Prototyping the Automated Food Imaging and Nutrient Intake Tracking (AFINI-T) system: A modified participatory iterative design sprint

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Table of Contents

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Abstract

Background: 45% of older adults living in long-term care (LTC) have some form of malnutrition. Several methods of tracking food and fluid intake exist, but are limited in terms of their accuracy and ease of application. Thus, an easy to use, objective, accurate, and comprehensive intelligent food intake system designed with LTC in mind may provide additional insights regarding nutritional support systems and nutritional interventions.

Objective: The purpose of this research was to conduct a multi-stage participatory iterative design sprint of a Goldilocks quality horizontal prototype for the Automated Food Imaging and Nutrient Intake Tracking (AFINI-T) system. Specific design objectives included: (1) identify practice-relevant problems and solutions through user-centered participatory design, (2) mitigate feasibility-related barriers to uptake, and (3) employ user-centered technology development.

Methods: A six-stage iterative participatory design sprint was developed and executed. Thirty-eight participants and advisors representing 15 distinct roles (e.g., personal support worker, nurse, dietitian etc.) were engaged in the design sprint. Trust, subjective workload (RTLX), subjective usability scales, and a modified Ravden checklist were used to assess project advisors' perceptions of the AFINI-T system prototype compared to the current method of food and fluid intake charting.

Results: The top three priorities for this system were identified as: (1a) ease of use, (1b) high accuracy, (2a) system reliability, (2b) ease of maintenance, and (3) requirement of integrating with the current PointClickCare system. Project advisors informed design decisions leading to a Goldilocks quality horizontal prototype of the AFINI-T system. Compared to the current food and fluid intake charting system, AFINI-T was perceived to have: less time demands ($P < .001$), less effort ($P < .001$), and less frustration ($P = .002$) with a lower perception of system deception ($P = .005$) and wariness ($P = .006$). Usability ratings of the AFINI-T prototype were high with a subjective usability score mean of 89.2 and the highest ratings on a modified Ravden usability checklist of “very satisfactory” for 7/8 sections.

Conclusions: Based on the design process, the concept of the AFINI-T system as a tool for an intelligent food and fluid intake appears to have good practice-relevance. Feedback from evaluation of the AFINI-T prototype suggests that many feasibility-related barriers to uptake could be removed with an improvement over the current system and that advisors are keen to try the AFINI-T system. Design decisions were informed through the application of a user-centered participatory iterative design sprint; we present this approach in the context of our case-study to provide tangible examples of how this method can be applied in the development of novel needs-based application-driven technology.

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Keywords: Participatory iterative design; Usability assessment; Perceived workload; Feasibility assessment; Application-driven research; Systematic prototyping; Nutritional support; Long-term care.

Abstract

Background: 45% of older adults living in long-term care (LTC) have some form of malnutrition. Several methods of tracking food and fluid intake exist, but are limited in terms of their accuracy and ease of application. An easy to use, objective, accurate, and comprehensive food intake system designed with LTC in mind may provide additional insights regarding nutritional support systems and nutritional interventions.

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Results: The top priorities for this system were identified as: ease of use, high accuracy, system reliability, ease of maintenance, and requirement of integrating with the current PointClickCare system. Data from project advisors informed design decisions leading to a Goldilocks quality horizontal prototype of the AFINI-T system. Compared to the current food and fluid intake charting system, AFINI-T was perceived to have: less time demands ($t = 4.89$, $df = 10.8$, $P < .001$), less effort ($t = 5.55$, $df = 13.5$, $P < .001$), and less frustration ($t = 3.80$, $df = 13.0$, $P = .002$). Usability ratings of the AFINI-T prototype were high with a subjective usability score mean of 89.2 and the highest ratings on a modified Ravden usability checklist of "very satisfactory" for 7/8 sections.

Conclusions: The AFINI-T concept system appears to have good practice-relevance as a tool for an intelligent food and fluid intake tracking system in LTC. The AFINI-T concept system may provide improvement over the current system and advisors are keen to try the AFINI-T system. This research gives tangible examples of how the sprint method can be adapted and applied to the development of novel needs-based application-driven technology.

