Customized 3D printed devices for individuals with physical disabilities: Satisfaction and performance of mobile device access

Sara Benham[1],* Brianna Milstrey[1], Jordan Stemple[1], Jennifer Davis[1], Derek Scatena[1], Jeffrey Bush[1], & Katelyn Amy[2]

[1]Moravian University, Bethlehem, PA, [2]Good Shepherd Rehabilitation Network, Allentown, PA

INTRODUCTION

Approximately 13% of Americans live with a disability, and of those individuals, 72% own a mobile device such as a smartphone. [1,2] Access to technology increases independence and confidence to participate in activities, however, access to technology for individuals with disabilities regarding physical barriers to using the device results in a disparity. [3] Mobile devices are increasingly incorporated into everyday life as engagement supports to participate in occupations such as activities of daily living (ADL), socialization, leisure, and sleep. [4] Three-dimensional (3D) printing may circumvent the barriers to off-the-shelf adaptive device acquisition of high out-of-pocket expenses and low availability. [5] However, 3D printed devices for mobile technology accessibility have not been studied regarding user satisfaction, occupational performance, and service delivery integration for those with physical disabilities. The research questions were: What is the satisfaction of 3D printed assistive devices to access mobile devices, as compared to the previous non-3D printed assistive device, as measured by the Quebec User Evaluation of Satisfaction with Assistive Technology (QUEST 2.0)? Does self-perceived occupational performance and satisfaction change after 3D printed assistive device integration when accessing the mobile device? To understand the feasibility of customizations of 3D printing, what are the acceptability, implementation, and potential efficacy of the intervention?

METHODS

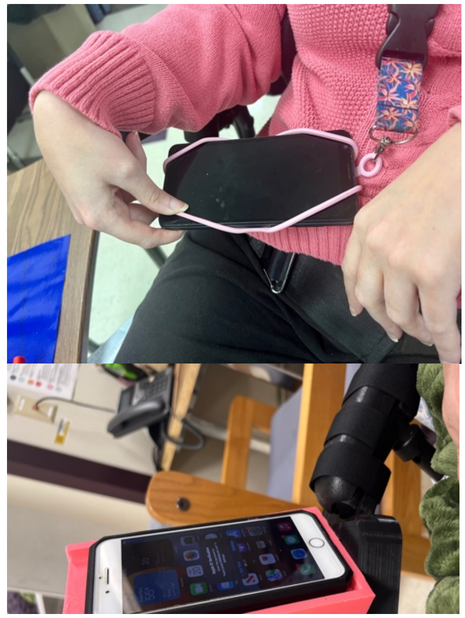
Design

This study design was quantitative and exploratory, to measure the changes of one group from pre-test to post-test and feasibility. The QUEST 2.0 was utilized to measure satisfaction based on the user's experience with the device subtest as well as the services subtest. [6] Participants rated their level of satisfaction on the questions from one (not satisfied at all) to five (very satisfied), and scores were averaged for each subtest. The self-reported Canadian Occupational Performance Measure (COPM) measured occupational performance and satisfaction with accessing the mobile device during occupations. [7] Researchers directed questions to focus on technology application during preferred occupations in the areas of self-care, productivity, and leisure. The Moravian University IRB approved this study and informed written consent was obtained from all participants.

Procedures

The study was conducted in person at two long-term care facilities within a rehabilitation healthcare network, where care is specialized for adults living with severe neurological diagnoses. Recruitment was initiated through an email from a member of the research team, who was an employee of the healthcare network, to rehabilitation clinicians which described the inclusion and exclusion criteria and requested that clinicians help to identify the appropriate residents for screening. This employee completed initial chart reviews of cognitive status and then approached the resident to confirm the inclusion criteria as an adult at least age 18, self-identified accessibility needs of their mobile device due to self-reported physical limitations, requests for increased accessibility to a mobile device that had not already been addressed by 3D printing, and the mobile device for personal use utilized an off-the-shelf accessibility method (i.e. the pre-test non-3D printed device assistive device may have included Velcro attachments to a wheelchair, elastic hand-strapping, or universally-designed phone holders with post-production adaptations). Exclusion criteria were individuals with severe cognitive impairment as measured by a Brief Interview for Mental Status (BIMS) score of seven or less. [8]

Session One included the demographic questionnaire, QUEST 2.0, and COPM regarding the pre-test off-the-shelf assistive device (see Figure 1). Then, the participant viewed a "catalog" of potential 3D printed devices and decided which device would best meet their accessibility needs. The researchers returned for *Session Two* to deliver, fit, and adjust the customized 3D print and add any attachments to the device (see Figure 1). The participants were instructed to use the 3D printed device while accessing their mobile device during everyday occupations for 10 to 14 days. During *Session Three,* the post-test QUEST 2.0 and COPM were obtained regarding the 3D printed device, and any last modification requests were finalized. Within one month after *Session Three*, the participants completed the services subtest of the QUEST 2.0.



Data Analysis

We analyzed data using IBM SPSS Statistics (Version 26; IBM Corp., Armonk, NY). Descriptive statistics were utilized to examine demographics, satisfaction, and performance of the pre-test and post-test reports of the 3D printed assistive devices, with post-test reports of "4=quite satisfied" and "5=very satisfied" considered as "satisfied" in the frequency counts when examining QUEST 2.0 scoring. To assess the preliminary effects with small sample sizes, nonparametric Wilcoxon signed-rank tests were conducted from pre-test to post-test on the QUEST 2.0 "Device" changes, as well as the COPM performance and satisfaction changes, with significance set at 5%. Effect sizes were calculated on all outcome measures. Feasibility examination aims were determined through frequency counts in the following key areas of focus [9]: *Acceptability* ("Satisfaction with 3D printed devices and service"), *Implementation* ("Retention of participants"), and *Limited efficacy* ("Intended effects of the program on key variables").

