An Assistive Technology for Cognition to Support Meal Preparation: The Concept Map of a User-centred Design Process and Procedure

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Abstract: In response to the long-lasting effects of cognitive impairments following acquired brain injury (ABI) on performing meal preparation safely and independently, our team has been working on developing a Cognitive Orthosis for coOKing (COOK) to meet these needs. In this paper, the concept mapping method was used to describe the processes and procedures of employing a user-centred design approach to develop this novel technology. For this purpose, a mixed methodology including qualitative and quantitative studies was conducted for needs analysis, prototype design, prototype evaluation, and technology validation via the examination of the usability and feasibility of COOK within real-life contexts. Our comprehensive studies have shown that COOK is a promising technology for meal preparation by individuals with severe ABI. Further study is warranted/in progress to develop a therapist's interface to tailor the required type and level of assistance to a broader population with cognitive deficits of varying severity.

1 INTRODUCTION

Cognitive impairments following acquired brain injury (ABI), may significantly affect cognitive domains such as executive functions (Funahashi S & Andreau JM, 2013). Executive functions are higher-level cognitive functions necessary for directing actions to perform instrumental activities of daily living (IADL) (Blomgren C, & et al., 2019; Crichton SL, & et al., 2016; Diamond A, 2013; Zinn D, & et al., 2004). Meal preparation is a complex IADL that heavily draws on executive functions and is essential for living independently (Doherty TA, & et al., 2015; Godbout L, & et al., 2004; Tanguay AN & et al., 2014). Long-lasting effects of executive function deficits in individuals with ABI may contribute to difficulties in the meal preparation process, including setting goals, planning steps, initiating meal preparation, monitoring actions, and inhibiting inappropriate behaviors (Bottari C, & et al., 2009; Doherty TA et al., 2015; Tanguay AN et al., 2014).

With the evolution of smart technologies, assistive technologies for cognition (ATC) are strategically positioned to enhance healthcare services and enable people with cognitive impairments to be more independent in their daily living activities such as meal preparation (Jamieson M & et al., 2020; WHO, 2015). ATCs refer to "technologies that enable, enhance, or extend cognitive function in which the human user is an autonomous agent using tools to facilitate their cognition" (O'Neill B & Gillespie A, 2014). Over the last decade, there has been a growing body of evidence about the potential of ATCs in enabling

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individuals with ABI to actively engage in daily activities while supporting formal and informal caregivers (Jamieson M, et al., 2020; Kettlewell J, & et al., 2019; Leopold A, & et al., 2015; Nam J, & Kim H, 2018; Vaezipour A, & et al., 2019; Wang J, & et al., 2016; Widehammar C, & et al., 2019). Among different categories of ATCs that focused on executive functions, most are designed to help with time management (i.e., reminding, and scheduling technologies) or developed to assist with guiding people through tasks (i.e., micro-prompting systems that support multi-step task performance) (Mihailidis A, & et al, 2008; O'Neill B & Gillespie A, 2014; Rudzicz F, & et al., 2015). However, very few of these technologies include a consideration of assisting with the multiple aspects of executive functions in complex tasks (e.g., setting a goal, organization and problem-solving, preventing hazardous behaviors, completing the task, and evaluation of the outcome), which are inherent to meal preparation (Wang J, & et al., 2019).

To propose a technological solution to target various aspects of executive dysfunctions while simultaneously improving independence and safety in meal preparation, our interdisciplinary team has been working on developing an ATC called “Cognitive Orthosis for coOKing” (COOK) (Giroux S, & et al., 2015; Olivares M, & et al., 2019;). COOK is a web-based and context-aware system that was developed based on the user-centred design (UCD) approach in the context of a living lab (Pinard S, & et al., 2019). COOK has three main components: 1) a sensor-based security system to monitor safety incidents via different types of sensors such as motion detectors, pressure and infrared sensors, developed based on a preventive assistance model (Olivares M, & et al., 2016); 2) a cognitive assistance application to increase independence providing step by step instruction in the process of meal preparation via a touch screen tablet and supporting executive function sub-skills of setting a goal, planning steps, choosing a recipe, following instructions, adjusting a reminder, completing a task, and goal attainment evaluation; and 3) a configuration system that makes it possible to tailor COOK’s features to the individuals’ needs while also providing accessibility to COOK’s activity log (e.g., type of errors that occurred in conforming safety rules) by expert clinicians, ideally occupational therapists (OTs) (figure 1). Also, an extra screen can be installed in the caregivers/ therapists’ room to inform them of the stove’s/oven’s status (on/off) and possible safety issues occurring while in use (dashboard). In this manuscript we aimed to provide a comprehensive overview of our projects to develop and validate COOK.

