

Project Title

3D-Printed Universal Adaptive Holder for Differently abled People

Project Lead and Members

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Project members: Chung Kai Siang and Wilson Chin Wei Sheng

Organisation(s) Involved

Tan Tock Seng Hospital

Project Period

Start date: 01 July 2021

Completed date: 30 June 2023

Aims

1) Create a new 3D-printed adaptive device that can help improve availability for clinical use, accommodate to many disabilities and weaknesses, while ensuring affordability and maximal usability for patients:

- Can be used with utensils and other personal daily items
- Can be semi-customized by adjusting the 3D print template file.
- Can be easily cleaned and made of sustainable material (reduced rate of wear and tear).

2) Obtain positive usability feedback on the innovated 3D-printed device and produce in scale for use.

Background

Adaptive devices are commonly prescribed by therapists to facilitate activities of daily living (ADL) and to maintain independence in individuals with physical impairments. There is an extensive range of adaptive devices available to individuals with impairments, ranging from low-cost devices to customised high-tech devices such as ADL equipment, communication devices, transfer devices, mobility devices, orthoses,

and environmental control units (ECU). There is a wide range of ADL equipment available in the market, such as feeding devices, adapted utensils, adapted dressing kit, shower chairs, and toileting items.

There are various kinds of adaptive device for feeding and grooming available in the market. However, there are several limitations to existing products:

- Limited models available in local context/ from local vendors; these have to be ordered from overseas manufacturers at high cost.
- Lack of flexibility to modify to client's needs.
- Lack of accommodation to different kinds of disabilities and weaknesses.
- Not interchangeable/ limited fitting with different types of utensils/ personal items.

Methods

1. Prototype iteration using 3D printing technology and it can be semi-customizable by adjusting the 3D files (electronic files that represent objects in three-dimensional created by Computer Aided Design programmes) to meet individualized needs. Special features of the innovation:
 - a) Multi-purpose use, it has an attachment that can hold various utensils, personal grooming items, handwriting tools and other daily use items that can fit in the device.
 - b) Has a quick release ball joint that has lock and unlock system, to allow changes of angle for the circular and horizontal motions, to reach to desired part of the body (for example: direct utensil/ toothbrush-to-mouth, comb-to-hair).
 - c) Has an enlarged handle with ergonomic adjustable strap to match different hand sizes and promote independency in wearing the device.
2. DSRB approved usability test to evaluate the design concept of the iterated universal holder prototype, and to determine the usability and functionality of the prototype, in assisting individuals with impaired upper limb impairments in self-care activities, specifically feeding and grooming tasks in the study. Prototype improvement and refinement based on the outcome of usability test.
3. 3D-printing of prototypes with internal and external 3D printing services

Results

- 1) Usability Testing started after DRSB approval obtained in March 2022 and completed in March 2023.
 - Aim of the usability testing:
 - Understand the usability and function of prototype in aiding users to perform feeding and grooming tasks.
 - Gather user's feedback on design of prototype.
 - Identify features of design which are useful to users for further refinement and improvement of device.
 - Understand the needs and challenges of individuals faced when conducting self-care tasks and their own existing solutions/devices.
 - Collated outcomes:
 - 10 out of 12 (83.3%) participants considered standard kit as Excellent/ Good in terms of user friendliness. 9 out of 12 (75%) participants considered advance kit as Excellent/ Good in terms of user friendliness.
 - 9 out of 12 (75%) participants feel more independent after using it.
 - 11 out of 12 (91.6%) participants prefer using it with the strap.
 - 4 out of 12 (33.3%) participants prefer using both standard and advanced kit; 3 (25%) of the participants prefer using advanced kit only, and 5(41.7%) participants prefer using standard kit only.
 - 8 out of 12 (66.7%) participants stated they will use it in the public.
 - The top 3 aspects of an adaptive aid that the enrolled users considered to be the most important: weight, ease of use and effectiveness.
- 2) Modification and refinement in the design features done after the team weighed between the collated data and team's prioritization of the design:
 - the weight of the prototype: modified the handle design and the 3D material filling of the handle while maintaining the durability and function.
 - ease of use and effectiveness: refined the design of the twist cap (smoothen the edge to enhance independence in using the feature) and the adjustment method of the handle strap.

Lessons Learnt

1. Collaborative decision making among team members, for the design refinement
 - Before moving forward with the project's progress, it is important to constantly review the project's goals, objectives and milestones, in order to ensure agreement and acknowledgement among team members.
 - After review, proceeding to design changes would be a clearer and smoother process. Design refinements happen when the needs and principles of the project are listed out and if the previous designs do not meet those principles

and needs. Refinements were made with engineering, design and user experiences in mind.