Introduction

The link between poor nutritional status and disease is well established; malnutrition is associated with decreased quality of life, increased hospital stays, pressure ulcers, morbidity and mortality [1–3]. Furthermore, malnutrition-related costs the health care system $10 billion per year in each the USA and UK [4,5]. Older adults are at increased risk for nutritional deficiency due to physical and physiological changes (e.g., reduced lean muscle, less efficient gastrointestinal tracts, changes in sensory ability like smell or taste), in addition to having a higher degree of co-morbidity [6]. Older adults living in long-term care (LTC) are particularly vulnerable; in Canada, 97% require assistance with activities of daily living (including eating assistance), 90% of the population is living with memory impairment, 61% are on 10 or more medications and 49% are living with depression [7]; these demographics are similar in the United States [8]. Approximately 44% of the LTC population is malnourished based on a recent Canadian study [9] which is consistent with a systematic review of global research (37 studies, 17 countries; malnutrition prevalence: 19% to 42%) [10]. Best practice metrics for ongoing nutritional assessment include monitoring unintentional weight loss, usual low intake of food, or other quality indicators to prioritise referrals and monitor effectiveness of nutritional support systems [11]. However, while inadequate intake is manageable [12], present guidelines for a nutritional intervention stipulate a resident must consume less than 75% of a meal most of the time [13–15]. Half of these residents who would benefit from an intervention are missed [14,15] because of difficulties assessing and charting food intake. Thus, monitoring nutritional status in LTC is crucial, but difficult to do effectively.

In LTC, nursing assistants or personal support workers (PSWs) chart food and fluid intake of residents using either a paper-based or electronic form to capture intake across a meal at 25% incremental proportions of intake. The accuracy of these methods is known to be poor with incorrect estimates over 50% of the time [16]. One contributing factor is time constraints in the LTC environment and is further confounded by frequent retrospective charting, which increases the probability of reporting errors [13]. While accuracy is important to ensure appropriate referrals of residents to a registered dietitian (RD) [14], the current method fails to differentiate between aspects of a meal; equal consumption across a plate is assumed. To address this, Andrews and Castellanos developed a food-type specific tool, however, consumption was still underestimated 25% of the time [13]. The challenge remains that comparisons either require time consuming methods or need to be completed by highly qualified personnel [14].

Technological innovations may provide a solution to remove subjectivity, enhance reproducibility, and inform higher levels of detail. There has been some progress in automatic food intake tracking systems. For example, several devices have been proposed for an individual to track and manage weight loss by recording intake using a mobile device [17–20]. While this on-the-go approach could potentially be modified for appropriate use in LTC settings, in their current state, they are tailored for a different purpose, rely on self-monitoring, and do not adhere to related best practices for food and fluid intake. Additionally, they require a series of images from multiple perspectives [17], or depend on reference objects to infer scale (i.e., fiducial marker) [19]. In a time-constrained environment such as LTC and hospital settings, these requirements make these approaches infeasible. Consistent with this apparent gap, a 2016 review by Pouladzadeh and colleagues [20] summarize both traditional and newer (smart-phone vision-based) methods for calorie intake tracking in the context of weight loss and weight maintenance. They conclude there remains several challenges including: the explicit need for user acceptance studies of nutritional monitoring technology, consideration of more complex meal scenarios, and computational requirement consideration [20]. Within the LTC context, the closest technological solution was a comparison to estimate food waste of regular and modified texture diets either with the visual estimation method or using digital photographs afterwards [21].

