User preferences for indicator and feedback modalities: A preliminary survey study for developing a coaching system to facilitate wheelchair power seat function usage

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ABSTRACT

Power seat functions (PSFs) allow power wheelchair users to adjust their posture independently for preventing pressure ulcers, ameliorating other medical conditions, and to assist with daily activities. Use of PSFs requires analysis of current environment, body position, and clinical recommendations, but these can be complex tasks for some users. We are developing an electronic coach system, entitled "Virtual Seating Coach" (VSC), to prompt users to use PSFs appropriately and warn against adverse events from improper use of PSFs. We conducted a survey to understand users' preference for PSF feedback modalities; PSF users and clinicians were recruited. They reviewed modalities with various features using a computer demonstration program, answered a questionnaire, and participated in a face-to-face interview. Trends in preferences for indicator and feedback modalities were identified, but some diversity of opinion also appeared. Findings from this survey study will guide the selection of VSC feedback modalities to accommodate individual differences.

Keywords: CUSTOMIZED REMINDER, POWER SEAT FUNCTION, USER INTERFACE, VIRTUAL COACH, WHEELCHAIR

INTRODUCTION

Importance of and Issues in Dealing with Using Power Seat Functions

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Power seat functions (PSFs) include power tilt, recline, elevating legrests, and elevating seat functions, as shown in Figure 1. These are important features prescribed with power wheelchairs to allow people who have lost functional movement or strength to change posture. In 2007, 173,300 Medicare beneficiaries received power wheelchairs. Power wheelchairs equipped with multiple seating functions are considered as complex rehabilitation wheelchairs, accounting about 7% of Medicare power wheelchair claims [1]. The PSFs are usually accessed through switches or navigating menus using joysticks. Using PSFs appropriately can decrease the risk of developing secondary conditions (e.g., pressure sores, contractures, venous pooling, spasticity) and assist with daily tasks, such as transferring and reaching objects [2]. Preventing pressure sores is a crucial life-preserving issue for wheelchair users [3]. Most users report that they are satisfied with the comfort of their wheelchair equipped with PSFs [4, 5]. However, less than 35% of the users reported using PSFs for pressure relief, and they seldom use these features to assist with transferring and positioning in order to reduce physical demands on themselves and their caregiver [5, 6]. To use PSFs appropriately, a user needs the knowledge of proper timing, sequences, and amplitudes [3]; and must be able to assess environmental setting and remember how to access their seat functions. Clinicians may prescribe tilt and recline angles as well as frequency and duration for positioning for users at high risk of developing pressure sores (e.g. stay in a combined position of 20° of tilt with 120° of recline for 1 minute, once every hour). It is difficult for some novice users to memorize all of the necessary information about using a new wheelchair within a short period of time. However, the user has to start using the wheelchair right after they receive it because the wheelchair is a primary means of locomotion. Unfortunately, inappropriate use of PSFs may cause harm to users, such as overstretching of lower limb joints, sliding in the seat (Figure 1), and tipping on a ramp due to changes in center of mass when the seat is tilted or the backrest is reclined. Furthermore, daily schedules and impaired sensation induced by diseases often cause power wheelchair users to forget or to ignore the importance of performing pressure relief. In addition, difficulty in obtaining transportation to a clinic and limitations of the reimbursement policy of medical insurance may prevent power wheelchair users from visiting clinics frequently enough to receive proper training.

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Figure 1. Power seat functions (PSFs) on a power wheelchair. The PSFs are illustrated in Photos a and b. Inappropriate use of PSFs may have adverse effects, such as over stretching knee joints when legs are elevated without the backrest being reclined (in Photo c) and sliding in the seat when the backrest is reclined but the seat is not tilted (in Photo d).