- Collaborative decision needed to determine which features of prototype to be revised not only based on users' feedback, but also clinical and engineering expertise, weighing the pros and cons, without compromising the overall intended functionality of the device.
2. Engagement with 3D printing services/ vendors
- In order to retain a long-term working relationship between the project team and vendor, communications between both parties have to be clear, including relaying project's objectives and milestones.
 - Evaluate available 3D printing services and engagement of other 3D printing service/ in-house service that allows long term collaboration if the device to be prescribed in the clinical setting.

Conclusion

Our results gathered from the usability test suggested the potential of this innovative 3D-printed adaptive holder to assist individuals with upper limb impairments in daily living activities.

Final 40 sets (20 standard and 20 advanced kits) with the improved features are printed out by TTSH Medical 3D Printing Centre, which the team will be using the final prints in OT dept inpatient and outpatient, to collate further data on proof of value and ensure usability to targeted population.

Additional Information

This project is funded by the Centre for Allied Health & Pharmacy Excellence (CAPE).

Project Category

Technology, Prototyping Resources

Keywords

Innovation, Usability Test, 3D printing

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Pictures Documentation

Initial



Standard Kit



Advanced Kit

Iterated Prototypes used in DSRB approved Usability test



Standard Kit



Advanced Kit



Strap and handle (indicator for palm placement)



Advanced kit locking mechanism

Final Prototypes



Revised prototype with 2 different diameters of handle



Revised twist cap design



Revised strap and its adjustment

ABSTRACT

Usability Testing of a Newly Innovated 3D-Printed Universal Adaptive Holder Prototype for Individuals with Upper Limb Impairments in Feeding and Grooming Tasks: A Pilot Trial



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INTRODUCTION

Individuals with upper limb impairments, may have difficulties to perform self-care tasks independently, which may affect their participation and quality of life. They can be prescribed an adaptive device to enable them in performing self-care tasks including grooming and feeding. This is a first in-human clinical trial to evaluate the design concept of the iterated 3D-printed universal holder prototype, and to determine the usability and functionality of the prototype, in assisting individuals with upper limb impairments in self-care activities, specifically feeding and grooming tasks in this study.

The features of the 3D-printed adaptive holder: (a) Multi-purpose use, it has an attachment that can hold various daily use items that can fit in the device. (b) Has a quick release ball joint that has lock and unlock system, to allow changes of angle for the circular and horizontal motions. (c) Has an enlarged handle with ergonomic adjustable strap.

A total of 12 subjects at subacute to chronic stage of their conditions, participated in the study.

METHODOLOGIES

The inclusion criteria:

- (1) Referred to Occupational Therapy service in inpatient or outpatient for acute or chronic Neurological or Hands conditions.
- (2) Adults aged 21 to 99 years old.
- (3) Ability to provide informed consent.
- (4) Shoulder and elbow flexors on the affected arm have at least muscle strength of 2/5 in manual muscle testing.
- (5) Can independently learn and setup the device or have a caregiver to assist.

- Observations on subjects performed feeding and grooming tasks
 - with or without the use of the standard and advance adaptive holders.
 - testing of two different locking mechanisms (twist cap and push button).
- The System Usability Test (SUS) and semi-structured interview questions were administered after.
- Descriptive summaries of data collected during the study are presented with appropriate summary statistics.

RESULTS

The System Usability Test (SUS)

- With reference to the benchmark score (an average product have a SUS score of 68, a good product have a SUS score of 80):
 - i. Standard kit
 - 4 subjects' SUS score at least 68
 - 2 subjects' SUS score above 80
 - ii. Advance kit
 - 1 subject's SUS score at least 68
 - 2 subjects' SUS score above 80
- In terms of user friendliness: 10 subjects considered standard kit as Excellent/ Good; 9 subjects considered advance kit as Excellent/ Good .

Observations and Semi-structured Interview Questions:

- 9 subjects independent with feeding, 7 subjects independent with combing using the prototypes.
- 8 subjects prefer to perform feeding and grooming the with prototypes.
- 7 subjects prefer twist cap for ease of adjustment in advance kit.

CONCLUSION

A convenience sample of 12 subjects was used given the early phase of testing the prototype and feasibility in recruitment within the study timeline.

- The SUS shows that the usability of the advance adaptive holder requires further improvement in terms of its features.
- Weight, ease of use, effectiveness are the top 3 aspects of an adaptive aid that users considered to be the most important (Diagram 1).
- Further design improvement will be targeted on these aspects.

