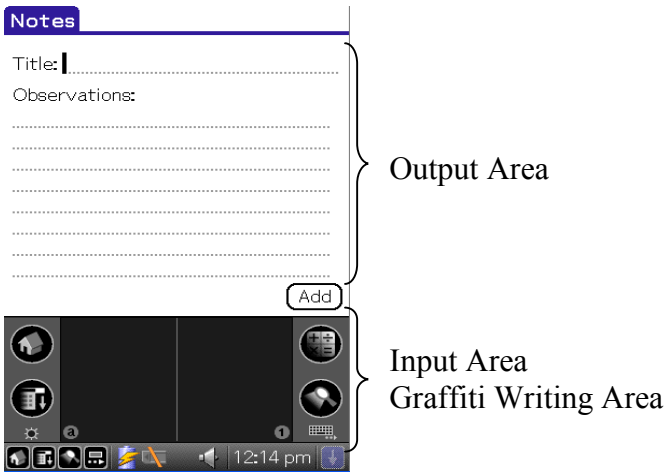


Figure 3:9 Textual Data Entry Interface with Graffiti Writing Area

In addition to the previously mentioned modalities the Clié also features a voice recorder. Notes can be recorded using a user interface provided by the Clié . The recorded note is saved on the PDA for later listening, along with the record title, date, duration of the recording and mode recording.

Chapter 4

Usability Tests

4.1 Introduction

In this chapter the methodology and results of three numeric data input and three textual data input usability tests are presented. The tests compared four numeric data input modalities and four textual data input modalities in terms of the time to complete a task and user satisfaction. Each test involved two input modalities.

The tests followed a within-subjects experimental design with a balanced order of module presentation to minimize transfer of learning effects. The tests were conducted at the Nursing and Electrical/Computer Engineering Departments of the University of Puerto Rico at Mayagüez. The participants were randomly selected based on a first-come first-serve basis. They were asked to participate after a brief description of the test and its purpose. If the participant accepted the test was administered on the spot.

For the first tests nursing students were recruited. Nursing students were selected instead of nurses because they were more available and easier to recruit than professionals nurses. For the last experiment we needed users with experience using Graffiti. Since very few nursing students had experience with Graffiti we selected electrical and computer engineering students with experience with Graffiti for this experiment.

4.2 Numeric Data Input Tests

Before the tests the participants were given an orientation about the procedure that would be followed during the test, the experimenter's role and what was expected from the participants. A short tutorial on the input modalities use for the test was given to each of the participants before the test (See Appendix B). A different group of participants were selected for each of the tests. Each participant was asked to enter the following vital signs information with each input modality:

Temp: 100.0 F

B/P: 130/090

RR: 50

Weight: 215.0 lb.

Height: 68 in.

HR: 60

O_2Sat: 85%

Pain: 5/10

After completing the previous task the participants were asked to rate each of the input modalities using a 1 to 7 scale where 1 is not satisfied and 7 is very satisfied (See Appendix C) and also to make comments or suggestions about the input modalities. After the participants completed the questionnaires a debriefing session was conducted to make sure that all their reactions were collected and understood.

The dependent variables of the tests were time to complete the vital signs entry task and user satisfaction. Paired t-test was used to analyze the completion time and a Wilcoxon test to analyze the user satisfaction. Linear regression was used for evaluating transfer of learning effect.

4.2.1 Increment/decrement vs. Custom-made Soft Keyboard Test

In this test the increment/decrement modality (See Section 3.2.) was compared with the custom-made soft numeric input modality (See Section 3.3.). Twenty four nursing students participated in the test. Only three of the participants had previous experience with PDAs. Five participants were in their first year of study, five were on their second year, four on their third year, four on their fourth year and six on their fifth year. The participants have an average of three years of concentration studies.

All the participants completed the test successfully. A t-Test analysis revealed no significant difference in the completion time between the increment/decrement modality and the custom-made soft keyboard modality (t stat = 1.15 < t Critical = 2.07). The custom keyboard resulted 10.38% faster than the increment/decrement modality. The participants completed the task in an average time of 62 sec. (SD = 14.27) with the increment/decrement modality and 56 sec. (SD = 26.11) with the custom-made soft keyboard modality (see Figure 4.1).

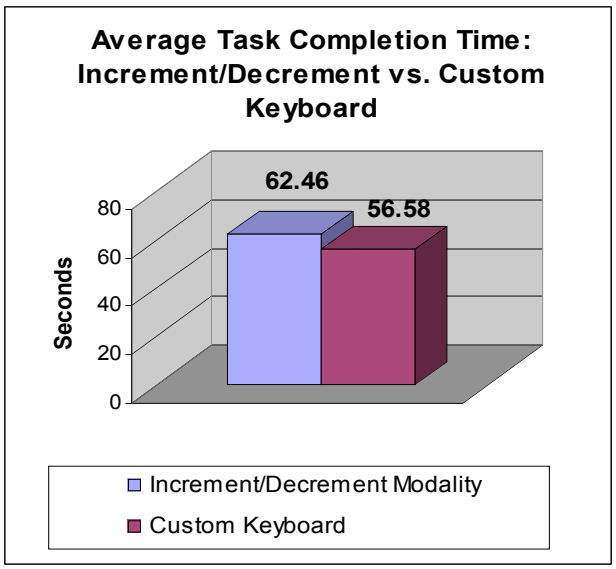


Figure 4:1 Average Completion Time in Seconds for the Increment/Decrement and the Custom Made Soft Keyboard Modalities.

A Wilcoxon analysis revealed a significant difference for preference ratings between the increment/decrement modality and the custom-made soft keyboard modality ($t = 76.5 < tCrit = 81$). The average rating for the increment/decrement modality was 4.91 and for the custom-made soft keyboard modality was 6.12 (See Figure 4.2.). A total of 18 users preferred the custom-made soft keyboard modality over the increment/decrement modality while 6 users preferred the increment/decrement modality over custom-made soft keyboard modality.