The above highlights the need for an easy to use, accurate, and comprehensive food intake system designed with the LTC context in mind. The goal of this research was to collaborate with representative end users to design a novel prototype system for Automated Food Imaging and Nutrient Intake Tracking (AFINI-T). End users in this context were team members working in long-term care involved in monitoring resident food intake (e.g., PSWs, RDs). We developed a Goldilocks quality horizontal prototype by accomplishing the following objectives: (O1) identify practice-relevant problems through user-centered participatory design, (O2) remove feasibility-related barriers to uptake, and (O3) facilitate confidence in design decisions for user-centered technology development. Our guiding principle was to accelerate research to uptake of novel technological solutions through practice-informed research. Each of the three objectives outlined above had several goals as follows: (A) understand workflow and the problem space including user perceptions of workload of the current system (O1); (B) conduct a needs assessment within the problem space (O1); (C) establish functional criteria for usability and feasibility including user interface requirements (O2); (D) evaluate a user-driven, practice relevant early-stage prototype to inform future directions including user perceptions of workload, usability and receptivity of the AFINI-T system prototype (O3). The primary contribution of this work is the novel AFINI-T system design created through participatory iterative design by the: (1) identification of functionality requirements and design considerations, (2) findings and insights from user testing, and (3) a demonstration of and a reflection on the effectiveness of this participatory iterative design methodology with a multidisciplinary team of project advisors. The remainder of this paper is organized as follows: the combined Design Stages section presents the six stages used in the design process along with related results and discussion for each stage, followed by a general discussion before closing with overreaching conclusions.

Design Stages

Our goal was to create a Goldilocks quality horizontal prototype. "Goldilocks quality" refers to having the "just right" amount of fidelity to elicit useful feedback from users without having to build an entirely functional prototype [22]. A horizontal prototype refers to a user interface-based design to allow user feedback on an early-stage conceptual walk-through of the process [28]. We implemented an iterative participatory iterative design process modeled off the Google Sprint framework to develop and evaluate this prototype for monitoring food and fluid intake in LTC [22,23]. The six stages of our process were:

STAGE 1: Design Ideation
STAGE 2: Reflect and Storyboard – *see Multimedia Appendix 1*
STAGE 3: Storyboard Critiques – *see Multimedia Appendix 1*
STAGE 4: Design of the Goldilocks Quality Horizontal Prototype
STAGE 5: Usability Assessment
STAGE 6: Final Validation

The design process was guided by several conceptual frameworks: (1) conducting interdisciplinary research [24,25]; (2) leveraging user-centered design and participatory design [26,27]; (3) applying rapid prototyping methodology via a modified Sprint [22,28]; and best practices for user interface design [28–33]; and (5) evaluating usability [34,35] and perceived workload [36]. The flow of information through each stage is shown in Figure 1. For brevity, the methods (including collaborators, data captured and analyses), results, and discussion for Stages 1 and 4 – 6 are presented below within the context of each stage; details regarding Stage 2 and 3 can be found in

Multimedia Appendix 1.

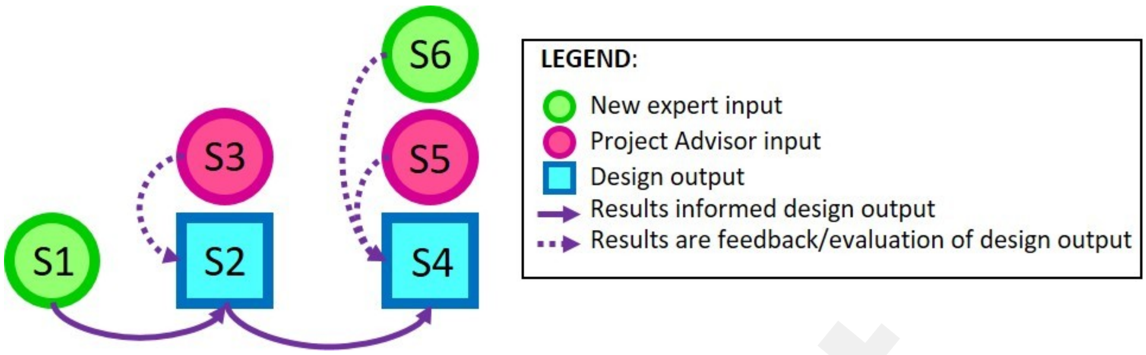

Figure 1. An overview of the 6 stages (e.g., S1 means Stage 1) including information flow between stages. Solid arrows indicate results directly influencing design output (e.g., S2's story boards, S4's Goldilocks prototype). Dashed arrows indicate feedback on a design stage. Feedback was collected from expert input (S1, S6 in green), and from ongoing project advisor engagement input (S3, S5 in pink).