Concept of the Virtual Seating Coach

To facilitate more frequent and appropriate use of PSFs, we are developing a coaching system, the Virtual Seating Coach (VSC), to be installed on a power wheelchair. Its purpose is to monitor PSF usage, to detect environmental characteristics, and to provide timely feedback for prompting the user to use the PSFs properly. The primary goal of the VSC is to extend the training period for the wheelchair user beyond the time available in clinic appointments so that the user will learn how to properly apply PSFs in daily activities and follow the recommendation for pressure relief prescribed by the clinician. The VSC will accompany the user whenever he sits in his wheelchair until he becomes familiar with proper usage of the PSF and can perform positioning effectively. Sensors are mounted on the wheelchair to monitor the seating angles and detect environment characteristics. A small display will provide image and audio output needed for coaching functions. The VSC will not interfere with control of the wheelchair base and seat functions.

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Purpose of this Survey Study

There have been numerous studies trying to identify which feedback modalities and formats optimize the learning effect for and experience with a computer-based training or coaching program, but there is little uniformity in the study results [7-10]. Subjective perception and learning effect resulting from being presented with certain feedback modalities may be sensitive to learner and tasks characters. The VSC is meant to accompany the user for long periods in order to impart knowledge and modify health behavior. It is highly possible that the user may be interrupted by the VSC in daily activities even the user can choose to ignore or dismiss feedback from the VSC. The nature of the desired performance and human-machine interaction when using the VSC is different from executing a task in a learning session. The VSC will need to obtain a user's attention to start coaching in the middle of different daily activities and various environments. Although some general rules could be drawn from previous studies, we decided to conduct a preliminary survey study to ensure that our design of the prototype would match users' expectation of and preference for a coaching system. Wheelchair seating clinicians were also recruited as participants because we desired to know whether medical experts perceive a long-term coaching system in a differing way from that of wheelchair users. This information is used to facilitate preliminary ideas of how to design the prototype and how to bridge the gap between medical experts and real end-users in terms of developing a coaching system.

SURVEY STUDY

Participants

PSF users and clinicians were recruited to participate in this survey study. The PSF user participants had to be experienced with using PSFs and able to operate seating functions independently. The clinician participants had to be experienced with prescribing power wheelchairs with PSFs. There were no exclusion criteria for either group of participants. Information about this study was distributed through study flyers posted in the Center for Assistive Technology and through the Human Engineering Research Laboratories (HERL) newsletter. Participant demographic information is shown in Table 1. People with spinal cord injuries (SCI), muscular dystrophy, cerebral palsy, and multiple sclerosis have impaired motor control and/or sensory function. Symptoms vary from person to person because of different injury level, sub-types of the disease or stages of progress. The diagnoses of people who are using PSFs are not limited within these four examples that our participants presented with. Generally anyone who is using a power wheelchair and cannot perform effective pressure relief and change posture independently is a candidate for using PSFs.

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Table 1. Participant demographic information

		PSF users (n=10)	Clinicians (n=5)
Gender	Female	3	3
	Male	7	2
Age (years)	<30	3	1
	30-50	5	3
	>50	2	1
Profession	Physical Therapist	--	4
	Occupational Therapist	--	1
Diagnosis	Spinal Cord Injury	5	--
	Muscular dystrophy	2	--
	Cerebral Palsy	2	--
	Multiple Sclerosis	1	--

Equipment

Computer program:

A computer demonstration program with a graphical user interface was used to present the examples of feedback that may be provided by the VSC. Indicator and feedback modalities, forms, and features are listed in Table 2. These were chosen because they are commonly used in daily electronics, computer and gaming interfaces to provide feedback when interacting with users. The program presented feedback with four different themes: reminding, warning, giving guidance, and giving encouragement. In the reminding theme, the feedback message was to inform the participant that it is time to perform pressure relief. In the warning theme, the message cautions the participant about sitting in a static position for too long. In the giving guidance theme, the message provides detail about how to perform position changes using PSFs. In the giving encouragement theme, the message gives praise that the task has been completed. Participants have the choice of using the tablet monitor and stylus, keypad, or joystick as the pointing device. To review the examples of feedback, each participant was asked to select the forms and features of feedback modalities from a menu, shown in Figure 2A, and then hit the "Preview" button to play the combination selected. The on-screen text, speech, and animation of PSF task output were congruent with the theme. Only one animation or static sign is displayed with on-screen text each time because the size of the display which can be added onto a wheelchair is very limited. Human animation agents, lifelike animated human characters widely used in computer-based learning programs, were not included at this stage of development. Static female and male faces [11] are used to simulate the effect of animated coaching agents, shown in Figure 2B. The cartoon animations are from Microsoft Agent Animations, and animations for the PSF task are generated from the mechanical design software SolidWorks as shown in Figure 2B. The demonstration program was run on a tablet computer, and audio feedback was played over a