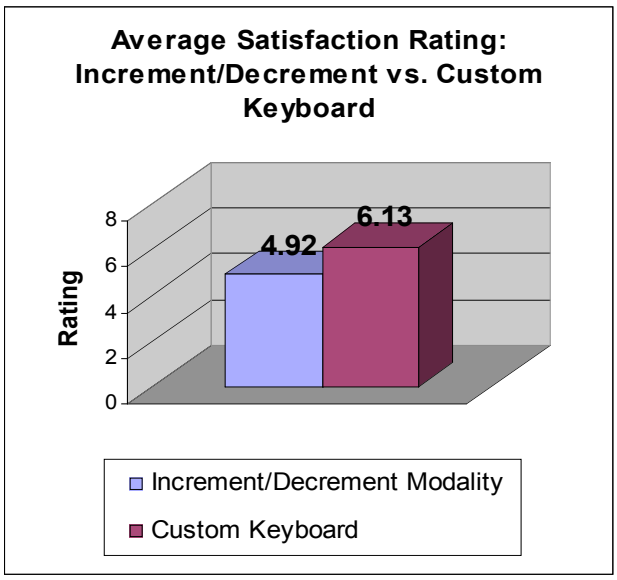


Figure 4:2 Average Preference Ratings for the Increment/Decrement and the Custom Made Soft Keyboard Modalities

A linear regression analysis revealed no significant transfer of learning effect carried between the increment/decrement modality and the custom-made soft keyboard modality and vice versa.

4.2.2 Clié's Soft Keyboard vs. Custom-made Soft Keyboard Test

The user interface used for this test is shown in figure 4.3. Twenty eight nursing students participated in the test. Only six of the participants had previous experience with PDAs. Five participants were in their first year of study, three were on their second year, seven on their third year, seven on their fourth year and six on their fifth year. The participants have an average of three years of concentration studies.

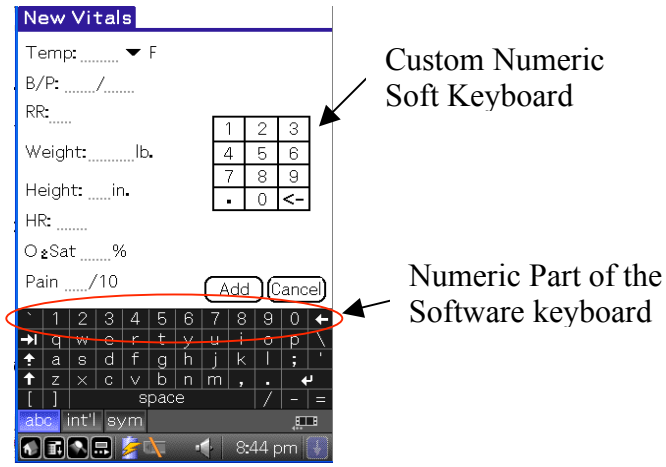


Figure 4:3 New Vitals Interface with Custom Made Soft Keyboard and Palm's Soft Keyboard

A t-Test analysis revealed no significant difference in the time it took the participants to complete the task. The mean completion time for the soft-keyboard was 52.32 sec. (SD = 19.51) and for the custom keyboard was 46.78 sec. (SD = 10.89) (See Figure 4.4.) The custom keyboard resulted 11.38% faster than the soft-keyboard method.

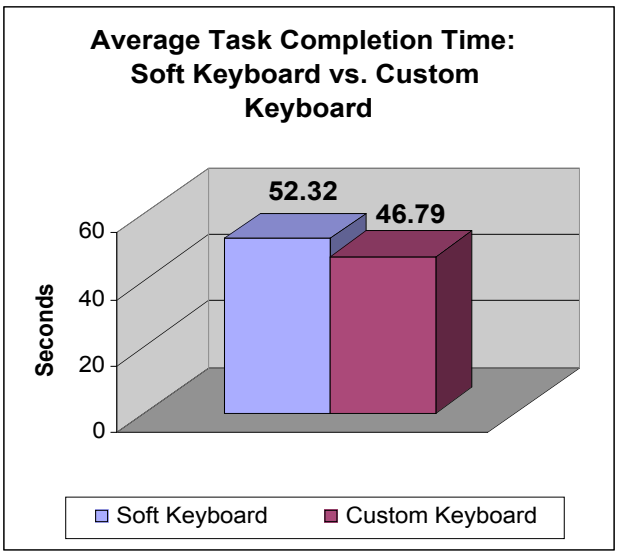


Figure 4:4 Average Completion Time in Seconds for the Palm's Soft Keyboard and the Custom Made Keyboard

A Wilcoxon analysis revealed significant differences in preference ratings between the soft-keyboard and the custom keyboard ($t = 82 < tCrit = 116$). The mean preference rate for the soft keyboard method was 5 points and for the custom-made keyboard the mean rate was 6.21 points (See Figure 4.5.). A total of 23 users preferred the custom keyboard while only 8 preferred the soft-keyboard.

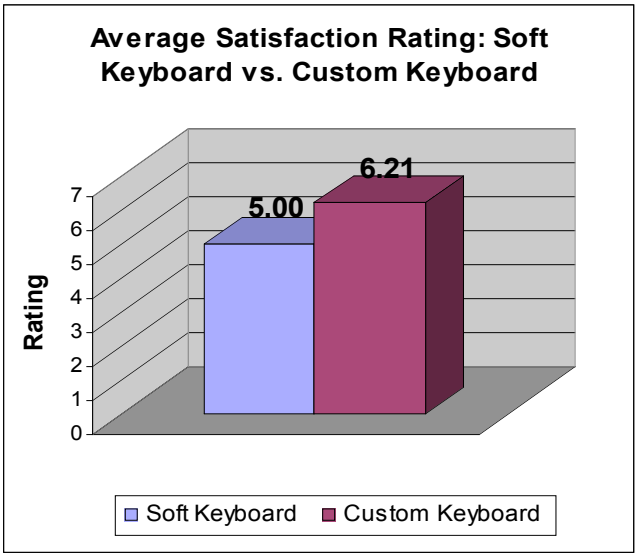


Figure 4:5 Average Preference Ratings for the Palm's Soft Keyboard and the Custom Keyboard.

A linear regression analysis revealed a significant transfer of learning effect from the custom keyboard to the soft-keyboard, but no significant transfer of learning effect vice versa.