2 METHODS

To meet the objective of this study, we used concept mapping as a structured methodology for illustrating steps and employed procedures within the UCD process to explain the whole procedure of designing, examining COOK’s usability, and implementing of COOK within real life contexts (figure 2) (Kane, 2007). This method includes an integrated mixed method of qualitative and quantitative data collection that enabled us to access in-depth knowledge from various stakeholders. Comprehensive information on the methodologies used for conducting studies at the different steps of the USD process are provided in the following sections.

Figure 1: COOK Hardware Components.

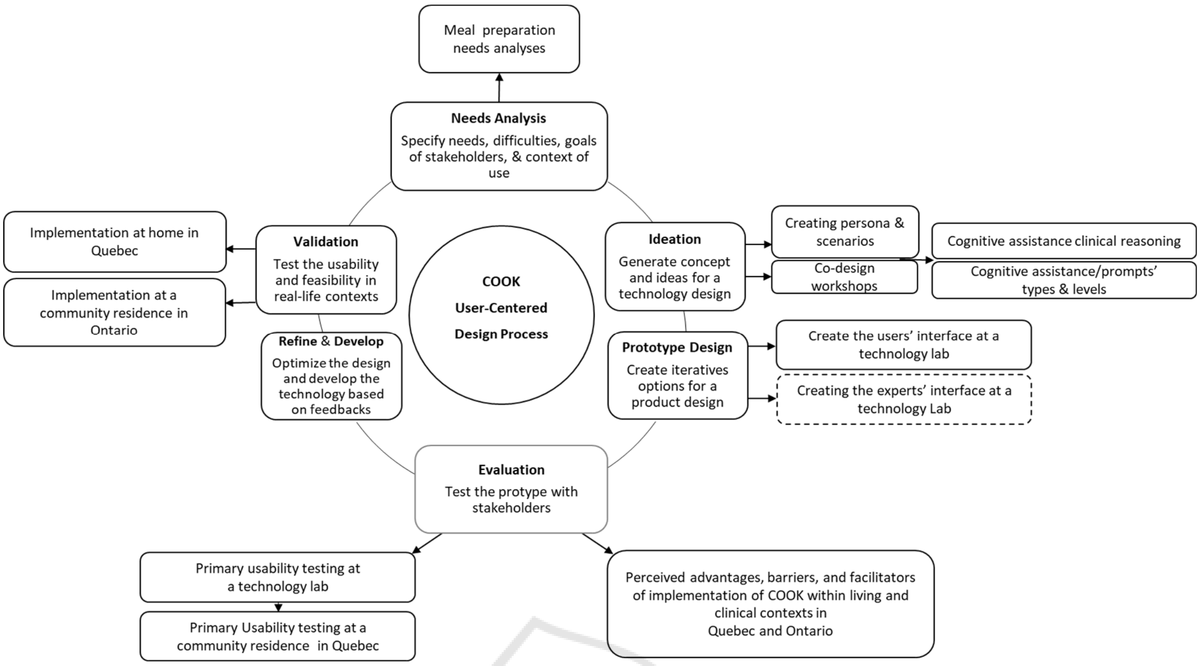

Figure 2: User-Centred Design Concept Map.

3 USER-CENTRED DESIGN PROCESS, PROCEDURES, AND RESULTS

UCD is an evidence-based and iterative approach that incorporates the needs and context of a specific end-user group and helps ensure that an invented and novel technology is acceptable and effective (User-Centered Design Basics, accessed October 2021).