STAGE 1: Design Ideation

STAGE 1: Purpose

The purpose of Stage 1 was to engage with end-users as collaborators to establish design directions. Specifically, we sought to understand current workflow, evaluate priorities, understand perceived workload of the current system and, identify potential project advisors. The output from this directly informed Reflect and Storyboard (Stage 2) and Usability Assessment (Stage 5).

STAGE 1: Methods

Stage 1 consisted of a 60-minute workshop in which three activities were completed: *Activity 1: The "Ask the Experts" activity*; *Activity 2: Priority ranking survey completion*, and *Activity 3: "Vote with dots" exercise* to keep participants engaged and reflect on priorities. Three research assistants plus the lead author took notes during this discussion and transcribed several comments verbatim. Following the workshop, three informal open-ended interviews were conducted to further inform the problem-space. The lead author took notes during these interviews; several comments were transcribed verbatim.

For the workshop, twenty-one participants representing 12 LTC and retirement homes were recruited through self-enrollment with following roles: Administrative Assistant, Chef, Dining Lead (similar to a dining room manager), Director of Recreation, Dietary Aides, Neighbourhood Coordinator, Recreation Assistant, Restorative Care, Senior Nurse Consultant, Directors and Assistant Directors of Food Services, Nurse, and Personal Support Workers (PSW). Activities were discussed with the Schlegel-UW Research Institute for Aging's (RIA) Research Application Specialist for input on how to conduct this exercise successfully with front-line team members.

Activity 1: The "Ask the Experts" activity

Workshop participants were asked about their experience with food and fluid intake. This aimed to build participants' confidence in the value of their experiences while probing current workflow and problem space.

Activity 2: Priority ranking survey.

Participants independently completed a survey to evaluate priorities and needs to limit bias. This survey asked about the current charting process (e.g., when it is done, task completion time, barriers and facilitators to task completion). For evaluating priorities, 5-point Likert scales were used to rate 16 statements' importance from "Not Important" (i.e., 0) to "Very important" (i.e., 4) or "Not Applicable". Perceived workload of the current system was retrospectively evaluated with the Raw Task Load Index (RTLX) [36,37] for its application simplicity and comparability to the NASA-TLX [37–40].

Activity 3: "Vote with dots" exercise.

Modeled from [22], participants transposed their individual Activity 2 responses into a group response by voting their preference using stickers on giant sticky notes to amalgamate opinions, keep participants engaged and to facilitate additional discussion.

STAGE 1: Analysis

Given the nature and size of this pilot study, a preliminary thematic analysis was used for qualitative components (e.g., discussions, comments, verbal/written feedback) that was combined with descriptive statistics for quantitative information including the average (μ), standard deviation (σ), mode, and median scores [41]. For scales with five or more categories (e.g., RTLX), $\mu(\sigma)$ are used; the mode was used for categorical data with fewer than five categories (e.g., Ravden Checklist). A weighted average was used to analyse Likert survey questions, excluding "Not Applicable", to yield a ranking of each statement.

