A Contextual Inquiry of AVEC: Power Assist Wheelchair Enhancing Communication

*AVEC means "with" in Frenc

***Abstract*— We designed AVEC, a power assist wheelchair system which has an intuitive interface the elderly population can use more easily. In the process of iterative design cycle, we conducted field interviews including contextual inquiry. According to the interview, it is proved that AVEC improved usability and enriched communication between the passenger and the caregiver.**

Keywords—Power assist wheelchair, assistive technology, interface to enrich communication, contextual inquiry

I. Introduction

The world is moving into a hyper aged society. As the elderly population continuously grows, wheelchairs are expected to be used more as means of transportation and not only assistive devices. This means the elderly users can be passengers and caregivers at the same time. However, manual wheelchairs have plenty of problems. Among those, we figured out two main problems. First, conventional wheelchairs are inappropriate for elderly users with weak muscle strength. Second, during the ride, the wheelchair caregiver and the passenger cannot communicate properly. Based on the 'Metodologia del Design' by Bruno Munari, we defined the problem, collected, and analyzed data to converge the problem space. [1] It was also important to follow Human Centered Design guidelines. [2] We conducted literary research and drew an emotional user journey map to maximize the understanding of the users. In order to finalize the optimized solution, we have planned to build multiple prototypes and got closer to the best option based on the iterative development model. Along the process, we conducted a field test with the primary prototype to prove the hypothesis of the solution and get feedback from the users.

II. System

The basic system of AVEC is to recognize the caregiver's intention via load cell interface and support his or her pushing force by controlling the hub motor. This system assists caregivers to easily manipulate the wheelchair. we modified a manual wheelchair as the first prototype which was built as a proof-of-concept of the solution. We displaced original wheels with BLDC hub motor wheels, installed PCBs and batteries, and put extended handle bar with load cells. The new interface enabled the caregiver to manipulate the wheelchair at the side of it. This enables both users to look at each other while having conversations. The user gets visual feedback from the system through LEDs right around the interface, showing changes of the operation modes. Despite of all the advancements, the body frame of the prototype remained almost the same so users could think of the prototype as a wheelchair and not a complex machinery.

Fig. 1. Prototype1(left), Visual feedback(below), Side interaction(above)

III. Field Interview

In order to test the usability of the prototype, we conducted a field interview. It consists of three sessions: preliminary interview, contextual inquiry, and final interview by filling up a questionnaire. The whole process was supervised by professionals from College of Nursing. Also, all the researchers completed an online research ethic course prior to the field test.

A. Participants

As our target users are elderly caregivers, participants had to satisfy the following: *(i)female who has at least 3 years of work experience as a professional caregiver, (ii)age of 50 or older, (iii)experienced with handling wheelchairs.* We recruited 5 caregivers and 2 simulated patients in total.

B. Contextual Inquiry(CI)

In this session, participants pushed the manual wheelchair and the prototype along the same route. They started from a simulated hospital room, went to the library and came back. (Fig.2) Based on the 'Think Aloud' method, participants were asked to say everything they think and feel at the moment. For every participant, one researcher observed his or her behavior and another researcher recorded behaviors for the further analysis.

C. Usability Questionnaire

Based on 8 questions from QUEST 2.0[3], a commonly used tool to evaluate the usability of an assistive technology, we added 6 questions about power assistance and 2 questions about communication. In this survey, each item was scored from 1(not satisfied at all) to 5(very satisfied).