3.1 Needs Analysis

To design an ATC that facilitates meal preparation for individuals with ABI, one of the imperative steps is to explore the main requirements and difficulties of these individuals and other stakeholders in various processes of meal preparation considering the interaction of personal, environmental, and task related factors (Dubuc E, & et al., 2019; Gagnon-Roy M, & et al., 2020; Pinard S & et al., 2019; Zarshenas S, & et al., 2020, 2021). For this purpose, descriptive qualitative studies were conducted by carrying out interviews and focus groups with individuals with ABI (n=20) particularly traumatic brain injury (n=14), their caregivers (n=13), and health care providers (n=30) and assessing individuals' level of independence in meal preparation using the IADL Profile (n=3) (Dubuc E & et al, 2019; Gagnon-Roy M et al., 2020; Pinard S & et al., 2019; Zarshenas S et al., 2020, 2021). Also, as another component of need analysis, clinical reasonings to provide various levels of verbal assistance by OTs (n=3) were investigated via performing IADL Profile to inform the computer scientists regarding the process of integrating the verbal assistance within the design of COOK's cognitive assistance (Gagnon-Roy M, & et al., 2021). Findings of these studies revealed various needs and difficulties in four main areas regarding meal preparation including psychosocial, cognitive, and physical abilities, and environment characteristics.

With respect to the psychosocial aspect, motivation to initiate the task, ability to maintain the energy level required to engage in the task following the onset of fatigue, need to change old habits in meal preparation that may no longer be adapted to the person's abilities, managing impulsive behaviors, and availability of caregiver's support were all considered necessary to engage in the meal preparation task (Dubuc E, & et al, 2019; Zarshenas S, & et al., 2020, 2021).

Regarding cognitive and executive function, difficulties in formulating a goal, planning, and carrying out the task, problem solving, tailoring the meal preparation process to the person's cognitive abilities were mentioned as important factors that may limit the ability to complete the task safely and independently (Dubuc E, & et al, 2019; Gagnon-Roy

M, et al., 2020; Pinard S, & et al., 2019; Zarshenas S, et al., 2020, 2021).

Further, adaptation of the meal preparation task to individuals' fine and gross motor abilities were mentioned as another necessary element to carrying out the meal preparation task in a safe manner (Dubuc E, & et al, 2019; Gagnon-Roy M, et al., 2020; Pinard S, & et al., 2019; Zarshenas S, et al., 2020, 2021). Finally, the level of support that could be provided within a living environment (home vs. supported residence) was considered as a determining factor to perform the meal preparation task successfully (Dubuc E, & et al, 2019; Gagnon-Roy M, et al., 2020; Pinard S, & et al., 2019; Zarshenas S, et al., 2020, 2021). Stakeholdrs also expressed that available commercial products have not been designed specifically to meet the needs of individulas with ABI which imposes a significant burden on caregivers who have to provide personalized cognitive assistance (e.g., verbal and visulal) to compensate the cognitive and excecutive impairments for their loved ones (Zarshenas S, et al., 2020, 2021). Also, our findings showed that four factors may affect providing verbal assistance including presence of safety and emotional issues, lack of progress in the task, requests for support, and off-task discussions (Gagnon-Roy M, & et al., 2021).

3.2 Ideation

After obtaining in depth knowledge regarding the needs and preferences of stakeholders, an interdisciplinary team including rehabilitation (n=4) and computer scientists (n=2), clinicians (n=3, OTs), and potential end-users (n=3) collaborated to brainstorm ideas to design different components of COOK (Pinard S & et al., 2019;). Various strategies were used to facilitate this step comprising persona and scenario creation, ideation workshops, and co-designing workshops (Olivares M, & et al., 2020; Pinard S & et al., 2019).

As part of the UCD process, persona and scenarios were used to characterize archetypes of various end users to facilitate the interdisciplinary collaboration between clinicians, computer scientists, and other stakeholders. Personas and scenarios were created through interdisciplinary workshops and video analysis of individuals with traumatic brain injury (n=4) being tested with the IADL Profile evaluation by an OT.

As a result of this study, personas and scenarios were created including individuals' demographic and clinical profiles and the types and levels of cognitive assistance provided by OTS to facilitate the meal preparation task for these personas. In total, three personas were developed for mild, moderate, and severe traumatic brain injury (TBI).