4.2.3 Graffiti vs. Custom-made Soft Keyboard Test

Once again the custom keyboard was tested but this time versus Graffiti (See Figure 3.5.). Twenty six electrical and computer engineering students with experience in the use of Graffiti for Palm participated in this test. The participants had an average of 18 months of experience with graffiti, although there was a fluctuation between 1 and 96 months of experience. The median was 12 months of experience.

A significant difference was found in the task completion time between Graffiti and the custom keyboard using a t-Test analysis. The custom keyboard resulted 39.25%

faster. The mean time for task completion using Graffiti was 56.08 sec. (SD = 22.11) and for the custom keyboard the mean completion time was 40.27 sec. (SD = 10.63) (See Figure 4.6.).

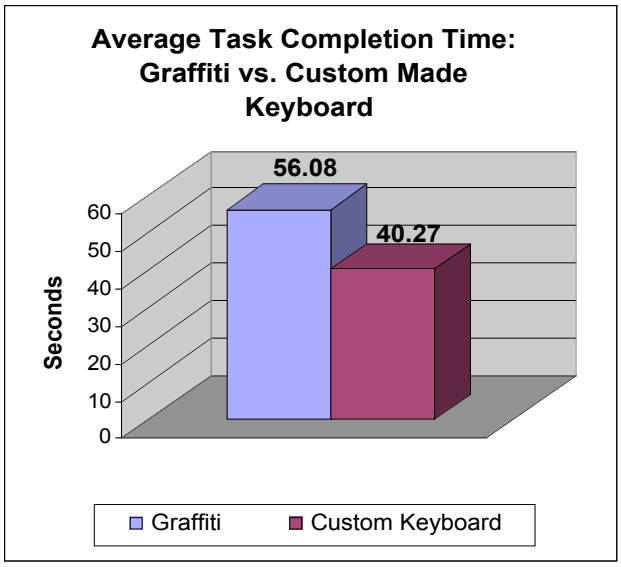


Figure 4:6 Average completion times in seconds for Graffiti and the custom keyboard.

For preference ratings the Wilcoxon analysis did not revealed a significant difference between Graffiti and the custom keyboard (t = 169 > tCrit = 98). The mean preference for Graffiti was 5.92 points and 5.88 for the custom keyboard (See Figure 4.7.) Eleven users preferred graffiti over the custom keyboard while 14 preferred the custom keyboard over graffiti, only one user preferred both methods equally.

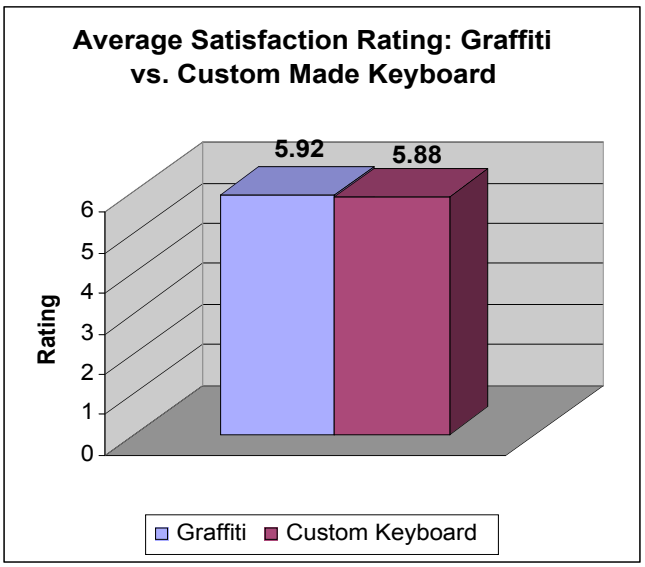


Figure 4:7 Average preference ratings for Graffiti and the custom keyboard.

A linear regression analysis revealed no significant transfer of learning effect from graffiti to the custom keyboard or from the custom keyboard to Graffiti. A correlation analysis revealed that there is no relationship between the task completion time and the months of experience of the subjects with graffiti (tCrit = -0.222 < .38).

4.3 Textual Data Input Tests

Before the tests the participants were given an orientation about the procedure that would be followed during the test, the experimenter's role and what was expected from the participants. A short tutorial on the input modalities used for the test was given to each of the participants before the test (See Appendix B). A different group of

participants were selected for each of the tests. Each participant was asked to enter the following note:

"*Abdomen suave con sonidos intestinales activos en los 4 cuadrantes. Niega dificultad con los intestinos o vejiga. Hematoma en la cadera izquierda, no edema, sensitivo al tacto.*"

After completing the previous task the participants were asked to rate each of the input modalities using a 1 to 7 scale where 1 is not satisfied and 7 is very satisfied (See Appendix C.) and also to make comments or suggestions about the input modalities. After the participants completed the questionnaires a debriefing session was conducted to make sure that all their reactions were collected and understood.

The dependent variables of the tests were time to complete the note entry task and user satisfaction. Paired t-test was used to analyze the completion time and a Wilcoxon test to analyze the user satisfaction. Linear regression was used to evaluate transfer of learning effect.

4.3.1 Clié's Software Keyboard vs. Hardware Keyboard Test

For this test the Clié's software keyboard (See Figure 3.6.) and the hardware keyboard (See Figure 3.7.) were used to enter the nursing note described in the previous section using the user interface for entering nursing notes presented in Figure 3.9. Twenty eight nursing students participated in this test. Only six had previous experience with PDAs. Five participants were in their first year of study, three were on their second year, seven on their third year, seven on their fourth year and six on their fifth year. The participants have an average of three years of concentration studies.

This test was completed successfully by all the participants. A t-test revealed a significant difference in the average time it took to complete the tasks using the two keyboards ((t Stat = 2.51) > (t Critical = 2.05)). The participants were 7.04% faster with the hardware keyboard than with the soft keyboard. The mean time to complete the task using the software keyboard was 168.39 sec. (SD = 37.41) and 157.32 (SD = 39.04) with the hardware keyboard (See Figure 4.8.).