STAGE 1: Results

Results from Stage 1 pertained to Objective 1: Address a practice-relevant problem through user-centered participatory design (Goals A, B) and Objective 2: Remove feasibility-related barriers to uptake and are as follows (Goal C):

Goal A: Understand workflow and problem space

PSWs, registered nursing team, RDs are primary users who conduct charting of food and fluid intake on iPads. This charting is completed whenever primary users have time which could be during meal service or retrospectively, consistent with [13]. In a follow-up discussion with the organization-wide director of food services who is responsible for policy, she indicated that conducting food intake in real-time is mandated (as opposed to retrospectively), but from the workshop discussion, it is clear there is a gap between policy and practice. While the workflow of AFINI-T is congruent with this mandate, a solution to support this mandate in practice may require policy modifications. For example, one person may need to be assigned to the sole task of tracking food and fluid intake during mealtime, which means they would be unavailable to provide assistance with residents' care needs for the duration of the meal. Changing policy is outside the scope of the current AFINI-T project but having sensitivity to this issue provides helpful context and informs that this may be a potential barrier to uptake of the system in practice.

Regarding the current system, respondents appreciated the ability to track fluids so they need not manually add and the output has units (mL). While the current system is dependable, substantial barriers and limitations were identified regarding the effectiveness and accuracy of the current system. One workshop participant shared, "What's being collected for solid food isn't useful. It's so high level and minimal can't make use of it. [We] can't infer anything regarding health or category of at-risk. [We] look at last 7 days, see 'they had 75% of a meal so they're eating well', but it doesn't say anything. [We] don't get a lot of info from the charts."

Insufficient time, data inaccuracy, unreliability and non-standardized measurements were identified as the largest barriers for task completion. Additionally, inability to differentiate between types of foods, and lack of relation to original serving size lead to data interpretation difficulties. For example, some residents prefer half portions; if they eat half of their portion, this could be recorded as 50% (i.e., half of the serving they received), or it could be input as 25% (i.e., ¼ relative to the full portion). There is no guarantee the proportion is input accurately or consistently. These themes were apparent through two sources, the “Ask the Experts” as well as on the survey. For more detail regarding the current system’s retrospective analysis of perceived user workload, see the sections of Table 3 pertaining to the “Current” system.

Goal B: Conduct a needs assessment of problem space including priority areas

Workshop participants were asked to rate need statements’ importance. The top three ranked priorities were tied between: (1) “ease of use” and “accuracy” (μ=3.9, mode: “very important”, 15/16 votes), (2) “reliability” and “maintenance” (μ=3.9, mode: “very important”, 14/16 votes), and (3) “The system should work well with PointClickCare.” (μ=3.8, mode: “very important”, 12/16 votes).

The following five themes emerged as wishes for a novel system to extend beyond the current infrastructure: (1) being able to leverage weight of food as a ground truth instead of relying solely on subjective proportions, (2) having the ability to track trends over time, (3) being able to discriminate between types of food, (4) being able to include fluid intake as well to discriminate between types of fluids, and (5) operating the system in different modes to accommodate various use cases (i.e., in the dining room vs for in-room service). One additional, complementary theme relevant to priorities identified independently through three interviews was the need to support prioritising referrals that consider symptoms and risk flags severity. One project advisor articulated, “There is 1 Registered Dietitian for 300 residents. It’s impossible to track properly … People are often missed because nurses aren’t identifying properly… If charting were accurate, this would help with the referral process.”

Goal C: Establish functional criteria for usability and feasibility

The current system mode time to complete task defined the time completion target: 10-14 minutes maximum per neighbourhood (i.e., “ward”) of 16 residents. Of the 21 workshop attendees, 11 self-identified as being involved in charting resident food and fluid intake and were asked about the amount of time required to complete intake charting for each of food, fluid or snack. Survey responses are outlined in Table 1

Table 1. Summary of length of time required to complete food and fluid intake charting for one neighbourhood comprised of 16 residents (Stage 1).

Charting Type	Mode Time (minutes)	(n/N responses)[a]	Time Range (minutes)
Food (meal)	10-14	30% (3/9)	<10 to 25+
Fluid	10-14	40% (4/10)	<10 to 25
Snack	<10	64% (5/9)	<10 to 19

[a] n is the number of responses with the mode rating out of N, the total number of responses.

STAGE 4: Design of the Goldilocks Quality Horizontal Prototype

STAGE 4: Purpose

The purpose of Stage 4 was to create low-fidelity prototypes by incorporating the most promising solution concepts identified through the storyboard critiques in Stage 3. These prototypes were then used for pilot evaluation in Stage 5's usability assessment.