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set of speakers. The equipment set-up is shown in Figure 2A. The set-up could be modified according to each participant's needs. For example, the laptop and the joystick could be placed on a lap-tray, and the stylus for the tablet monitor could be attached to the participant's finger with Velcro.

Table 2. The indicator and feedback modalities in the demonstration program

Modality	Form	Feature
Audio	Beeping	Beeping frequency is around 1.5 Hz, lasting for 5 seconds.
	Melody	Simple piano playing lasting for 8 seconds
	Speech	Type: Cartoon, Female, Male, Synthetic(monotonic) Tone: Professional (Calm) and Enthusiastic (emotional) for female and male voices Dialogue Length: Short: Direct command and key information Long: Full sentence of polite social communication and including more detailed information
Visual	Light (supplemental device)	Steady red light
	Static sign	Collective signs commonly used in daily human-machine interfaces.
	Animation	Cartoon, Female face, Male face, Task of using PSFs
	On-screen Text	Dialogue Length: Short: Direct command and key information Long: Full sentence of polite social communication and including more detailed information
Somatic	Vibration (supplemental device)	Steady 60 Hz vibration

Note: Contents of speech and on-screen text feedback match each other. For example, the short dialogue of the warning theme for both speech and text is "Pressure relief now!" The long dialogue is "You should perform pressure relief now. You have been sitting in a static position for more than an hour."

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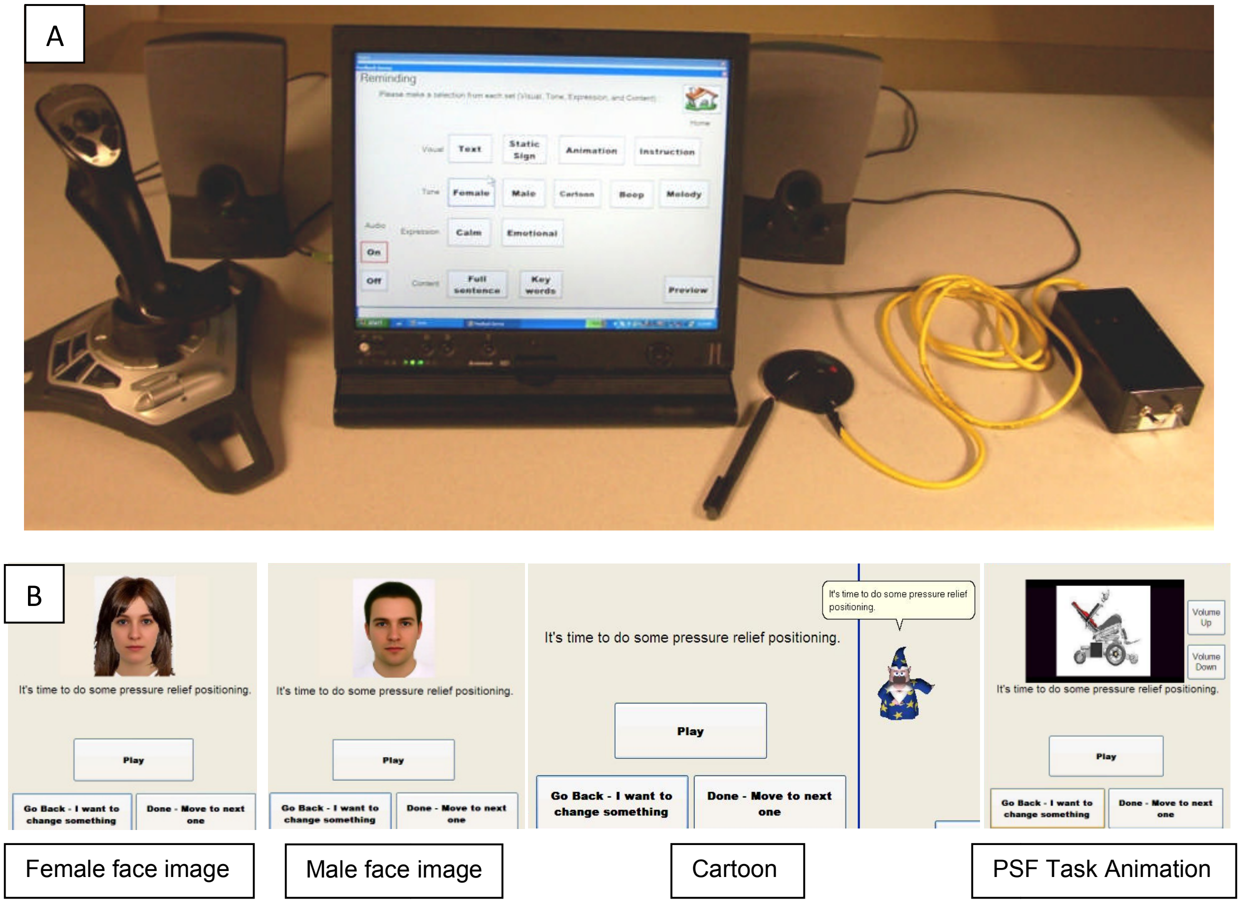