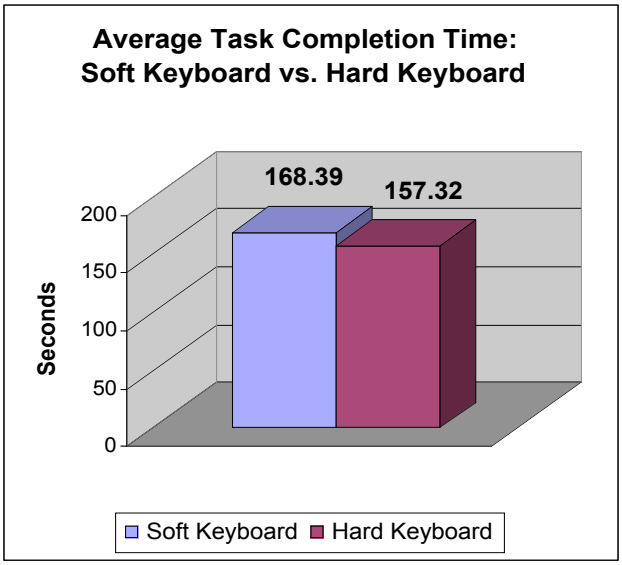


Figure 4: 8 Average completion time in seconds for the palm's soft keyboard and the device's hard keyboard

For preferences a Wilcoxon analysis showed no significant difference between these two methods. The mean preference for the soft-keyboard was 5.25 and 5.53 for the hard-keyboard (See Figure 4.9.) Fifteen of the twenty eight participants preferred the hard keyboard over the soft-keyboard.

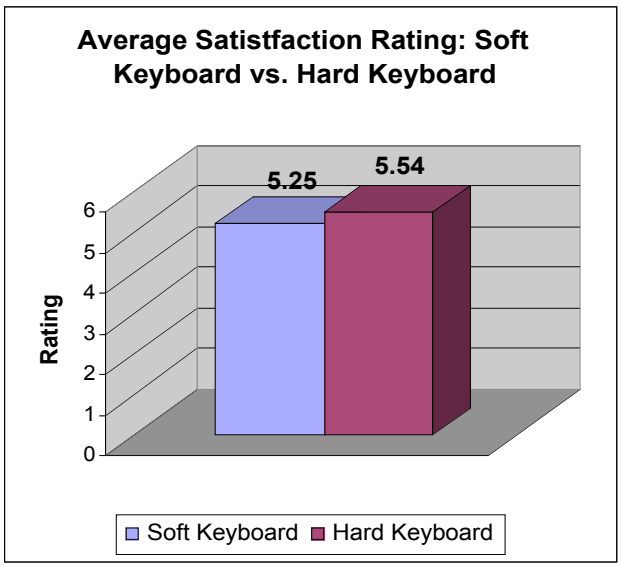


Figure 4:9 Average preference ratings for the palm's soft keyboard and the device's hard keyboard.

A linear regression analysis showed no significant transfer of learning effect from the soft- keyboard to the hard-keyboard or vice versa.

4.3.2 Clié's Hardware Keyboard vs. Voice Recorder Test

For this test the Cilé's hardware keyboard and graffiti were used to enter the nursing note described in section 4.3, using the user interface for entering nursing notes presented in figure 3.9. Twenty six nursing students participated in this test. Only one had previous experience with PDAs. The participants had an average of two and a half years of nursing studies.

A t-Test analysis revealed a significant difference in average completion time between the hard-keyboard and the voice recorder input methods. The mean time for task completion was 147.11 sec. (SD = 33.73) for the hard-keyboard and 13.08 sec. (SD =

2.65) for the voice recorder (See Figure 4.10.) The voice recorder resulted 1,025% faster than the hard-keyboard.

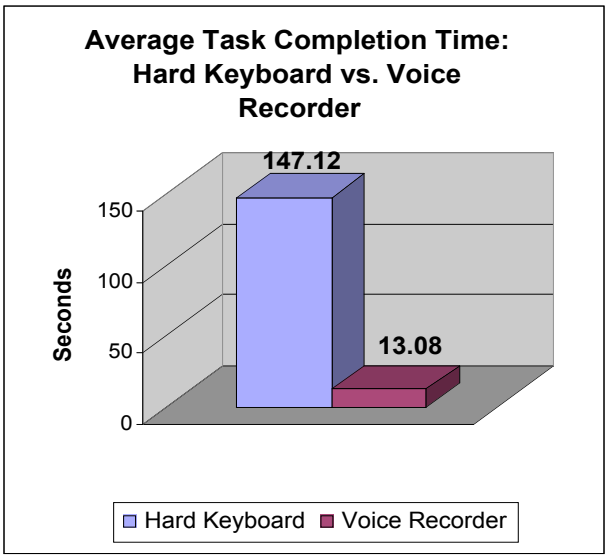


Figure 4:10 Average completion time in seconds for the device's hard keyboard and the voice recorder

A Wilcoxon analysis revealed no significant difference in the preference ratings between these two methods, (t = 147.5 > tCrit = 98). The mean preference for the hard-keyboard was 5.34 points and 5.65 for the voice recorder (see Figure 4.11). A total of eleven participants preferred the hard-keyboard and fifteen users preferred the voice recorder.

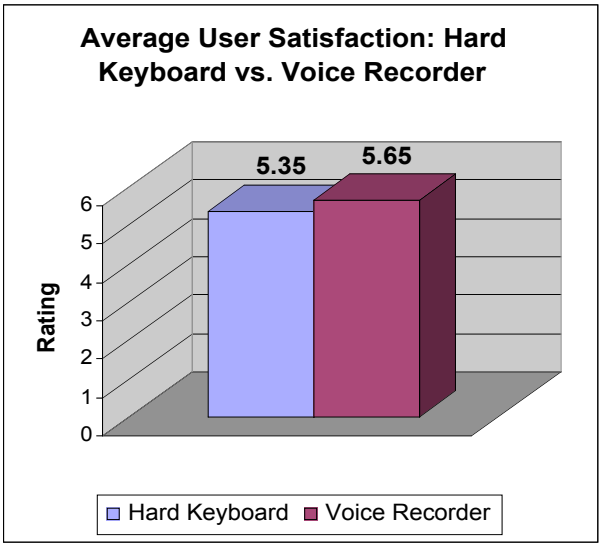


Figure 4:11 Average preference ratings for the device's hard keyboard and the voice recorder.

