ICIC Express Letters
Part B: Applications
Volume **14**, Number **1**, January **2023**
ICIC International ©2023 ISSN 2185-2766
pp. **39–45**

FOCUS GROUP EVALUATION OF USER INTERFACE MODES FOR MEAL-ASSISTANCE ROBOT

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Received June 2022; accepted September 2022

Abstract. *The number of elderly people around the world is growing rapidly and many patients suffer from different upper limb disabilities so they need help from others for activities of daily living (ADL). As a result, the number of people requiring help, either at home or in long-term care facilities, to complete their daily chores has increased. Various robots have been created to help the elderly and persons with upper limb infirmities acquire independence in eating, which is one of the most common and time-consuming daily duties. This research aimed to evaluate the user interface modes for meal-assistance robot for patients who need a machine to feed them. Participants experimented with five interface modes: joystick, touch screen, voice recognition, eye-tracking, and physical button. The task completion time and error rate were recorded during the experiment. The patient's preference evaluation for a developed meal-assistance robot (MAR) is also gathered. The findings showed a significant difference in task completion time between UI. The error rate of voice recognition was the highest among all UI modes. The touch screen is the most preferred UI mode for patients to interact with the meal-assistance robot. This study can help to design a better UI mode of meal-assistance robot for upper limb disabilities patients.*
Keywords: Meal-assistance robot (MAR), Interface mode

1. **Introduction.** Robotics is the field that combines science, engineering, and technology to create devices called robots that do human tasks. A robot is a product of the robotics sector, which involves the creation of programmable robots that can aid humans or duplicate their operations. Robots can help disabled people in their daily lives. As the robot industry grows, it increased the demand for development. A variety of specialized assistive devices, including robots, have been developed to aid people with disabilities in performing ADLs independently [1]. Each gadget is designed to provide a certain type of help to people with specific disabilities. Researchers have also used general-purpose mobile manipulators in a range of applications, including rescue, support, and residential services [2,3]. A variety of assistive robots have been designed to improve the physical

DOI: 10.24507/icicelb.14.01.39

or cognitive of children, early, or disabled persons with a variety of disabilities, such as autism [4,5] and cerebral palsy disease [6]. Learning and applying knowledge, mobility, control, vision, attention, memory, and communication capabilities are among the technological and functional aspects of these helpful robots. To emulate advanced capabilities, many social robots were partially or fully remote-controlled. One of the most demanding robots is the meal-assistance robot (MAR).

Eating, toileting and clothing are examples of activities of daily living (ADL) that are critical to one's quality of life [7]. People with physical or mental disabilities require extra help from carers to accomplish activities of daily living (ADL). Yet, without the support of a human caregiver, many people with disabilities, including those with upper limb limitations, find such chores difficult. However, a shortage of healthcare personnel and rising healthcare expenditures necessitate the development of new technologies that make help more affordable and effective. One of the most difficult responsibilities for caretakers is feeding the patients. Technology interventions can be a solution by bridging the gap between physical capability and necessary functional ability [8]. Depending on the severity of the user's disability, different modes of interaction and control of the robot can be considered, for instance, via a joystick, head- or eye-tracking, or brain-machine interfaces (BMIs) [9-11]. The act of helping someone to eat a meal is a process that must be completed for each meal of the day, and it is the most time-consuming and labor-intensive task for both patients and caregivers. As a result, a meal-assistance robot (MAR) is being created, which would independently feed a person with a disability. Even though numerous varieties of MARs have been launched and made available to the public, there is still a lack of study on how to improve the interactions between MARs and users (patients). Many previous studies focused on developing the functionalities of MARs [12] like taking the food and placing it in the user's mouth. These researches did not create a clear user interface or evaluate the system for individuals who had mobility issues. However, little research has been done to examine how user acceptance of robot-assisted feeding systems is affected by autonomy, perceived error rate, and characteristics like user interfaces. By examining numerous variables and examining the impact of error rate, this research seeks to close this gap. Researchers have tried their best to accommodate the needs of users, patients, and elderly persons who have expressed the desire for an assistive device that not only helps them eat more easily and neatly, but is both safe and comfortable to use, and will allow them to minimize their dependence on nurses, caregivers or family members. Variety of human-machine interfaces, from simple switches operated by different parts of the body depending upon patient disabilities to more advanced, such as voice recognition, joy stick, touch screen and eye-tracking using by human.