RESULTS

Ten participants were recruited, screened, enrolled, and were then followed to study completion (n=10, 100%) with a 100% recruitment and retention rate. Participants consisted of more females (n=6, 60%) than males (n=4, 40%) with an average age of 47.20 (±12.15) years. The QUEST 2.0 "Device" satisfaction with the pre-test assistive device and the post-test 3D printed device had average scores of 3.28 (±1.36) and 4.55 (±0.75), respectively, with statistically significant changes (p = 0.005), and a large calculated effect size (d =1.21) (see Table 1). [10] In the examination of the changes in occupational performance and satisfaction, the average COPM performance score on the pre-test was 6.62 (±2.45) and on the post-test was 8.26 (±1.76), with statistical significance (p = 0.016), which was calculated as a medium to large effect size (d = 0.78). Similarly, the COPM satisfaction pre-test average was 6.54 (±2.89), which increased to 8.50 (±1.86) on the post-test, with statistical significance (p = 0.037), with a large effect size (d = 0.83).

The last research question was to examine the feasibility, as determined by the three objective areas: *Acceptability*, or satisfaction, as indicated by "4" or "5" on the QUEST 2.0 post-test, which was 90% with the 3D printed device (n=9) and 100% satisfaction with service delivery (n=10); *Implementation*, or participant retention, which was 100% successful (n=10); *Limited efficacy*, or the intended effects on variables, which were all statistically significant with at least medium effect sizes (see Table 1).

Table 1. Pre-test to Post-test Satisfaction and Performance (n=10)

	Pre-test Mean (SD)	Post-test Mean (SD)	*p*	Effect Size
QUEST 2.0 Device	3.28 (1.36)	4.55 (0.75)	0.005	1.21
QUEST 2.0 Services	*N/A	4.78 (0.28)	*N/A	*N/A
COPM Performance	6.62 (2.45)	8.26 (1.76)	0.016	0.78
COPM Satisfaction	6.54 (2.89)	8.50 (1.86)	0.037	0.83

*= Services subtest not questioned upon pre-test.

DISCUSSION

This study provides evidence that increased satisfaction resulted from 3D printed device integration for accessing mobile devices, with a large effect size. These findings are consistent with previous studies that also resulted in favorable outcomes with 3D printing to develop or replicate customized assistive devices. [11,12] The participants in this study were involved in the decision-making process through participant-centered procedures such as choosing and fitting the device and reporting the satisfaction and performance outcomes. This high level of participatory involvement in the procedures has been shown to improve satisfaction and the use of the assistive device, as well as ensure that the final product fulfilled participants' unique wants and needs. [13] This evidence supports that the service delivery process should be client-centered and include self-chosen customizations, which also increases satisfaction with use and deters technology abandonment. [13,14]

The second aim of this research study was to examine changes in self-perceived occupational performance and satisfaction with the 3D printed device. This resulted in an increase in occupational performance and satisfaction and is in alignment with previous findings of assistive device integration and satisfaction as measured by the COPM. [15] In other previous studies, technology abandonment or underutilization of assistive devices may be due to failure to provide support or education to the individual. [13] Therefore, including education in the procedures may increase the effectiveness and satisfaction of using 3D printed devices to target the integration of occupations while using the mobile device.

The final purpose of this study was to determine the feasibility of integrating 3D printed assistive devices in long-term care facilities for individuals with physical disabilities. Feasibility was generally met and the findings are in concurrence with previous literature. [12] Reports of satisfaction with devices and service delivery indicate positive participant response to intervention, as well as potential effects on performance. Successful recruitment and retention are indicative of the benefit of clinician participation in the implementation of the procedures and highlight how partnering with facility clinicians facilitated successful recruitment of those who may benefit from 3D printing interventions. Participant retention was indicative of adherence and amenability to the implementation. These researchers recommend using a catalog with participants to ensure the designs have been printed successfully on the facility's printers and can be customized. A research team that is knowledgeable about 3D printers and complex 3D printed assistive devices is highly suggested for the successful replication of this study to allow for more complex customizations.

Limitations

There was no performance assessment integrated, as the questions were aimed to examine the use and preference of the new equipment, however in the future, studies should aim to integrate an objective measure to understand if the 3D printed device worked as intended. Direct effects of satisfaction and performance cannot be attributed to the intervention alone, due to the lack of a control group. As researchers look to continue to integrate self-reporting and on-demand intake of outcome measures, the use of technology as data collection tools may be considered, for example, via smartphone technology or phone call reporting, as the QUEST 2.0 has been utilized in research with phone interviews. [16] Establishing and integrating technology-based measures may allow for more consistent data collection within the proposed timing of the procedures.

CONCLUSIONS

For individuals with physical disabilities, 3D printed assistive devices may contribute to increased satisfaction and perceived occupational performance, through improved mobile device accessibility. This evidence suggests that the implementation of 3D printed assistive devices and the service delivery process is feasible and beneficial in long-term care, provided that clinicians utilize designs that have been printed successfully for timely delivery and follow-up, integrate client-centered procedures and education to enable device usability and increase access to preferred occupational activities, and have familiarity with common customization and modification requests to facilitate timeliness of the service delivery.

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