STAGE 4: Methods

Design decisions were informed by heuristics as in Stage 2 [33,28,32] and feedback received from the storyboard critiques in Stage 3. The following heuristics were emphasized: universal usability was considered by testing the prototypes with different types of users (e.g., academics, PSWs), providing informative feedback and error prevention, the output this stage (Stage 4) was a Goldilocks quality horizontal prototype. This included interfaces for each of the three levels of primary users currently involved in residents' food and fluid intake charting (i.e., PSW, registered nursing team, and RD).

STAGE 4: Results

Design heuristics were applied in the four ways and sample output from this stage is illustrated in the right pane of Figures 2 and 3. First, related to universal usability, mapping was considered through matching the system with users language and familiar concepts in reality (e.g., Figure 2 contains tab names for snacks such as "AM", "PM" and "HS" refer to the morning, afternoon, and evening snacks respectively) [28,32]. Second, informative feedback on a change of state was provided [33,28] when users attempted to submit or track an action, a pop-up there is a pop-up banner at the bottom of the screen (not shown). Third, error prevention [33,28,32] was incorporated through limiting types of responses and providing feedback. For example, the PSW interface would prompt for a picture or a progress note before submission with the ability to finish charting at a later point of the meal service. Fourth, efforts were made to reduce short-term memory load and enhance visibility/ discoverability [28,33,32] by placing the workspace into panes with all information accessible on one screen. Other features included making "smart" suggestions when selecting items or filling out portion sizes. For example, notes entered from RD interface (not shown) would auto-populate on RD instructions tab in the PSW interface.