A representative assistive task is meal-assistance, which is an essential ADL for staying healthy. Feeding difficulties are common among people with upper-body and limb disabilities. Socially assistive robots with high HRI play the role of peers or companions, requiring intimate social, emotional, and cognitive relationships with their users [13]. As a result, MARs who are used in nursing care and rehabilitation must have social abilities that help to make user interactions more convenient [14]. Thus, when designing MARs, careful consideration of UX and social skills is required. Although there are a variety of commercially available specialized meal-assistance robots (e.g., My Spoon [15], Bestic arm and Mealtime partner [16]), these robots can only help you with your meals. These robots are created for a specific task (such as meal help), and frequently have a desk-mountable fixed base and a low degree of freedom arm. Physical buttons, touch interfaces, switches, and joysticks are all examples of interfaces for meal-assistance robots [17,18]. Some robots are compatible with numerous interfaces, allowing them to switch between them and use the required interfaces.

Although the achievement of practical use at the commercially available level is a dramatic advancement in the field of assistance robots, there still exist problems such as most preferred interface and cost. The objective of this paper is to evaluate different user interface modes for MAR according to task completion time, error and subjective preferences evaluation.

There are many papers related to meal-assistance robots. However, it is somehow difficult to find any most preferred UI design according to the patient preference for meal-assistance robots. Therefore, the focus of this paper is to design a better UI mode of meal-assistance robot for patients suffering from upper limb disabilities. The rest of the paper is structured as follows. Section 2 describes the research method which includes participants and apparatus, experimental conditions and task, procedure and statistical analysis. In Section 3, we analyze the results of dependent variables. Then in Section 4, we discuss the results of this study, and finally, we present the whole conclusion of the study.

2. Method.

2.1. **Participants and apparatus.** In this study, five patients participated in the experiment. Participants were only male and their mean age was 45 years ($\pm$ 9.45). All the participants received written and oral information about the study and they signed consent forms before the experiment. The study was approved by the institutional review board of Seoul National University Bundang Hospital (IRB number: N-2109-806-603). None of the participants had any prior experience with MARs. The participants suffered from cervical spinal cord injuries. However, they are still able to manage the joystick of MARs and use touch screen devices (phones, tablets, etc.), and also, they can press/push physical buttons.

The MAR consists of a robot arm with 6 degrees of freedom along with a food tray. A spoon and chopstick were attached to the robot arm. The food tray consists of 5 sections each for rice, soup, and 3 side dishes. The food tray is detachable from the MAR and can be washed. Control of the MAR was done using the UI application from the Bluetooth-tethered tablet or physical buttons or Joystick. The UI application offers 3 controlling modes: touch screen, voice, and eye-tracking. The size of the MAR was $47.0 \times 32.0 \times 28.8$ cm when folded and the weight was 5.38 kg. The maximal capacity of the food tray was 473 ml.

2.2. **Experimental condition and task.** A group of patients was initially explained how to interact with MAR using the joystick, touch screen, voice recognition, physical button, and eye-tracking. The independent variables of this study were UI mode (joysticks, touch screen, voice recognition, eye-tracking, and physical button) and the dependent variable was the task completion time required for each UI mode, error rate, and subjective preference rating. Participants were asked to select a specific mode and operate the MAR to lift a specific food material from the food tray where rice, soup, beans, and boiled beef were placed. The selection of the mode and the food material was predetermined and was instructed by the evaluator. The experimental environment for the study of the meal-assistance robot is shown in Figure 1. The food intake was performed 15 times per participant. The food intake simulation allows the disabled person to use five input devices to move food to a designated position. The intake order was executed with joystick, touch screen, voice recognition, eye-tracking, and physical button. Task completion time was defined as the interval between the instruction of the evaluator and the intake of the food material using MAR. Patients were asked about their subjective preference of the modes from the most preferred mode (1) to the least preferred mode (5) at the end of the evaluation.

Figure 1. Experimental environment

2.3. **Procedure.** In this study, the pre-experiment instructions were given in a separate room for participants, with images and videos of MARs items shown on the room's screen. To understand MARs, the patients were shown images and videos of different MARs. Every participant personally experienced all UI modes before the experiment. They were asked to perform meal-eating tasks. Once they confirmed to be confident with the control systems, they were asked to perform tasks. The participants performed the task with the joystick, touch screen, voice recognition, physical button and eye-tracking which are independent variables. Eye-tracking interfaces, which are mostly used for people with tetraplegia, are interfaces in which the user locates and selects the desired function via eye-tracking. The joystick is an interface that uses hands. Recently, voice recognition interface is studied a lot and it is controlled by using voice recognition technology [19]. Along with them, the touch screen and physical button mode were also evaluated.