**All authors contributed to this work equally.

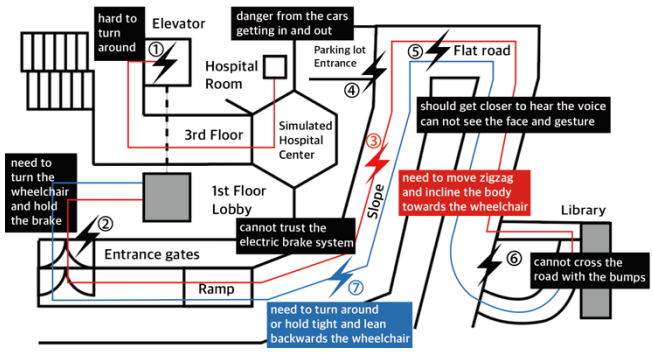

Fig. 2. Contextual design; Sequence and physical model combined

IV. Analysis and Findings

The data from the field interview was analyzed based on grounded theory. We first open coded every piece of information from the recorded data. It resulted in about 110 codes. Then we axial coded them into 11subcategories, which includes communication, safety, manipulation, power assistance, changing posture, ergonomics and so on. In order to clarify the problem, we also used contextual design method using physical and sequence model to find out the breakdowns throughout the expirement.(Fig.2) Meanwhile, the increase in QUEST 2.0 total mean score proves improved usability of the prototype wheelchair compared to the manual wheelchair. The combination of the final data pattern and the questionnaire score data ended up with the findings below:

A. Effectiveness of power assistance

According to the survey, the comfort Score of climbing up a slope increased from 2.2(close to "not satisfied") to 4.4, which is higher than score 4, "quite satisfied". (Table 1) Also, while conducting contextual inquiry, we observed that the participants' postures had been changed. The increase in low back moment at L5-S1 disc is mainly caused by the increase of trunk inclination, the angle of the trunk in the sagittal plane relative to the vertical axis. [4] As shown in the Table 2, the trunk inclination during climbing up slopes decreased when they used the prototype. This result proves AVEC could prevent caregivers from back injuries. Finally, from 110 codes of the initial open coded data, 35 codes were about power assistance. The quote below is one of those categorized codes.

- *P3: "This is just like walking alone naturally on the flat road. (while going uphill) It moves easily even if I don't push too hard. It feels light."*

B. Increased amount of Communication

First, the survey data implies that participants found it much easier to recognize the passenger's status. The score went up from 3.4 to 4.4. Moreover, the score of 'having conversation with the passenger' were increased by almost 2 points (1.8), out of 4 points maximum. (Table 1) Second, the instances of eye contact increased 9 times, while the usage of the gesture increased more than 2 times It is important to notice there was almost no eye contact using the manual wheelchair, but when using AVEC, the number of instances went over 5 times. (Table 2)

- *P1: "It is much comfortable to handle a wheelchair right next to the grandmas so they can read my lips to communicate. Usually, they can't hear well."*

TABLE I. Usability Survey Data

Items		Manual Wheelchair	AVEC Prototype1
QUEST 2.0 Total mean score		26.6	31
Power Assistance	***Going up a slope***	2.4	4.4
	Going down a slope	2.2	4.4
Communication	***Recognizing passenger's status***	3.4	4.4
	Having conversation with the passenger	2.6	4.4

[a.] Below the first row each score indicates the average score of all the participants.

TABLE II. Observational Data

Items		Manual Wheelchair	AVEC Prototype1
Power Assistance	***Trunk inclination(deg)***	46.82	24.7
Communication	***Instances of eye contact***	0.6	5.4
	Gesture usage	4	8.6

[b.] All the data is based on the recorded videos.

There were 19 codes about the prototype's benefits of seeing the passenger's face. Considering 11 codes implied disadvantages of using a manual wheelchair, in total 30 codes were about improving the quality of communication..

C. Intuitive Interface

Although the participants were age of 50 or more, they easily learned how to use the AVEC prototype without any extra training. Also, seeing the LED lights turn on and change the color, the participants could easily get visual feedback.

V. Conclusion and Future Work

There are clearly many problems with manual wheelchairs, considering the rapidly aging population. In order to solve them, we propose AVEC, a novel power assist wheelchair system. We conducted a field interview using a proof-of-concept prototype, and conducted contextual inquiry. According to the axial coded data, the participants showed higer satisfaction with power assistance, enriched communication, and intuitive interface. However, some of data indicated critical flaws. Most of them were about the fragile structure, beside the psychological anxiety caused by the lack of a physical brake system. We will gradually get closer to the optimal solution by building more prototypes, combining insights from the user and by simulating various formats of physical architecture.

References

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