A linear regression analysis revealed no significant transfer of learning effect between the hard-keyboard to the voice recorder or vice versa.

4.3.3 Clié's Voice Recorder vs. Graffiti Test

Twenty six electrical and computer engineering students with experience using Graffiti for Palm participated in this test. The participants had an average of 18 months of experience with graffiti, although there was a fluctuation between 1 and 96 months of experience. The median was 12 months of experience.

A t-Test analysis revealed a significant difference between the Graffiti input modality and the voice recorder input modality. The mean completion time for a task using Graffiti was 404.08 sec. (SD = 178.88) while the mean time using the voice recorder was of 14.85 sec. (SD = 3.13) (See Figure 4.12.). The voice recorder resulted a 2,621% faster than Graffiti.

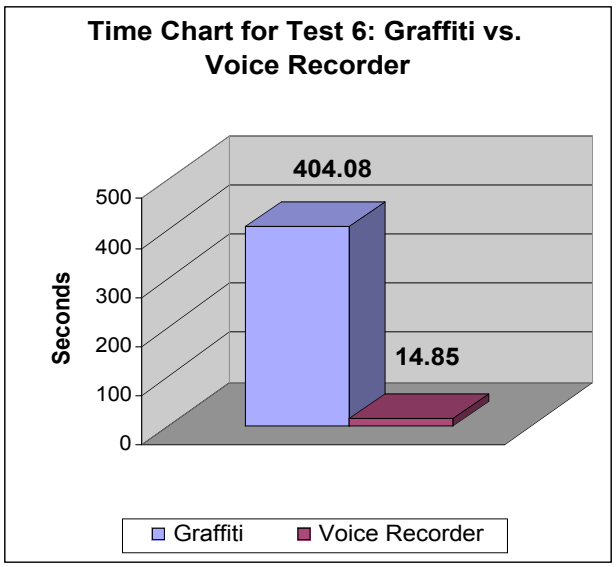


Figure 4:12 Average completion time in seconds for Graffiti and the voice recorder.

A Wilcoxon analysis revealed a significant difference in the preference ratings for Graffiti and the voice recorder input modalities ($t = 60 < tCrit = 98$). The mean preference rating for Graffiti was 4.54 points and 5.96 for the voice recorder (see Figure 4.13). A total of twenty participants preferred the voice recorder over graffiti and a total of six preferred Graffiti over the voice recorder.

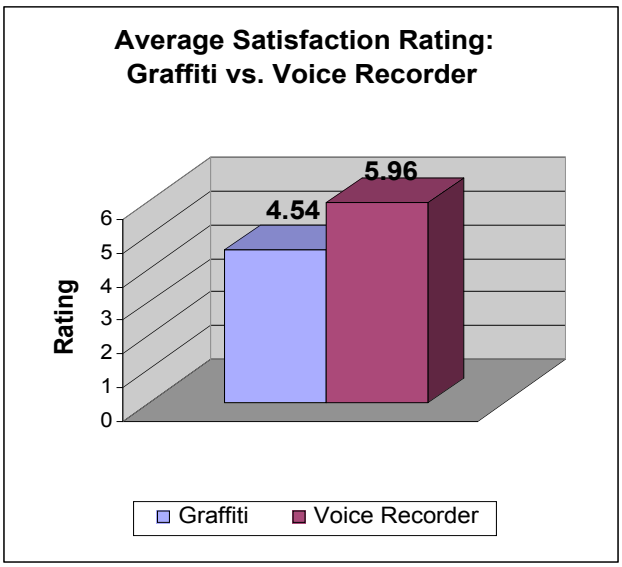


Figure 4:13 Average preference ratings for each method Graffiti and the voice recorder.

A linear regression analysis did not reveal a significant transfer of learning effect from the Graffiti to the voice recorder or vice versa.

Chapter 5

Discussion of the Results

5.1 Introduction

This chapter provides a discussion of the results of the experiments conducted in this study. In addition to the dependent samples t-test analysis and Wilcoxon analysis that were used to analyze the results of the experiments, independent samples t-tests analysis and Mann-Whitney U-test were used to compare the results of other combinations of input modalities. The independent samples t-test was used for the analysis of the completion times of independent samples while the Mann-Whitney U-test was used to analyze the preferences of independent samples.

5.2 Discussion of the Numeric Data Input Tests

The custom keyboard resulted significantly faster than Graffiti; with an average completion time of 40.27 sec. (SD=10.63) while Graffiti had an average of 56.07 sec. (SD=22.12). It seems that this difference in performance was due to the graphical design of the custom keyboard. Some users commented that with the keyboard the user only have to tap in the keyboard while with graffiti the user has to draw the symbol of the number. Also, users commented that with the custom keyboard they commit fewer errors than with Graffiti. In addition, the keyboard was closer to the data entry area.

An independent samples t-test revealed that the Soft Keyboard resulted significantly faster than the increment/decrement method. The Soft Keyboard had an average completion time of 52.32 sec. (SD=19.51) while the Increment/Decrement

method had an average completion time of 62.46 sec. (SD=14.28). No other combination of modalities resulted in a significant difference in completion time.

The custom made keyboard resulted significantly preferred than the Increment/Decrement method. The Custom Keyboard had an average preference rating of 6.13, while the Increment/Decrement had an average preference rating of 4.91 points. The graphical design of the custom keyboard seems to account for this difference in preference. Users said that with the custom keyboard they can obtain more rapidly the desired number. Also they felt that this interface was less prone to cause errors than the other interface. The custom keyboard had bigger and more defined buttons so they were easier to tap.

The custom keyboard also resulted significantly preferred than the soft keyboard method. The Custom Keyboard had an average preference rating of 6.21, while the Soft Keyboard had an average preference rating of 5.00 points. Again, the graphical design of the custom keyboard seems to account for this difference in preference. Users commented that the custom keyboard resulted faster for them because the buttons were closer to the entry fields than the buttons of the other method. Also, they said that the numbers were closer to each other in the custom keyboard, this accelerates the data input process. Also the buttons were bigger and easier to access. Although, some users commented that they preferred the Clié's software keyboard because they had more options to choose from.