2.4. **Statistical analysis.** A one-way ANOVA was conducted to test the effect of the independent variable (joysticks, touch screen, voice recognition, eye-tracking, and physical button) on the dependent variable (task completion time). If an ANOVA identified a significant effect, a post hoc was conducted. The student-newman-keuls (SNK) test was performed to analyze the time required for each UI mode. The statistical analysis was performed using SPSS statistics.

3. Results.

3.1. **Time required for each UI mode.** The statistical results showed a significant difference in task completion time ($F = 3.181$, $p = 0.036$) among the UI modes. According to post-hoc results, the joystick took significantly greater time than other UI modes. The physical button took a minimum task completion time (Figure 2).

3.2. **Error rate by UI mode.** According to the results, the error rate with the joystick, touch screen, voice, eye-tracking and the physical button was 18.8%, 11.1%, 50%, 30% and 0%, respectively. The error rate was the highest with voice while the lowest with the physical button (Figure 3).

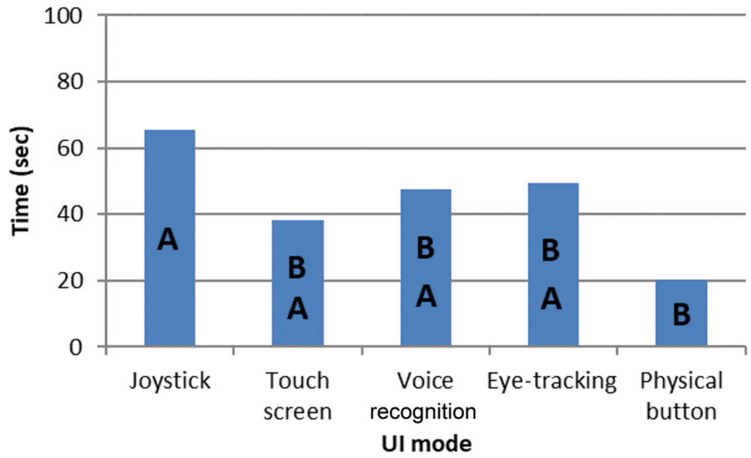

Figure 2. The time required for each UI mode. Different letters are indicating a significant difference.