These personas were used in co-designing workshops with various stakeholders to inform how certain features should be designed or integrated to meet end-user's needs particularly in the client's interface of COOK. As part of the ideation and co-designing workshops, several multidisciplinary team meetings were held regarding strategies to maximize safety and facilitate cognitive difficulties during meal preparation that helped with the COOK mock-up ideas (Pinard S, & et al., 2019).

3.3 COOK Iterative Prototype Design

The design process of COOK was iterative and incremental with new features added gradually over the course of several different studies. The design team that remained stable throughout all stages of the design process included computer scientists, OTs, a psychologist, an implementation science expert, and potential end-users including individuals with a moderate to severe TBI (Pinard S, et al., 2019).

The interactive prototype was designed progressively through simulating features and functions via an interdisciplinary collaboration and applying qualitative feedback from end-users regarding their interaction with features and functions to improve simulated features. During these sessions, various strategies such as interviews, storyboarding, scenario testing, and Wizard of Oz were used for the iterative and incremental development process to design the COOK interface for individuals with ABI (Pinard S, & et al., 2019).

3.4 Evaluation of the COOK Prototype

To evaluate the prototype, different techniques were used including cognitive walk-through, lab testing of usability, and field testing of usability.

3.4.1 The Cognitive Walk-through

The cognitive walk-through method is "a usability evaluation method in which one or more evaluators work through a series of tasks and ask a set of questions from the perspective of the user" (Usability Body of Knowledge, accessed December 2021). For this purpose, we carried out interviews and focus groups with various stakeholders including individuals with moderate to severe ABI (n=20), caregivers (n=13), and health care providers (n=30). They were provided a short demo of COOK's features and functions to enable them to provide feedback on the perceived advantages, barriers, and facilitators to implementing COOK within living and clinical contexts (Gagnon-Roy M, & et al., 2020; Zarshenas S, & et al., 2020, 2021).

Findings showed that participants perceived COOK as a promising technology to improve independence and safety in meal preparation in the ABI population while addressing caregivers' burden of care. For instance, availability of various types of recipes with different levels of complexity, lists of ingredients for each recipe, weekly meal, and grocery planner, step by step instructions, portability, and possibility of installing COOK on various electronic stoves were all reflecting the positive potential of this technology. However, limited access to financial resources or funding to cover the cost of purchasing technology, being trained on, and using COOK, severity of injury, cognitive impairments and psychosocial deficits, absence of supportive caregivers, and some gaps in COOK's software (e.g., not designed for multiple users, not accessible in all languages) and hardware (e.g., not designed for a gas stove) of the technology were described as the main barriers that needed to be addressed to scale the implementation of COOK. Further, raising awareness about COOK, providing training to end-users and their caregivers/providers, and availability of technical support were considered as facilitators to the eventual widespread implementation of COOK and address some of the perceived barriers.

3.4.2 The Lab Testing of Usability

The primary version of technology was evaluated by conducting two rounds of usability and user experience (UX) evaluations which were completed in a laboratory context including 3 sessions with 5 experts and 2 sessions with 10 TBI participants. Lab usability tests measure a user's ability to complete tasks (Usability Body of Knowledge, accessed December 2021). Examination of the usability in the lab, provided us with an opportunity to involve more participants to ensure the reliability of the results (Gagnon-Roy M, & et al, 2021, submitted).

Each session included the use of scenarios and questionnaires regarding the users' experience and the technology's usability. The UX and usability evaluations of the user interface components of COOK were completed via three steps: 1) a general presentation of COOK, 2) simulating the use of the technology via scenarios, and 3) administration of two questionnaires; the System Usability Scale and the Attrak-Diff Scale (Brooke J, 1996; Lallemand C, & et al., 2015). During each simulation, participants were asked to describe their thoughts using a think aloud process, explaining their understanding of the task and the technology, and comment on the technology's ease of use and potential. Both rounds demonstrated good usability outcomes and good hedonic qualities. Various usability issues were identified by participants, such as navigation inconsistencies and technical bugs. Factors to consider in the future implementation of COOK were also mentioned by TBI participants, including environmental and personal factors (e.g., level of comfort using the technology, and possible impact of visual deficits on use of the technology).