Figure 2. Equipment used for the study. A: Equipment setup for participants to review indicator and feedback modalities and feature, showing the Menu from which the participant can select forms and features of feedback modalities for the reminding theme. B: Screens shots of human face images used to simulate the effect of animated coaching agents, and examples of cartoon and PSF task animations for the reminding feedback. The screenshots were captured respectively after the "Preview" button was pressed to show the combination of modalities and features by the subject.

Supplemental device:

A supplemental device independent from the tablet computer allowed participants to turn on light and vibration alerts using switches. A steady red light was generated from a LED indicator light bulb (12 V DC, 5 milliamperes). Steady 60 Hz vibration was generated from a mini motor (length: 14.2 mm; diameter: 6.0 mm) housed in a flat case (6.5 cm x 6.5 cm x 1 cm). This device is shown in Figure 2B.

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Questionnaire

A paper-based questionnaire was developed to collect information on participant preferences for the modalities. The first part of the questionnaire asked participants to select one appropriate form of indicator modality for reminding and warning feedback in five different contexts, including a noisy restaurant, a park, an office, a class or a meeting, home. The second part of the questionnaire asked participants to rank modality features of animations and speech, and then rank locations for the vibration indicator. They were also encouraged to note the reason for their rankings and to provide any suggestions or concerns about certain modality features.

Protocol

An investigator started by giving an introduction to the purpose of and concept behind development of the VSC, and then demonstrated how to use the demonstration program. The participant could select or change the pointing device and the volume of an audio output. They were directed to review the reminding theme first, followed by the warning, guidance, and encouragement themes. There was no time limit for participants to review the modality features. After the participant finished reviewing the modalities in each theme, the investigator showed her/him the LED indicator light signaling an alert for reminding and warning, and the participant could instruct where they wanted this light to be located. Then the vibration box was turned on and placed on the participant's shoulder, back of mid upper trunk, back of head, and forearm, or any other locations that the participant would like to try. As the next step in the procedure, the participant went on to answer the questionnaire. Each participant was informed that this study was being conducted to gain a better understanding of users' preference with respect to indicator and feedback modalities rather than to evaluate the quality of the example feedback demonstrated in the program. If the participant preferred certain modality feature but was not satisfied with the example feedback, the participant should confirm her/his preference for the feature in the questionnaire and then note her/his suggestions or expectations with regard to the feature. The interview, lasting around 15 minutes, was conducted at the end of the protocol and was audio-recorded. The whole protocol lasted about 40 minutes.