A Mann-Whitney U-test revealed a significant difference between Graffiti and the Increment/decrement input method (See Table 5.1.). Graffiti was significantly preferred (average rating = 5.92 points) than the Increment/Decrement method (average rating =

4.92 points). Also a Mann-Whitney analysis revealed that Graffiti was significantly preferred than the soft keyboard with an average rating of 5.92 points while the Soft Keyboard had an average preference of 5 points.

Summaries of the results of the statistical analysis for the completion time and for the preference are presented in tables 5.1 and 5.2 respectively. The keyword in parenthesis for the significant results corresponds to the modality that resulted significantly better for the particular variable. In terms of completion time the only modalities that resulted significantly better than another modality are the custom keyboard and the soft keyboard. On the other hand the only modalities that resulted significant better than another modality in terms of preference were the Custom Keyboard and Graffiti. Among the four modalities the Custom Keyboard is the only modality that is significantly better than the other three in one of the two dependent variables. In general, none of the other modalities is significantly better than the Custom keyboard in any of the two dependent variables.

Table 5.1: Summary of the completion time results of the statistical analysis comparing all numerical data input modalities.

	Custom Keyboard	**Inc/Dec**	**Soft Keyboard**
Graffiti	Significant (Custom Keyboard)	Not Significant	Not Significant
Soft Keyboard	Not significant	Significant (Soft Keyboard)	
Inc/Dec	Not significant		

Table 5.2: Summary of the results of the statistical analysis comparing all the preference ratings for numeric input modalities.

	Custom Keyboard	**Inc/Dec**	**Soft Keyboard**
Graffiti	Not significant	Significant (Graffiti)	Significant (Graffiti)
Soft Keyboard	Significant (Custom Keyboard)	Not significant	
Inc/Dec	Significant (Custom Keyboard)		

The Soft Keyboard vs. Custom-made Soft Keyboard Test was the only that revealed a significant transfer of learning. A linear regression analysis revealed a significant transfer of learning effect from the custom keyboard to the soft keyboard (significance $f = 0.0021 < .05$), but no significant transfer of learning effect vice versa. Some users commented that the custom keyboard seemed familiar to them because it resembles a calculator keyboard but there were no comments about familiarity for the software keyboard. Maybe this lack of familiarity with the software keyboard leaded users to spend more time trying to get accustom to it than learning the task.

5.3 Discussion of the Textual Data Input Tests

In general, for textual data input the voice recorder resulted significantly faster than any of the other input modalities for textual input (See Table 5.3.). However, voice recorder was not significantly better in terms of preference than any of the other modalities (See Table 5.4.). Users commented that it was easier to press a button and start to dictate than writing with a keyboard. However, some users felt the keyboard interfaces

more reliable, because they can see the written data. In addition they felt that with the keyboard the information was more private and the voice recorder can lead to misinterpretations of the recorded nursing notes. Users felt especially concerned about the loss of patients' privacy with the use of the recorder; however, they recognized that nurses' need to save time. Some users said that it would be good to have both methods available. The users also expressed that it was easier to press a button and dictate than to write with Graffiti. Most of the users had to review the Graffiti alphabet because some letters or symbols were forgotten; especially the letters Q, T, V, and the comma, among others. Also some of the users found graffiti tedious, slow and frustrating. Other users said that they preferred graffiti, but for short texts for longer data the recorder was better. Others complaint that sometimes the system confused similar letters like O and Q, G with C, and V with U, etc.

Table 5.3: Summary of the completion time results of the statistical analysis comparing all the textual data input modalities.

	Voice Recorder	**Hard Keyboard**	**Soft Keyboard**
Graffiti	Significant (Voice Recorder)	Significant (Hard Keyboard)	Significant (Soft Keyboard)
Soft Keyboard	Significant (Voice Recorder)	Significant (Hard Keyboard)	
Hard Keyboard	Significant (Voice Recorder)		

Table 5.4: Summary of the results of the statistical analysis comparing all the textual data input modalities for preference comparison.

	Voice Recorder	**Hard Keyboard**	**Soft Keyboard**
Graffiti	Significant (Voice Recorder)	Not significant	Not significant
Soft Keyboard	Not significant	Not Significant	
Hard Keyboard	Not Significant		

The device's hard keyboard resulted significantly faster than the soft keyboard. The independent samples t-test revealed that the hard-keyboard resulted significantly faster than Graffiti. Some users said that the hard keyboard was faster because they can use both hands to press the buttons of the keyboard; with the other method they have to tap the buttons with the stylus one by one. Participants felt a certain level of familiarity with the hard keyboard because it resembles a desktop computer keyboard, although the "Ctrl" key was out of place in comparison to the computer keyboard. This caused the users to instinctively press the "Ctrl" key instead of the desired "Shift" key because these two keys were interchanged. But once the participants were aware of the error they tried to be more careful when pressing the shift key. Some commented that the Clié's stylus was very thin and small. Others felt that the keys on the hard keyboard were too small, and too close to each other.

The t-Test for independent samples revealed a significant difference between the completion times of the Soft Keyboard and Graffiti. This finding coincides with the [Giambalvo01] study. In general Graffiti resulted to be the slowest method of all while

the voice recorder resulted significantly faster than any of the other modalities (See Table 5.3.).

The only significant difference in preference rating was for the Voice Recorder vs. Graffiti test. The Voice Recorder resulted significantly preferred than Graffiti (See Table 5.4).

In the analysis of the results for the textual input tasks we need to take into consideration that no text was generated when the voice input modality was used. Thus, if a transcription of the recorded note needed to be generated, then, the transcription time need to be added to the completion times for the voice recorder to make a more fair comparison with the other modalities. However, if an audio record of a note can be a valid mode of keeping notes in a patient's record, then, the results of this experiment are realistic measures of performance differences between the inputs modalities considered. Considering the huge time difference between the voice recorder and the other modalities if an automatic transcription method could be used with the voice recorder the additional time introduced by the transcription is unlikely to be significant. Thus, it would be reasonable to expect that the significant time differences with the other modalities will hold.

A correlation analysis did not show a significant correlation between the users experience with Graffiti and their performance when entering the nursing note. This is an interesting finding because it is reasonable to expect that users' performance improve as they gain experience with a system.