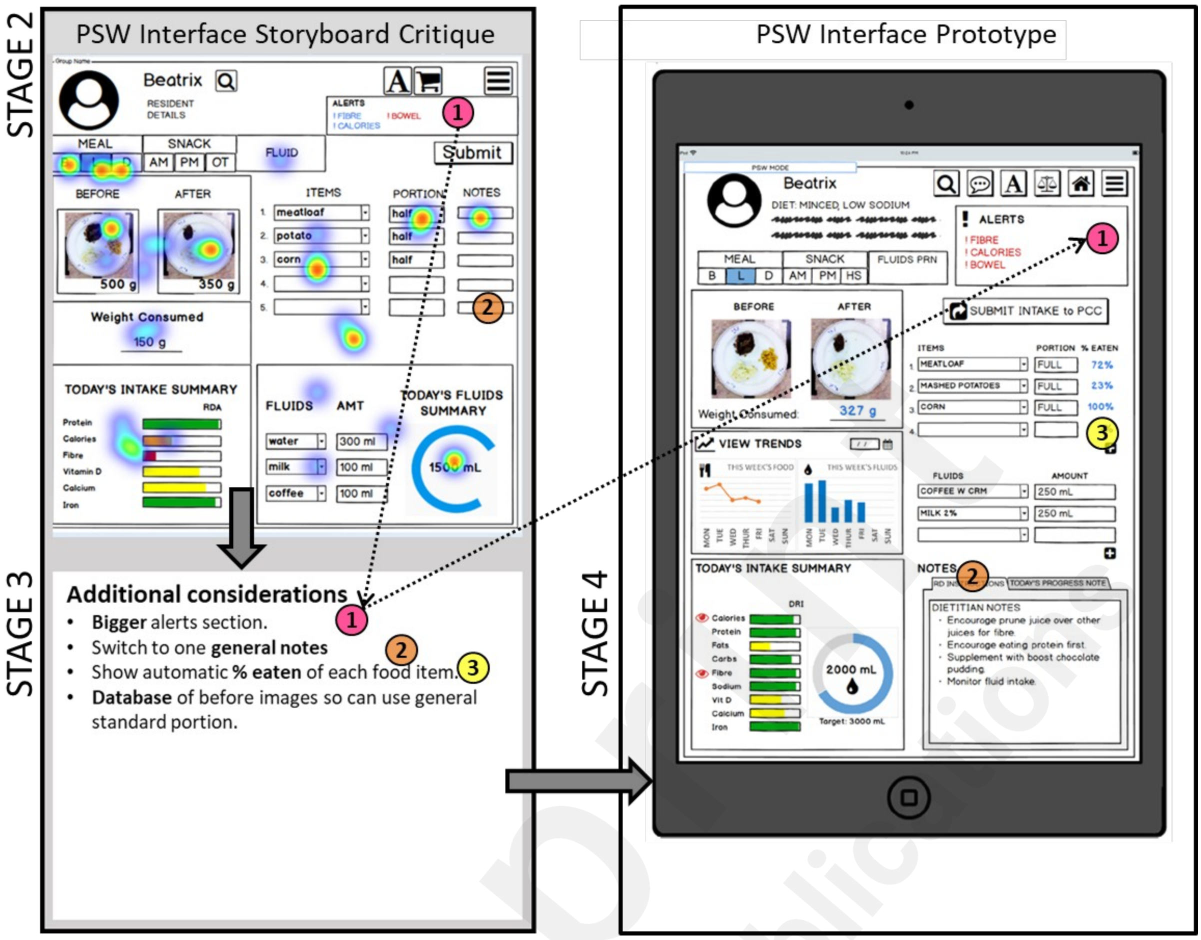

Figure 2. Stage 2 PSW user interface. Output from Stage 3 included a heatmap on the most promising aspects (red indicates more votes, n=5) with qualitative feedback highlights for additional considerations. The right pane illustrates an example of the prototype interface. Numbers correspond to the flow of information and adapted feedback from Stage 2 through to 3 and 4 using the first example (#1 in pink) to further illustrate flow with the dashed arrow.