3.4.3 The Field Testing of Usability

To test a product in the actual context, we used field usability testing (Usability Body of Knowledge, accessed December 2021). Considering the lessons learned from the lab testing of COOK, we continued to evaluate the usability of a modified version of COOK over a 6-month period for 3 individuals with severe TBI, with an average of 22 years post-injury, through evaluating effectiveness, efficiency, and satisfaction. This study took place at a community residence in Sherbrooke where we made a partnership to run the COOK project and expand our study scope. Results of effectiveness and efficiency evaluation revealed that the number of meals prepared with COOK's support increased significantly over time while safety warnings and automatic stove shot downs by the autonomous safety system decreased over time. As part of the design process, technology bugs and malfunctions (e.g., false alarms, sensitivity of sensors) were precisely documented and prototype modifications and refinements were made (Pinard S, & et al., 2019). Further, findings highlighted the importance of considering training as an imperative complementary component to use COOK over extended period by individuals with TBI.

3.5 Refinement and Development of the Prototypes

While refinement and modification of the technology was considered as an ongoing process during the course of developing COOK, and after lab and field testing of its usability, the interdisciplinary team continued working on COOK to advance both French and English versions of it, removing bugs, setting a technical support team, and creating a light and portable version to make it prepare for usability and feasibility testing within real-life contexts in Quebec and Ontario.

3.6 Validation

To validate the usability and feasibility of COOK within real-life contexts, COOK was implemented at a shared community residence for a 47-year-old woman with chronic severe stroke (C1) in Ontario and within the home of a 35-year-old man with chronic severe TBI in Quebec, Canada (C2) (Gagnon-Roy M, & et al., 2021, submitted; Zarshenas S, & et al., 2021).

For both studies we used a mixed-methods single case design, including a multiple baseline single-case experimental study and a descriptive qualitative study (Onghena P, & et al., 2018). C1 received comprehensive training on using COOK within a shared kitchen space at the residence. During meal preparation, independence and safety were evaluated using three target behaviors: required assistance, task performance errors, and appropriate responses to safety issues, which were compared with an untrained control task, making a budget. Benefits, barriers, and facilitators were assessed via three individual interviews with the client and three focus groups with the care team before, during and after the COOK implementation. For C2, target behaviors included the number of meals prepared each week using COOK, and indicators of performance during both a meal preparation task and a control task, obtaining information. Both quantitative and qualitative analyses of C1 data showed that COOK significantly increased independence and safety during meal preparation. No changes were observed in the control task. Stakeholders suggested that the availability of a training toolkit would facilitate the involvement of a greater number of therapists at the residence and the installation of COOK within the client's own apartment would help with the successful adoption of this technology (Zarshenas S, & et al., 2021). Also, C2 showed an improved ability to prepare meals overtime with less assistance being required and a more efficient preparation of meals using COOK (Gagnon-Roy M, et al., 2021, submitted). Comparing the results of these two studies showed that a client who was surrounded by a team of care at the residence could receive more support than a client who lived at home. However, both clients and care providers/givers comprehended COOK as an effective technology to increase independence of clients with ABI (Gagnon-Roy M, & et al., 2021, submitted; Zarshenas S, & et al., 2021).

4 CONCLUSION AND FUTURE DIRECTIONS

To our knowledge, COOK is the first assistive technology for cognition, designed for performing meal preparation task by individuals with a severe ABI. Our current studies showed the successful usability and feasibility examination of this technology particularly for individuals with severe ABI. However, considering the variation of ABI individuals' needs based on their severity of injury and cognitive impairments, our team is presently working on developing the expert interface as part of the configuration system where therapists will have the possibility of adjusting the types and levels of cognitive assistance provided by the technology's prompts to expand the usefulness of this technology for a broader population with ABI with various level of cognitive functions. In line with this goal, our interdisciplinary team is also collaborating with OTs to translate their clinical reasonings regarding types and levels of cognitive assistance to appropriate visual and verbal prompts within the configuration system in COOK to meet the individuals' needs during meal preparation (Tekemetieu A, & et al, in preparation). Finally, to explore application of COOK to a broader population, we are exploring the implementation of COOK for older adults with mild cognitive impairments. Preliminary findings indicated the potential of COOK for this population (Yaddaden A, & et al., 2020). Further studies are warranted regarding the usability and feasibility of this technology for the aging population.

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