Interview

A semi-structured interview was conducted with some standard questions to elicit participant expectations of a coaching system and to provide an open forum for discussing any concerns or suggestions participants have with respect to use of feedback modalities and the concept of the VSC. A question about the potential of machine automaticity was included in the interview to

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identify power wheelchair users' and clinicians' acceptance of an auto-positioning device as compared to a tailored coaching device. The standard questions are as follows:

1. What are your major concerns about using the VSC?
2. Can you think of any feedback features that would be acceptable and useful to be added onto the VSC interface?
3. What other functions could be useful to be included in the VSC?
4. Do you want the ability to turn off the VSC? Why?
5. Would you allow the VSC to control your power seat functions? Why?
6. Would you share your PSF usage data collected by the VSC with your caregivers and clinicians? (for user participants only)
7. How would you like to review your client's PSF usage data collected by the VSC?
8. Do you have any comments or suggestions with respect to the development or design of the VSC?

This study was approved by the Institutional Review Board of the University of Pittsburgh.

Data Analysis

Because of the sample size due to the small population and limitations in transportation for PSF users, frequencies are reported for observing the trend toward modality selections rather than testing hypotheses. Qualitative data collected from the questionnaire are described in the results and discussion section. Frequent comments elicited in the interview are listed in a table with their frequencies presented.

RESULTS AND DISCUSSION

Selection of indicator modality for reminding and warning feedback

User participants preferred to receive audio alerts, especially beep and speech, for reminding and warning feedback, but seldom selecting vibration, as shown in Table 3. The participants selecting beep recognized that beep was annoying, but they wanted to be alerted when the VSC was sending important messages. They suggested that a lower pitch might make it friendlier, but it may not be necessary since the main purpose is to alert the user. Clinicians

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thought that vibration would be an appropriate modality to alert the user on most occasions because it is low-profile. They rarely selected a beep because it is obtrusive and so might lead the user to become annoyed with the VSC.

Accessibility to the modality could be the primary factor influencing the selection of indicator modalities. PSF users might have impaired or absent sensation and so could not be able to sense vibration effectively. Visual modalities would be less revealing than audio, but the user would easily miss them if the display were not in their line of sight. Audio modalities, perhaps because they do not rely on tactile stimulus or visual contact, were chosen by PSF users for most occasions. Another factor for choosing different audio modality forms could be related to the sense of inter-personal distance and chance of being noticed. For the noisy restaurant and office contexts, where the user would be sharing the space with others but the people are doing individual activities, user participants were open to choosing beeping to indicate reminding and warning messages. The beep is bold enough to alert the user but will not interrupt others' personal interactions. The distance among people is even larger in a park, and therefore user participants were less concerned about confidentiality issues; therefore, a speech indicator would be most intuitive and efficient for the user because the user is alerted and receiving feedback messages at the same time without looking at the display.

Table 3. Top choices of indicator modality forms, listed according to number of participants ranking each modality feature as their first choice; followed by speech length and tone and on-screen text length selection that most participants chose for different themes. (number of participants selecting the modality form or feature)

	User (n=10)	**Clinician (n=5)**
Preference for Reminding Indicator Modality Forms for Different Context		
Noisy Restaurant	1. Beep(5) 2. Speech(1), Static sign(1), Vibration(1), Text(1)	1. Vibration(4) 2. Light(1)
Park	1. Speech(3) 2. Beep(2), Melody(2) 2. Static Sign(1), Animation(1), Light(1)	1. Melody(2), Vibration(2) 2. Speech(1)
Class or Meeting	1. Light(3) 2. Melody(2), Text(2) 3. Beep(1), Speech(1) , Light(1)	1. Vibration(4) 2. Light(1), Text(1)
Home	1. Speech(7) 2. Beep(2), Animation(1)	1. Melody(2) 2. Beep(1), Speech(1), Light(1)
Office	1. Speech(3) 2. Beep(2), Melody(2), Light(3)	1. Vibration(3) 2. Light(2)
Preference for Warning Alert Modalities for Different Context		
Noisy Restaurant	1. Beep(4)	1. Vibration(3)