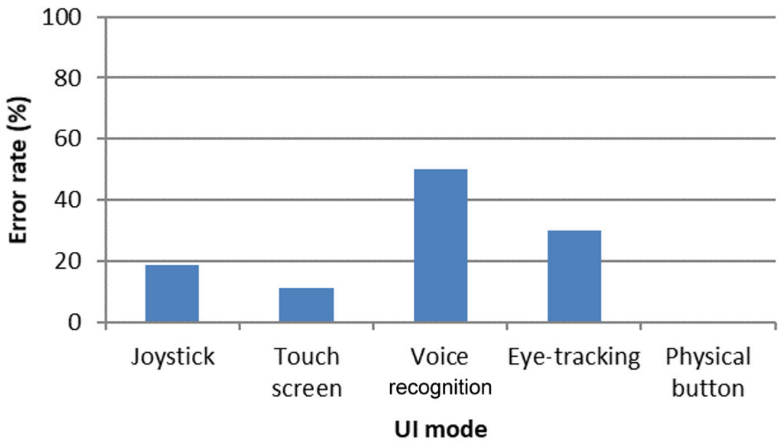

Figure 3. The error rate for each UI mode

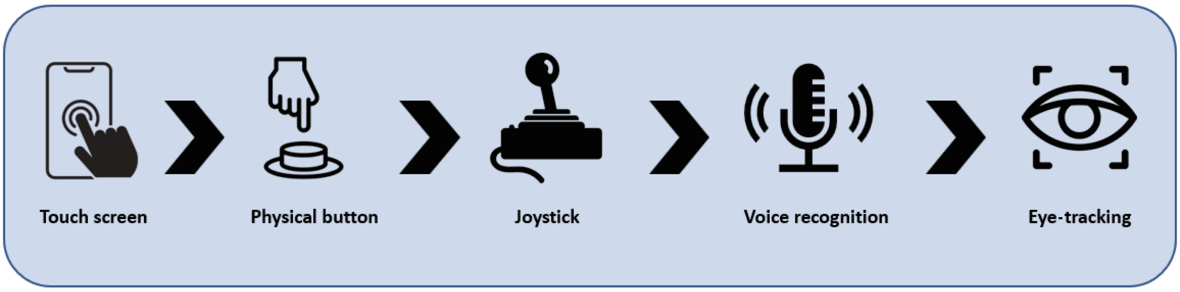

Figure 4. Patient preference evaluation of UI mode

3.3. **Patient preference evaluation of the developed MAR.** According to the subjective preference evaluation results, the patient's most preferred UI mode is a touch screen and the least preferred UI mode is eye-tracking among all UI modes. The most preferred UI mode in sequence for patients is the touch screen, joystick, voice recognition, physical button and eye-tracking (Figure 4).

4. **Discussion.** A meal-assistance robot is one of the assistive devices that has been proposed to help patients with disability for feeding/eating meals. According to the previous studies, most of the UI modes used in meal-assistance robots are controllers, switches, and

joysticks which were directly manipulated using body parts. Some of the latest technology-intensive UI modes are touch screen, voice recognition, and eye-tracking. Considering these UI modes, this study evaluated five-user interface modes for MARs according to task time, error rate and patient preference evaluation. According to the statistical results, there is a significant difference in task completion time among the UI modes. Among five-user interfaces, the maximum task time was taken by joystick and the minimum task completion time was taken by a physical button. The highest and the lowest error rate while experimenting was voice recognition and physical button, respectively. The most preferred UI mode by the patients was the touch screen after the experiment.

The maximum task time is taken by the joystick and the minimum by a physical button. It is hard for patients to interact with joysticks due to their hardness. The movement of the robot arm was time-consuming and confusing for patients with the joystick. Although the physical button also needs a gentle push, it was less time-consuming for the user to interact with.

The highest error rate while performing the task was with voice recognition and eye-tracking. Both technologies are in their developing stage and a high error rate was expected. The other reason might be the proper communication problem for patients. The voice recognition was difficult for patients to command the MAR. The least error rate occurred by physical button because the patient has to push the button which was most easy for the patient to perform. The physical button and touch screen were better for interaction according to error rate. According to the subjective preference, the most preferred UI mode was the touch screen for the patient. It was more convenient, less confusing and easy to operate than other UI modes for patients. The least preferred UI mode was eye-tracking because the recognition rate was a little lacking.

The results of this study demonstrate that even a small difference in hand motor capabilities may affect the subject's ability to interact with UI modes such as the joystick, touch screen, and physical button. The review of different available user interface modes of MARs reveals that the touch screen and physical button is the most suitable UI mode for meal-assistance robot. This can increase accuracy and reduce the task completion time. The number of a participant in this study was five so further research is recommended with a large number of participants in the future. In this study, only spinal cord injury patients participated.

5. **Conclusion.** The meal-assistance robot is one of the supporting devices that has been proposed to help with the self-feeding process of patients. This paper presents an evaluation of user interface modes for the meal-assistance robot. Five UI modes were considered and studied according to task completion time, error rate and user preference evaluation. An experiment was carried out with five patients to evaluate the UI modes. According to the results of this study, the touch screen and physical button-based UI mode are recommended for meal-assistance robots. This study can be referred to during designing MARs and UI modes for assistive robots.

Acknowledgment. This work was supported by the Technology Innovation Program or Industrial Strategic Technology Development Program (20005096, Development of intelligent meal-assistant robot with easy installation for the elderly and disabled) funded by the Ministry of Trade, Industry & Energy (MOTIE, Korea).

REFERENCES

[1] P. Rashidi and A. Mihailidis, A survey on ambient-assisted living tools for older adults, *IEEE J. Biomed. Health Inform.*, vol.17, no.3, pp.579-590, DOI: 10.1109/JBHI.2012.2234129, 2013.

[2] M. Schwarz, T. Rodehutskors, D. Droeschel et al., NimbRo rescue: Solving disaster-response tasks with the mobile manipulation robot momaro, *Journal of Field Robotics*, vol.34, no.2, pp.400-425, DOI: 10.1002/rob.21677, 2017.