This study supports the conclusion of the Young study [Young01] that the choice of an input device depends on the type of data to be input. For example, both Graffiti and

the Soft keyboard were tested for numerical and textual data entry; the soft keyboard resulted significantly faster than Graffiti for textual data input but not for numerical data input. In addition, participants significantly preferred Graffiti for numerical data input but did not significantly preferred Graffiti or the Soft Keyboard for textual data input.

Chapter 6

Conclusion

In terms of performance (completion time) for numeric input it cannot be concluded that one modality is superior to the others. The custom-made software keyboard and the software keyboard are the only modalities that resulted significantly superior to one of the other modalities but no significant difference was found between the two. In the majority of the cases of the comparison of the pair of modalities the results of the statistical analysis were non significant. Thus, new input modalities for numeric input should be considered for future studies.

In terms of preference for numeric input it can be concluded that the custom-made software keyboard and Graffiti are the best modalities of the four. However, from the analysis of the results it cannot be concluded that the custom-made software keyboard is superior to Graffiti and vice versa.

When the results of the statistical analysis of the two dependent variables (time to complete the task and preference) are considered it can be concluded that the custom-made software keyboard is the best modality of the four considered in the study. This conclusion is supported by the fact that the custom-made software keyboard resulted significantly superior to each of the other three modalities in one of the dependent variables, and also because none of the other modalities resulted significantly superior to the custom-made software keyboard in any of the dependent variables. These results support the inclusion of custom-made software keyboards for tasks requiring numeric input.

The results of the statistical analysis support the conclusion that the voice recorder should be seriously considered for nursing tasks requiring significant textual data input. However, there are issues of transcription, confidentiality and security that need to be addressed when this modality is used for clinical applications. Any patient's note need to be transcribed, thus a transcription mechanism need to be integrated to any application using voice recorder. Thus, the automatic transcription of voice recorder notes should be considered for future studies. On the other hand, to maintain patient's confidentiality the voice recorder need to be used in places isolated from the public. Thus, it cannot be used for bed side applications.

One important finding of this study was the inferior performance exhibited with Graffiti. In terms of performance it was significantly inferior to any of the other modalities for textual input and it was not significantly superior to any of the modalities for numeric input. In terms of preference it was significantly superior to two of the modalities for numeric input but it was not significantly superior to any of the other three modalities for textual input. Thus, the results of this study do not encourage adopting Graffiti for clinical tasks.

References

[Ayan01] N.F. Ayan, B. Karagol-Ayan, D. Kuehnert, A. Thakkar, "Which is faster and More Accurate on a Handheld: Graffiti or Keyboard Tapping?", Student HCI Online Research Experiments, SHORE2001, University of Maryland.

[Bohan99] M. Bohan, C.A. Phipps, A. Chaparro, C.G. Halcomb, "A Psychophysical Comparison of Two Stylus-Driven Soft keyboards", Proceedings of the Graphics Interface '99, pp. 92-97.

[Freedman01] A. Freedman, "Computer Desktop Encyclopedia", The Computer Language Company Inc., Osborn/McGraw-Hill, 2001. http://www.techweb.com/encyclopedia/defineterm?term=pda&x=43&y=10

[Gianbalvo01] D. Giambalvo, A. Frolov, N. Norouzi, "A Comparison of Graffiti vs. the On-Screen Keyboard for Experienced Palm Users", Student HCI Online Research Experiments, SHORE 2001, University of Maryland.

[Jao03] C. Jao, D.B. Hier, J. Su, "Evaluating a Digital Resident Diagnosis Log: Reasons for Limited Acceptance of a PDA Solution", AMIA 2003 Symposium Proceedings, 2003, pp. 876.

[Lu03] Y.C. Lu, J.K. Lee, Y. Xiao, A. Sears, J.A. Jacko, K. Charters, "Why Don't Physicians Use Their Personal Digital Assistants?", AMIA 2003 Symposium Proceedings, 2003, pp. 405.

[Rodríguez03] N.J. Rodríguez, J.A. Borges, Y. Soler, V. Murillo, D.Z. Sands, T. Bourie and C.R. Colón Rivera, "PDA vs. Laptop: A Comparison of Two Versions of a Nursing Documentation Application", 16th IEEE International Symposium on Computer-Based Medical Systems, 2003.

[Rubin94] J. Rubin, “Handbook of Usability Testing: How to Plan, Design, and Conduct Effective Tests”, John Wiley & Sons, 1994.

[Soler03] Y. Soler, “A usability Study of Physicians’ and Nurses’ Interaction with PDA and Laptop Applications to Access an Electronic Patient Record System”, Master Thesis, Electrical and Computer Engineering Department, University of Puerto Rico at Mayagüez, 2003.

[Young01] P.M.C. Young, R.M.W. Leung, L.M. Ho, S.M. McGhee, “An Evaluation of the Use of Hand-Held Computers for Bedside Nursing Care”, International Journal of Medical Informatics, 2001, vol.62, pp. 189-193.

Appendix

Test Materials

Appendix A

Orientation Scripts

Good Morning, my name is Naomi Acosta and I am a computer engineering student. I am testing two data entry methods in a PDA based patient record program for hospitals. The purpose of this test is to know what input method is faster and easier to use.

The test consists of doing a task with one method first and later with the other. I will be taking the completion time of each task to know which one of the two methods was faster to you. Also, I will be taking notes during the test. Please do your task as usual. If you have any questions during the test you can ask me, but maybe I will not answer, because I want to know how you could work independently. After the tasks are completed you can answer a questionnaire in which you can expose your opinions about the methods that you will test today.

Do you have any questions?

Appendix B

User Instructions

Instructions for the Hardware Keyboard vs. Software Keyboard Test

How to use the Hardware Keyboard

- To obtain a capital letter, press the “shift” key and the desired letter at the same time.
- To obtain a number press the “Fn” key and the key that have the desired number below at the same time.
- To erase press the “BS” key (backspace).
- To move the cursor on the screen use the arrow keys on the bottom of the keyboard.

How to use the Software Keyboard

- To obtain a capital letter tap on the arrow key that points to the top and is above the “ [“ key.
- To erase tap on the arrow that points to the left on the top of the keyboard.
- To move the cursor tap on the desired position with the stylus.