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	2. Speech(2) 3. Light(1), Animation(1) , Vibration(1)	2. Light(1), Animation(1)
Park	1. Speech(4) 2. Beep(3) 3. Melody(1), Animation(1) , Text(1)	1. Vibration(2) 2. Beep(1), Melody(1), Speech(1)
Class or Meeting	1. Beep(4) 2. Text(3) 3. Light(1), Vibration(1) , Text(1)	1. Vibration(2) 2. Light(1), Animation(1), Text(1)
Home	1. Speech(5) 2. Beep(2) 3. Light(1), Animation(1) , Text(1)	1. Speech(2) 2. Beep(1), Melody(1), Vibration(1)
Office	1. Beep(3), Speech(3) 2. Light(1), Animation(1), Vibration(2)	1. Vibration(4) 2. Light(1)
Preference for Speech length and tone		
Reminding	Short + Professional (6)	Long + Professional (2) Short + Enthusiastic (2)
Warning	Long + Enthusiastic (4)	Long + Enthusiastic (3)
Guidance	Long (7)	Long (3)
Encouragement	Short + Enthusiastic (4) Short + Professional (3)	Short + Enthusiastic (3)
Preference for On-screen text length		
Reminding	Short (6)	Short (4)
Warning	Short (8)	Short (4)
Guidance	Long (7)	Long (4)

Preferences for length and tone of feedback message

Both user and clinician participants preferred similar speech length and tone and on-screen text length for warning, guidance, and encouragement feedback. Preferences for the reminding feedback, however, were different, as shown in Table 3. Clinician participants felt that reminding feedback needs to be detailed and delivered in a professional tone to convince users to follow the recommendations, or be short and enthusiastic to motivate users. User participants, on the other hand, just wanted short and calm feedback to remind them what they need to do. The perceived role of the VSC may contribute to this difference. Clinicians may consider the VSC as an educational tool and an extension of themselves interacting with users. Therefore, they expect that this system should explain detailed recommendations to novice PSF users, or

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enthusiastically convince them to follow commands when the reasoning behind the recommendation is too complicated for the user to understand, just like they themselves would do when interacting with clients in clinics. However, because the user participants were experienced in using PSFs, they may have felt it unnecessary to receive tedious information about PSFs. That is, the most important function of the VSC for them is to remind them when to perform position changes for how long instead of how to use PSF.

Providing detailed information supports beginners in learning new tasks, but it may become redundant as the user gradually memorizes the procedures to perform the tasks. Decreasing the amount of information provided by the VSC program according to the user's compliance may avoid information redundancy after a user has gradually learned how to use PSFs. In addition, a "Help" tool on the interface can be a useful resource to allow the user to access supplemental information and keep feedback messages succinct.

Interview results: Concerns and Suggestions

Frequent concerns and suggestions stated during the interview are presented in Table 4. The size and location of the VSC is a common concern because any additional device on a power wheelchair can further decrease users' accessibility to the environment. However, a display that is too small is difficult for the user to read messages. Therefore, the hardware needs to be built with flexibility for custom modification. Some participants would like to have more options for feedback modality features to personalize the device. Several participants suggested that the VSC could include more reminder functions, such as nutrition and medicine reminders. However, some clinicians are concerned about the complexity of adding more technologies on a power wheelchair. They suggest that the VSC should be kept simple and straightforward to avoid information overload since it is a newly developed device and its effect is not clear yet. Although the VSC will have the potential to be a personal digital assistant on a wheelchair, building a reliable coaching system with an uncomplicated and friendly interface is the goal for our current development stage.

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Table 4. Frequent concerns and suggestions reported during the interview.

	Concern/Suggestion	N	
		PSF User (n=10)	Clinician (n=5)
1	Concerned about the size and location of the VSC on a wheelchair	10	2
2	More options of indicator and feedback modality should be provided	5	2
3	More reminder functions can be included	7	4
4	VSC may increase the complexity of a wheelchair system	0	2
5	The user should have the ability to turn off the VSC	7	4
6	The VSC should not operate PSFs automatically	7	5
7	The user is willing to share PSF data with clinicians and caregivers	9	--
8	The clinician would like to review the PSF usage data with the frequency according to individual needs (e.g., risks of developing pressure sores)	--	4

User autonomy is an intriguing issue to consider when developing this coaching system to assist with health management. Most users expressed a desire to have the ability to turn off the coaching program even though ideally it can detect the proper timing to provide reminders. Participants felt that there may be certain occasions when they want to be sure that the VSC will not disturb them. However, some clinicians felt that users should not be allowed to turn off the coaching program because they may forget to turn it on, and thus the opportunity of providing tailored feedback would be missed. Both concerns are important, but no clear conclusion can be drawn because no power wheelchair user has used the VSC. For the purpose of investigating the effect of tailored feedback provided by the VSC, the prototype will not allow the participants to turn off the coaching program in a future three-day pilot trial study, but will provide the options to snooze or dismiss the feedback message.

The potential of machine automaticity is controversial for power wheelchair users. Many participants did not agree with the idea of allowing the VSC to automatically operate their PSFs. Even though the VSC knows the schedule and position for position change, it may not be able to detect whether the user is ready to change position. Some users specifically stated that they have lost a lot of control in their lives, and therefore they wanted to maintain as much independence and control as possible in spite of the convenience of using assistive technologies. In contrast, some participants thought that this is a good idea because the system can position users with cognitive issues or very limited functional movements for pressure relief according to the prescribed schedule. Simplifying the process to use PSFs for pressure relief by automatic control is a potential method to facilitate health management, and allowing the user to initiate positioning may help to eliminate users' worry of losing control over the device. The development of an automatic positioning device can be a future project after we have obtained

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more knowledge from this study about the nature of PSF usage and power wheelchair users' response to a machine that is closely monitoring and interacting with them.

Potential Applications to Other Assistive Technologies

Some of our findings can be applied when designing display effects and feedback content for assistive devices which are needed to alert and communicate with users about daily routines. Examples of these are prompting devices for following complicated medicine regimens, daily schedule reminding devices for people with memory impairments, and telerehabilitation programs persuading people to perform therapeutic exercise at home, are tasks in which pervasive computing technology can be used to improve compliance with medical prescriptions, health management, and independent living. Implications from our survey results suggest that reminder and warning messages should be short to prevent redundancy and to provide minimal disturbance, but that the device should provide convenient control to allow the user to access detailed instructions or supplemental information efficiently. However, people with different health issues have different needs. As mentioned in the Purpose of this Survey Study, the researchers and engineers should investigate the trends in user preferences for specific target populations and specific tasks. Even though the results from this study may not directly apply to different assistive devices, the methods of this study can be considered as a way for those conducting future studies to ensure end-users' participation in the design process.

Limitations and Future Studies

Although the investigator asked each participant to express their preferences without being limited by our examples, some bias was difficult to avoid. For example, it is unknown whether participants would have preferred virtual agents if we had presented them as animations. This is a cross-sectional study, and participants were engaged by changing feedback modalities and features using the computer program. Users' preference may change after using the VSC for a longer period of time when alerts and feedback pop up several times a day. The investigation on users' preferences and satisfaction with the interface and feedback should be conducted in a future clinical trial. Future studies will reveal more information about the appropriate multimedia interface modalities for a real-time interactive coaching device.

CONCLUSION

Some trends in participants' preferences with regards to indicator and feedback modalities were observed. Differences in preferences may have resulted from different considerations of

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clinicians versus wheelchair users, the various personalities of the participants, environments, and individual needs. The findings from this study give us a guide to design alerts and feedback for the coaching system and build the prototype with flexibility to accommodate individual differences. The results do not specify which modalities should not be used. Instead, we should provide a reasonable number of options for personalization, and develop the VSC with the ability of context awareness to select proper feedback and indicator modalities for different environmental situations and user condition. More human-machine interaction through using this coaching system will be observed in-depth in future studies.

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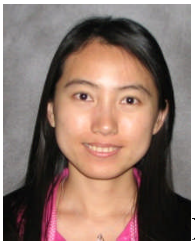

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