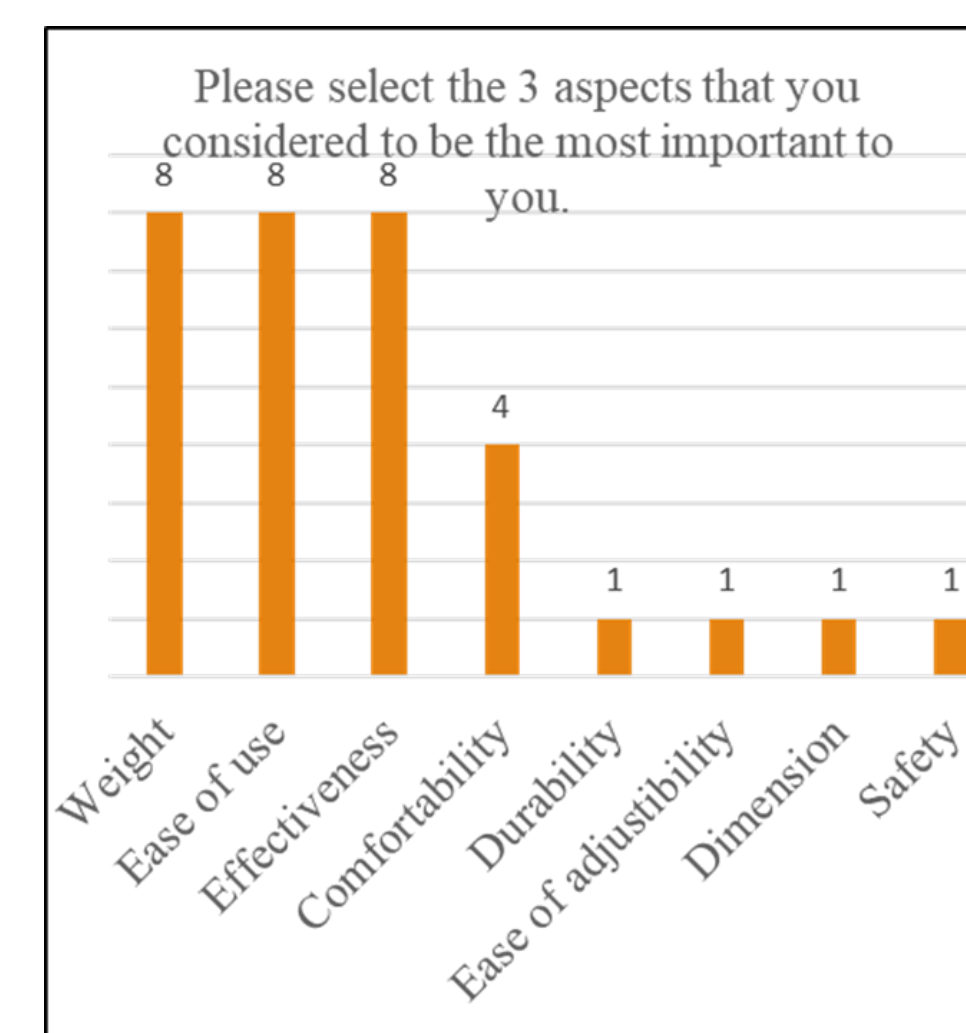


Diagram 1. Top 3 aspects of an adaptive aid that subjects considered to be the most important

We recognized the following study limitations:

- i) small number of subjects
- ii) single session trial of prototype with limited time of usage by subject
- iii) lack of comparison between users with impaired upper limb functions sustained from acute and chronic conditions

The results suggest the potential of this 3D-printed adaptive holder to assist individuals with upper limb impairments in daily living activities. Further usability testing with the revised prototype is needed to ensure usability and functionality to targeted population, and to justify the prototype's unique proposition to differentiate itself from what are already in the market.

Acknowledgements:

Head of Department/ Project Advisor – Florence Cheong Wai Fong
Centre of Allied Health & Pharmacy Excellence, CAPE – Prototype development
Occupational Therapy Enabling Fund (Innovation & Research) – DSRB approved study
Allied Health & Pharmacy Research & Translation Office (ARTO) - Chloe Chung Lau Ha
Clinical Research & Innovation Office, Sr Epidemiologist – Achanwa Sanchalika

FIGURES/ DIAGRAMS



Figure 1. Basic components of prototype



Figure 2. Standard kit



Figure 3. Advance kit



Figure 6. Locking mechanisms – twist cap and push button