[3] P. Deegan et al., Mobile manipulators for assisted living in residential settings, *Auton. Robots*, vol.24, no.2, pp.179-192, DOI: 10.1007/s10514-007-9061-8, 2008.
[4] E. Martinez-Martin, F. Escalona and M. Cazorla, Socially assistive robots for older adults and people with autism: An overview, *Electronics*, vol.9, no.2, DOI: 10.3390/electronics9020367, 2020.
[5] A. Tapus, C. Tapus and M. J. Mataric, The use of socially assistive robots in the design of intelligent cognitive therapies for people with dementia, *2009 IEEE International Conference on Rehabilitation Robotics*, pp.924-929, DOI: 10.1109/ICORR.2009.5209501, 2009.
[6] R. Raya, E. Rocon, E. Urendes, M. A. Velasco, A. Clemotte and R. Ceres, Assistive robots for physical and cognitive rehabilitation in cerebral palsy, in *Intelligent Assistive Robots: Recent Advances in Assistive Robotics for Everyday Activities*, S. Mohammed, J. C. Moreno, K. Kong and Y. Amirat (eds.), Cham, Springer International Publishing, DOI: 10.1007/978-3-319-12922-8_5, 2015.
[7] J. M. Wiener, R. J. Hanley, R. Clark and J. F. Van Nostrand, Measuring the activities of daily living: Comparisons across national surveys, *J. Gerontol.*, vol.45, no.6, pp.S229-S237, DOI: 10.1093/geronj/45.6.S229, 1990.
[8] T. L. Mitzner, J. A. Sanford and W. A. Rogers, Closing the capacity-ability gap: Using technology to support aging with disability, *Innov. Aging*, vol.2, no.1, igy008, DOI: 10.1093/geroni/igy008, 2018.
[9] L. Hochberg, D. Bacher, B. Jarosiewicz et al., Reach and grasp by people with tetraplegia using a neurally controlled robotic arm, *Nature*, vol.485, pp.372-375, DOI: 10.1038/nature11076, 2012.
[10] J. L. Collinger et al., High-performance neuroprosthetic control by an individual with tetraplegia, *The Lancet*, vol.381, no.9866, pp.557-564, DOI: 10.1016/S0140-6736(12)61816-9, 2013.
[11] T. L. Chen et al., Robots for humanity: A case study in assistive mobile manipulation, *Robots for Humanity: Using Assistive Robotics to Empower People with Disabilities*, DOI: 10.1109/MRA.2012.2229950, 2013.
[12] T. Bhattacharjee et al., Is more autonomy always better? Exploring preferences of users with mobility impairments in robot-assisted feeding, *2020 15th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*, pp.181-190, 2020.
[13] M. A. Goodrich and A. C. Schultz, Human-robot interaction: A survey, *Found. Trends Human – Computer Interact.*, vol.1, no.3, DOI: 10.1561/1100000005, 2008.
[14] K. Dautenhahn, Socially intelligent robots: Dimensions of human-robot interaction, *Philos. Trans. R. Soc. B Biol. Sci.*, vol.362, no.1480, pp.679-704, DOI: 10.1098/rstb.2006.2004, 2007.
[15] C. Shih, Q. Lai, H. Ho and W. C.-C. Chu, Smart feeder robot for severely disabled patients, *2020 IEEE 20th International Conference on Software Quality, Reliability and Security Companion (QRS-C)*, pp.603-608, DOI: 10.1109/QRS-C51114.2020.00103, 2020.
[16] D. Park, H. Kim, Y. Hoshi, Z. Erickson, A. Kapusta and C. C. Kemp, A multimodal execution monitor with anomaly classification for robot-assisted feeding, *2017 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, pp.5406-5413, DOI: 10.1109/IROS.2017.8206437, 2017.
[17] Obi, *MeetObi*, https://meetobi.com/, Accessed on Jun. 17, 2022.
[18] Richardson products, *Meal Buddy*, https://www.performancehealth.com/meal-buddy-systems, Accessed on Jun. 17, 2022.
[19] J. Zhang, B. Wang, C. Zhang, Y. Xiao and M. Y. Wang, An EEG/EMG/EOG-based multimodal human-machine interface to real-time control of a soft robot hand, *Front. Neurorobotics*, vol.13, https://www.frontiersin.org/article/10.3389/fnbot.2019.00007, Accessed on Jun. 16, 2022.