Instructions for the Hardware Keyboard vs. the Voice Recorder Test

How to use the Hardware Keyboard

- To obtain a capital letter, press the “shift” key and the desired letter at the same time.
- To obtain a number press the “Fn” key and the key that have the desired number below at the same time.
- To erase press the “BS” key (backspace).
- To move the cursor on the screen use the arrow keys on the bottom of the keyboard.

How to use the Voice Recorder

- To start recording a note press the grey button on the left side of the PDA. Immediately the button that says REC in the bottom-right of the screen will turn red if the PDA is recording, if not the button will appear black.
- To stop recording press the grey button again and the button that says REC on the screen will appear black.

Instructions for the Graffiti vs. Voice Recorder and Graffiti vs. the Custom-made Soft Keyboard Tests

How to use Graffiti

- The PDA has a space on the bottom of the screen for you to write the letters and numbers in Graffiti using the stylus. The letters are written in the left side of the space and the numbers on the right.
- To move the cursor tap with the stylus where you want the cursor on the screen.
- I will provide you with the Graffiti alphabet as a reference.

How to use the Voice Recorder

- To start recording a note press the grey button on the left side of the PDA. Immediately the button that says REC in the bottom-right of the screen will turn red if the PDA is recording, if not the button will appear black.
- To stop recording press the grey button again and the button that says REC on the screen will appear black.

How to use the Custom-made Soft Keyboard

- To move the cursor, tap with the stylus wherever you want on the screen.
- To obtain a number, tap with the stylus the button of the desired number.
- To erase (backspace) tap on the button with the arrow [←] that is on the bottom-left side of the keyboard.

Appendix C

Questionnaires

Questionnaire for the Increment/decrement Interface vs. Custom-made soft keyboard Test

Please answer the following questions:

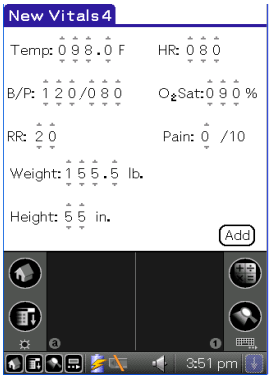
1. Concentration:_____
2. Year of concentration: _____
3. ¿Do you have any experience with PDA's? ___ years ___months
4. ¿If you have had any experience, what operating system you have used? Palm, WindowsCE, other:_____
5. ¿Do you use glasses or contact lenses? Yes__ No__

Circle the number that represents best your satisfaction (1 means not satisfactory and 7 very satisfactory):

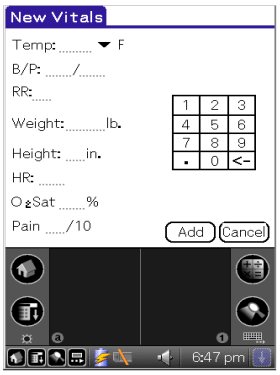
1. Interface A (Increment/decrement): 1 2 3 4 5 6 7

2. Interface B (custom-made keyboard): 1 2 3 4 5 6 7

If you have any comment or observation about the interfaces please express yourself in the following space:



Interface A



Interface B

Questionnaire for Software Keyboard vs. Hardware Keyboard and Software Keyboard vs. Custom-made Soft Keyboard Tests

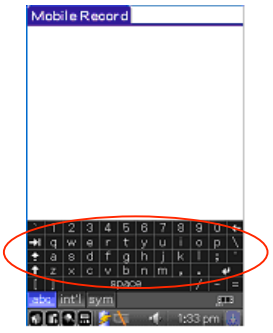
Please answer the following questions:

1. Concentration:_____
2. Year of concentration: _____
3. ¿Do you have any experience with PDA's? ___ years ___months
4. ¿If you have had any experience, what operating system you have used? Palm, WindowsCE, other:_____
5. ¿Do you use glasses or contact lenses? Yes__ No__

Circle the number that represents best your satisfaction (1 means not satisfactory and 7 very satisfactory):

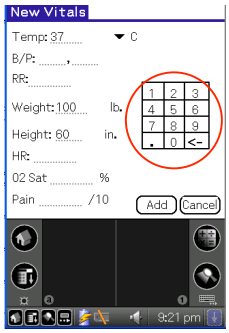
Textual Data Entry	
Method A (software keyboard):	1 2 3 4 5 6 7
Method B (hardware keyboard):	1 2 3 4 5 6 7
Numerical Data Entry	
Method A (software keyboard)	1 2 3 4 5 6 7
Method C (custom-made keyboard):	1 2 3 4 5 6 7

If you have any comment or observation about the interfaces please express yourself in the following space:



Method A

Method B



Method C

Questionnaire for the Hardware Keyboard vs. the Software Keyboard Test

Please answer the following questions:

1. Concentration:_____
2. Year of concentration: _____
3. ¿Do you have any experience with PDA's? ___ years ___months
4. ¿If you have had any experience, what operating system you have used? Palm, WindowsCE, other:_____
5. ¿Do you use glasses or contact lenses? Yes__ No__

Circle the number that represents best your satisfaction (1 means not satisfactory and 7 very satisfactory):

3. Interface A (Hard keyboard): 1 2 3 4 5 6 7

4. Interface B (Voice Recorder): 1 2 3 4 5 6 7

If you have any comment or observation about the interfaces please express yourself in the following space:

Questionnaire for the Graffiti vs. Voice Recorder and Graffiti vs. Custom-made Soft Keyboard Tests

Please answer the following questions:

1. Concentration:_____
2. Year of concentration: _____
3. ¿Do you have any experience with PDA's? ___ years ___months
4. ¿If you have had any experience, what operating system you have used? Palm, WindowsCE, other:_____
5. ¿Do you use glasses or contact lenses? Yes__ No__

Circle the number that represents best your satisfaction

1 means not satisfactory and 7 very satisfactory

Textual Data Entry	Rating
Method A (Graffiti):	1 2 3 4 5 6 7
Method B (Voice Recorder):	1 2 3 4 5 6 7
Numerical Data Entry	
Method A (Graffiti):	1 2 3 4 5 6 7
Method C (Custom-made soft keyboard):	1 2 3 4 5 6 7

If you have any comment or observation about the interfaces please express yourself in the following space: