Survey Data Analysis for Repositioning, Transferring, and Personal Care Robots

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ABSTRACT

Robotic aids can perform repositioning, transferring, and personal care tasks and increase independence of persons who have reduced motor functionality. Our goal is to develop robotic aids by actively involving the target population, their caregivers, family members, and friends in the design process to increase user acceptability through participatory design. We conducted a survey to explore the needs for robotic aids and to evaluate the perceived pros and cons of prototypes that we have designed and built in simulation. Survey responses will help us to build a physical robotic system that will improve the quality of life for individuals with disabilities and their caregivers.

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1 INTRODUCTION

With advances in robotics technology, there is immense potential for supporting the demands of caregiving. Our goal is to evaluate the perceived pros and cons of robotic prototypes that we have designed and built in simulation for repositioning, transferring, and personal care assistance. We aim to understand the perceived degree of importance of each robotic prototype, gauge overall attitudes, gather preferences on interaction modes, and desired physical robot features. Survey responses will help us build physical realizations of our prototypes by emphasizing the important issues and associated challenges in the assistive robotics field.

2 BACKGROUND AND RELATED WORK

The collaboration efforts of the Human Engineering Research Laboratories (HERL) at the University of Pittsburgh and commercial companies have utilized participatory design in evaluating and increasing functional mobility for patients and their caregivers after development [8]. Specifically, the design of the transferring technologies AgileLife Patient Transfer System and the STRONGARM were revised to meet user requirements and preferences that were found in focus group and field trials for planning refined prototypes to increase the likelihood of commercial success.

For user involvement, many studies have also focused on the participatory design approach in the early stages of product design and development to maximize usability and acceptance [10]. Although there are many techniques to obtain early feedback, an increasingly popular and reliable methodology in gathering data of user preferences is the Video HRI research paradigm where participants watch and provide their insight of the computer-animated or actual robotic prototypes that has been efficient in time and resources [3].

To evaluate user experience of prototype systems, a study was performed to explore and refine qualitative methods from interviewing participants of video prototyping in Human-Robot Interaction [9]. Results showed that the open-ended interviews regarding user experience of video prototypes is a valuable tool for collecting participants' opinions and attitudes of a system.

Although user-centered approaches provide feedback for making existing robotic systems more accessible, our work aims to gain a solid understanding of the functional needs and preferences of the target population to support researchers with mechanical design requirements with a questionnaire survey. Human-robot interaction behaviors are simulated in the video demonstrations in specific scenarios of our robotic prototypes. Design recommendations from collecting the survey responses can be used as a blueprint to develop a robotic system that can provide physical assistance for daily living.

3 CURRENT RESEARCH

Using participatory design, we conducted a 30-minute online, anonymous survey with several demographic questions and requested comments on prototypes. The survey covered four major topics to collect demographic information, current practices of repositioning and transferring, perceived pros and cons of our eight prototypes, and future perspective on assistive robots. We structured the survey with close-ended questions with multiple-choice and ratings for quantitative data and open-ended questions to identify opinions of prototypes for qualitative data to generate discussion. For example, participants were asked to comment on each design and make suggestions for improvements from viewing the 3D video simulations of a robotic mattress (Piano Mattress), three different transferring systems, toileting aid, robotic toothbrush, and universal gripper (UniGripper). For fast and frugal demonstration, we used 3D video simulations of the robotic prototypes.

We targeted 200–300 survey responses. Participants that must be 18 years or older were recruited from contacting organizations such

PETRA '17, Rhodes Island, Greece.

1.	**Demographics**	
	a)	Male or Female
	b)	Age Group
	c)	Highest Education Completed
	d)	Participant Type
	e)	Primary Disability Description
	f)	Current Input Mode Devices
2.	**Repositioning**	
	a)	Experienced Lack of Repositioning
	b)	Time Frequency of Repositioning Needed
	c)	Repositioning Process Description
	d)	Piano Mattress Interest
	e)	Piano Mattress Pros-Cons Description
	f)	Robotic Repositioning Ideas Description
3.	**Transferring**	
	a)	Experienced Lack of Transferring
	b)	Current Transferring Description
	c)	Wearable Sling Pros-Cons Description
	d)	Piano Lifter Pros-Cons Description
	e)	Penta-Gripper Pros-Cons Description
	f)	Transferring Prototypes Likert
	g)	Robotic Transferring Ideas Description
4.	**Personal Care**	
	a)	Grooming Assistance Choices
	b)	Motorized Commode Chair Pros-Cons Description
	c)	Toilet Tongs Pros-Cons Description
	d)	UniGripper Pros-Cons Description
	e)	Robotic Toothbrush Pros-Cons Description
	f)	Personal Care Prototypes Likert
	g)	Robotic Personal Care Ideas Description

Table 1: Summary of Survey

as Cure SMA and the Muscular Dystrophy Association via email and posting messages on social media groups. Their responses have shaped ongoing development of the prototype devices by identifying attractive alternative design solutions.

Our User Study 1: Mechanical Design Survey is registered and granted approval from the UMBC Institutional Review Board (IRB). Participants were informed of the study's goals in the beginning of the survey. The survey contains 29 questions in total with the first question requesting participation consent the last two questions inquiring for additional thoughts and opinions on the survey topics and to provide an email address if interested in receiving information about the survey results. Table 1 summarizes the survey questions in sequence. Data were collected between December 2015 and January 2017. To obtain the perspective of participants view on the future usability of the robotic prototypes, there was a question to rate each of the eight prototypes on a four Likert-scale with categories labeled as Very Positive, Somewhat Positive, Somewhat Negative, and Very Negative. Additional information about the survey can be found here [4]. The survey can be accessed here: http://www.csee.umbc.edu/~kavi1/survey.html.

The following prototypes are in our survey.

Piano Mattress: an inflatable contoured mattress with air chambers that can be pressurized to be raised/lowered for mobility and repositioning in bed, shown in Figure 1. Video URL: https://youtu.be/GfEsKwcvxdM.

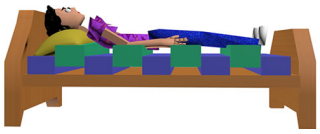

Figure 1: Piano Mattress with even air chambers raised.

Piano Lifter: a transfer system to accompany the Piano Mattress with five tines that fit in the deflated segments of that mattress and has two grippers, shown in Figure 2. Video URL: https://youtu.be/27uVb7h4ZLY.

Figure 2: Piano Lifter that accompanies the Piano Mattress for transferring.

Wearable Sling: a motorized mobile base supporting nine separate slings for both right and left forearms, upper arms, thighs, lower legs, and trunk with head support for transferring, shown in Figure 3. Video URL: https://youtu.be/oqzlCLctWhw.

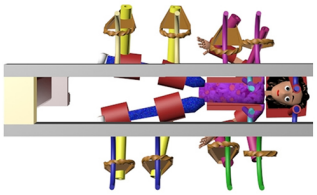

Figure 3: Wearable Sling in top view.

Penta-Gripper: a transferring system with five grippers that can wrap around the limb/body to perform movement, shown in Figure 4. Video URL: https://youtu.be/0xNNJ2o_N9A.

Figure 4: Penta-Gripper in side view.

Motorized Commode Chair: a joystick-controlled commode wheelchair with seat elevation, tilt, recline, brakes, and adjustable head support, armrests, and footrests. Video URL: https://youtu.be/U9-aF1sAMKY.

Toilet Tongs: a toileting aid that supports head-trunk, retrieves toilet paper with motorized tongs, and has a bidet. Video URL: https://youtu.be/E9zr_zGv7JY.

Motorized Commode Chair and Toilet Tongs are shown in Figure 5.

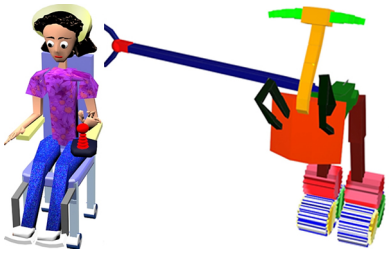

Figure 5: Motorized Commode Chair (left) and Toilet Tongs (right).

RoboticToothbrush: a oral hygiene system with a head supporter and three grippers each for water supply for rinsing, a toothbrush, and a spit cup, as shown in Figure 6. Video URL: https://youtu.be/t9rYUetF2Tc.

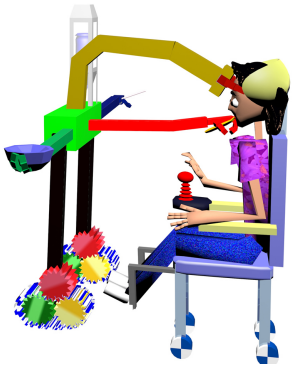

Figure 6: RoboticToothbrush brushing teeth.

Universal Gripper (UniGripper): a robotic arm for feeding and fine motor tasks with head support, as shown in Figure 7. Video URL: https://youtu.be/7zK3J1hMvRE.

3.1 Preliminary Results

As of now, we have 154 survey participants and all of our prototypes have received positive ratings in our preliminary results. This is very positive for our research and provides confirmation to move forward.

In order to gain insights about the complaints and compliments regarding the Piano Mattress, topic modeling, specifically Latent Dirichlet Allocation(LDA) [1], was performed using the tool Mallet [6]. Topic modeling was also performed on other devices, but significance tests were only done so far on this device, so the results

Figure 7: UniGripper feeding the user.

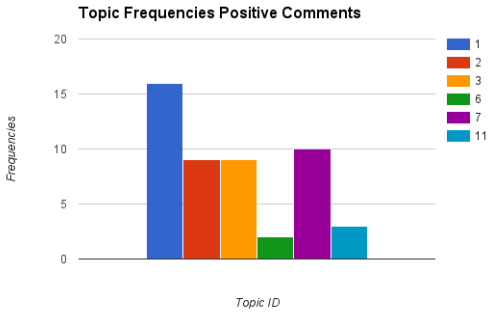

Figure 8: Frequencies of the topics appearing in the top 3 highest topic proportions for positive comments.

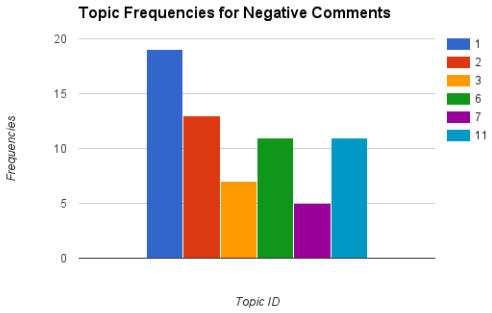

Figure 9: Frequencies of the topics appearing in the top 3 highest topic proportions for negative comments.

pertaining to the Piano Mattress will be shown for this paper. Tests were performed using the first 150 survey responses (due to only having 150 at the time). Each comment was viewed as a separate document. From a previous experiment [5], running topic modeling on the survey comments showed a noticeable difference in topic composition between complaints and compliments. Because of this, the words associated with topics of different compositions for positive and negative comments are of interest, since they will provide insight about what participants like or feel uncomfortable about. A disadvantage to this approach is that the most topics discovered for these responses are not clearly distinguishable from one another

-	cons	insurance	cover	comfort
-	level	keys	initially	average
-	afford	costs	full	build
7	repositioning	reposition	disabilities	movement
-	design	adjust	long	tiles
-	fear	voice	included	control
11	piano	user	easily	control
-	pain	positioning	adjustable	head
-	caregivers	communicate	automatic	arm

Table 2: Top words for topics 6,7, and 11.

from a human perspective(topics appear to be mostly about the same thing). Also, it can be somewhat difficult to generalize how a lot of words within topics relate to one another. Nonetheless, it yielded noticeable differences. In this paper, the topic composition difference was tested for statistical significance using a 1 sided hypothesis t-test.

Comments containing both a complement and a criticism were split into separate parts for more data. The resulting interdependence between the two groups of negative comments and positive comments was controlled by shuffling all comments. Since there were also few occurrences of having to split comments, the interdependence should not have had a significant effect on the experiment. Since each surveyor can provide at most 1 response of negative or positive feedback, there was independence within groups.

Topic modeling was run on the first 90 of the shuffled comments. Stop words were removed, and 15 topics were learned. This resulted percentages of topics per comment. For example, a comment would be composed of 20 percent of topic 1, 10 percent of topic 2, etc. The percentages of topic composition per comment were then sorted from greatest to least. For positive comments, each topic was counted for the number of times it appeared in the top 3 of the sorted percentages. This was also done for negative comments. Figure 8 shows the number of times each topic appeared in the top 3 for positive comments, while figure 9 shows this for negative comments. It is noticeable that topic 7 appears more frequently with positive feedback, whereas topics 6 and 11 appear more frequently with negative feedback. Table 2 shows the top 8 words for these topics.

For testing purposes, the remaining 27 positive comments and 38 negative comments (that were not included in topic modeling) were used. For testing significance of topic 7, word occurrences of the top K words from topic 7 were counted among the test set of comments. A 1 sided hypothesis t-test on the mean counts from positive and negative words was conducted where the alternative hypothesis was that the mean count any of the first K words of topic 7 appearing in positive comments is greater than that of negative comments. The software [7] was used here. In this test, outliers were dropped, and the words ficonsfi and fiprosfi were excluded. The results of this test are shown in figure 10 for K = 5,10,15,20. Similarly, a test for the significance for comments 6 and 11 was conducted. These results are shown in figure 11. Since 2 topics are considered here, the top K/2 words from each topic were used for K=4,8,12,16. Using more words per topic appeared to be more effective for negative comments, where the lowest P-value achieved was 0.0988 for using

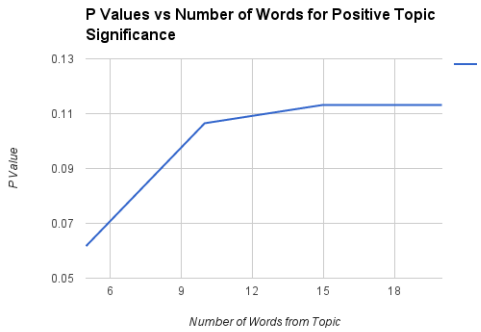

Figure 10: testing significance for mean word frequency difference between positive and negative comments for Topic 7. P-Values for using varying numbers of words from topic 7 are shown.

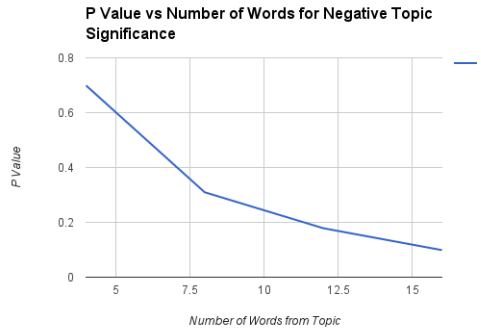

Figure 11: testing significance for mean word frequency difference between positive and negative comments for Topics 6 and 11.

16 total words (8 words per topic). This would be significant at the 90 percent level. Since the word "cons" was omitted from the significance test, the 8 words from topic 6 include "afford" and "insurance" which can indicate concerns about affordability. The lowest P-value achieved for using 1 topic with positive comments was 0.0617 using 5 words from topic 7. Since words appearing in the top 5 include "repositioning" and "movement", there is positive sentiment about the overall repositioning process.

3.2 Quantitative Results

Further statistical analyses were performed using SAS software version 9.3 [2]. Our survey contains 15 variables that hold discrete values for gender, age, education, profile, experienced lack of repositioning assistance, frequency time of repositioning, interest in Piano Mattress prototype, experienced lack of transferring assistance, and Likert ratings for the Wearable Sling, Piano Lifter, Penta-Gripper, Motorized Commode Chair, Toilet Tongs, UniGripper, and RoboticToothbrush. We calculated the Chi squared values to determine statistical correlation among variables. By default,

the significance level alpha is set to 0.05 typically in the field of statistical analysis.

Figure 12 shows the distribution of the survey participants with respect to their gender and age group. Figure 13 shows the distribution of the survey participants with respect to their gender and category profile. Based on the chi-square test derived from the SAS SURVEYFREQ procedure, we found that the chi-square test statistic value is 7.9104 and the associated p-value is 0.0479. Given the default alpha level is 0.05 and the p-value is approximately the same, we can conclude that there is not a statistically significant association between gender and category profile.

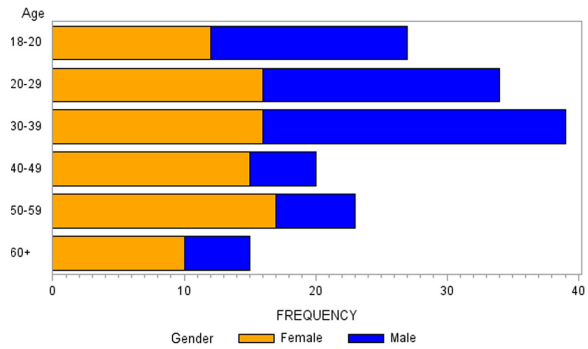

Figure 12: Distribution of Gender and Age.

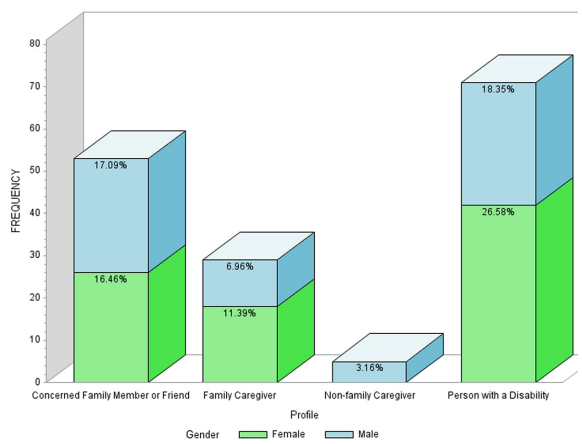

Figure 13: Distribution of Gender and Profile.

For the chi-square test between the participant category profile and Likert scale of the UniGripper, statistic value is 19.4201 and the associated p-value is 0.0218 (¡ p-value= 0.05) so we can conclude that there is a statistically significant association between the Likert ratings of the UniGripper and category profile.

Figure 14 shows the distribution of the survey participants with respect Likert ratings of the UniGripper and category profile.

3.3 Qualitative Results

High number of survey responses are expected to increase statistical precision. Open comments identified the following desired factors: safety, comfort, reliability, and independence. Throughout the survey analysis and topic modeling process, lists of desired features and concerns were compiled together for each the different devices. They were put into the following word clouds for visualization purposes. This included all 158 responses.

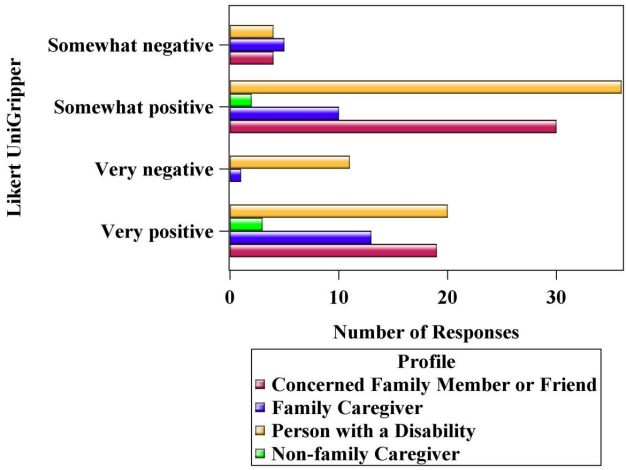

Figure 14: UniGripper Likert and Category Profile.

Figure 15: Word Cloud of desired features for the Piano Mattress.

Figure 15 shows the desired features and concerns for the Piano Mattress. "Side Positioning" was a top desire for this prototype. The words "grid" and "vertical keys" further emphasize this need. "Pressure" on the body was a common concern. "Adjustable force" and related phrases imply a desire for customization, which is reasonable, since different people have different body tones.

Figure 16 shows the desired features and concerns regarding the transferring device prototypes. There is a strong need for head support and trunk support. "Falling Over" shows concern for the device maintaining balance while lifting, whereas "slippage" shows concern about falling through the device handles. Similarly to

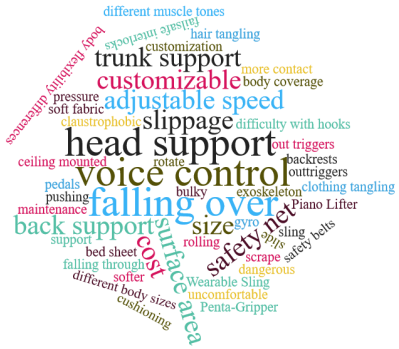

Figure 16: Word Cloud of desired features for the Piano Lifter, Wearable Sling, and the Penta-Gripper.

Figure 17: Word Cloud of desired features for the Uni-Gripper, Robotic Toothbrush, Motorized Commode Chair, and the Toilet Tongs. Larger words imply more frequency(highest frequency of 3 for being desired in all 3 devices)

the Piano Mattress, customization and voice control were desired improvements.

Figure 17 shows the desired features and concerns regarding the personal care device prototypes. Once again, head support, trunk support, and voice control were desired. The size of the word "Space" emphasizes the concern of having too many large devices around. The word "universal machine" further highlights this by suggesting many of these features be integrated into 1 chair. Other than this, words such as "adjustable force" illustrate need for customization as before.

4 CONCLUSION AND REMAINING WORK

Our results are a valuable source of information to explore and discover the target population's point of view that inform mechanical design configuration for robotic systems to overcome the challenges faced by persons with physical disabilities. To achieve a user-centered design and development of assistive robots for the target population, we need to thoroughly understand both the perceptions and expectations of robotic systems that can provide support for repositioning, transferring, and personal care to provide insightful opportunities for promoting higher rates of user acceptance and usefulness. Analysis using Topic Modeling was shown to highlight differences between positive compliments and negative complaints, more specifically word choice. Word clouds were also used to display wanted features and how significant they are across devices of similar purpose. Future work will also involve conducting more significance tests on word frequencies for topic models of the other devices, collecting more survey responses, and developing these devices around those results.

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