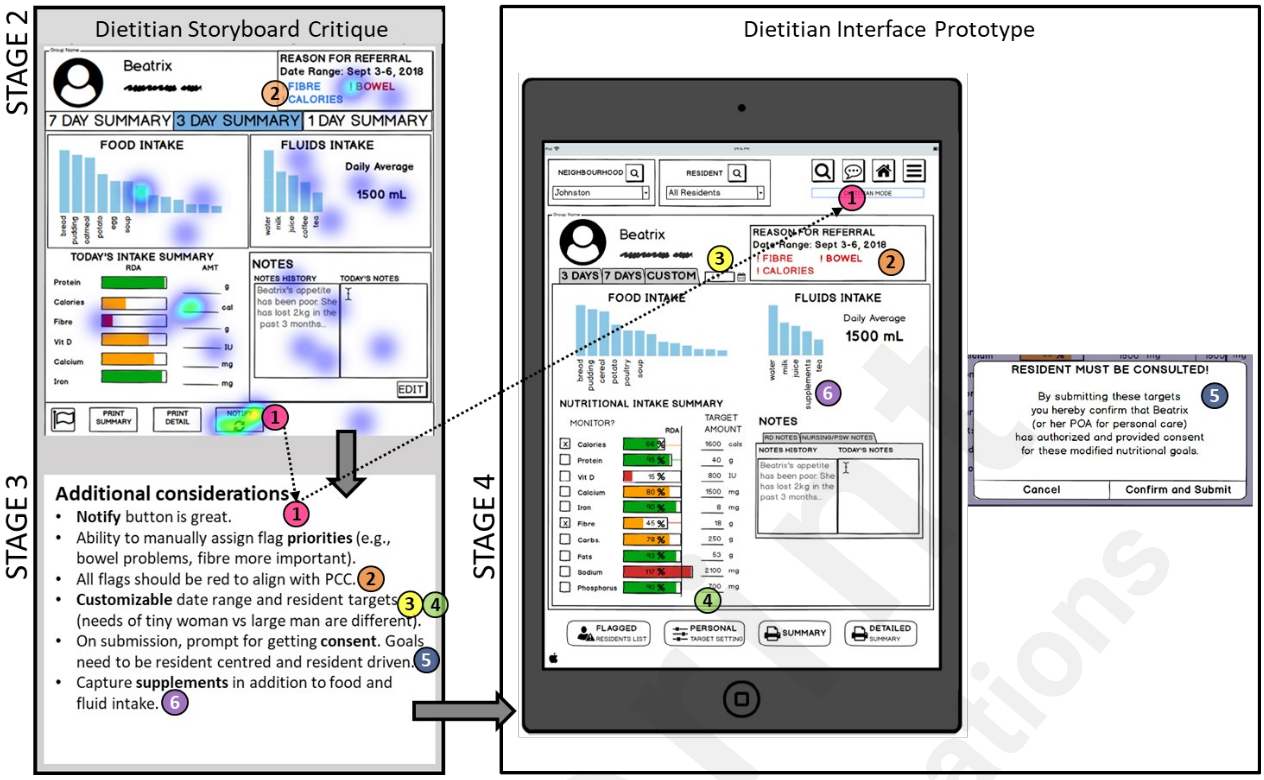

Figure 3. Stage 2 Registered Dietitian user interface. Output from Stage 3 included a heatmap on the most promising aspects (red indicates more votes, n=5) with qualitative feedback highlights for additional considerations. The right pane illustrates an example of the prototype interface with a sample pop-out box. The numbers correspond to the flow of information and feedback from Stage 2 through to 3 and 4 using the first example (#1 in pink) to further illustrate flow with the dashed arrow.

STAGE 5: Usability Assessment

STAGE 5: Purpose and Objectives

The goal of Stage 5 was to elucidate preliminary feasibility with end-users early on through the evaluation of prototypes through pilot testing. Output from this stage informed how the prototypes could be improved for development of a working system in the future.

STAGE 5: Methods

Prototypes were evaluated by comparing perceptions of the AFINI-T prototype to the system currently in place regarding usability and workload. Usability was assessed using the SUS [34] from the user perspective and a modified Ravden usability evaluation checklist [35] from technical experts' perspectives; items pertaining to help, including all of section 9, were removed as this was beyond the scope of the Goldilocks quality horizontal prototype.

Four project advisors from Stage 4 were tester participants (PSW, Dining Lead, Dietary Aide, and Nutrition Research Expert). By word of mouth, two new project advisors requested inclusion as observers for a total of six advisors. All testing was completed in-person though one-on-one sessions. Testing sessions were audio-recorded and relevant quotes were transcribed verbatim. Testing began with an interview walk-through of the prototypes based on script adapted from [22] to ascertain usability and feasibility barriers. A novel pre-defined strict set of tasks was completed by each advisor. The student investigator completed a checklist to capture the degree of success to which each task was completed (i.e., success, required prompting, or failed).

The RTLX [36,37] was administered to enable comparison of perceived workload of the current method in place with the AFINI-T system prototype (Table 3). Usability was assessed with the Subjective Usability Scale (SUS), which was selected over other usability questionnaires for its ease of use, minimal training requirements, and low application time [38,42]. The RTLX, and SUS were also completed by the two observers (Director and Assistant Director of Food Services) based on their experience during the observation (Figure 5). These two project advisors had no previous experience or knowledge of this project.

For evaluating usability more formally, an adapted Ravden checklist was used by two technical experts with backgrounds in systems design engineering and limited exposure to the users' perspectives. The Ravden checklist was selected for its low-cost and ease of use to assess the interface with good inter-rater reliability and predictive validity [38,42] (Multimedia Appendix 3).

STAGE 5: Analysis

A two-tailed t-test assuming unequal variances [43,44] was conducted to compare the current system and the AFINI-T system for users' perceived workload for the RTLX. Quantitative data were analysed using descriptive statistics, with highlights from qualitative data as described in Stage 1.

STAGE 5: Results

Stage 5 results address Objective 3: Facilitate confidence in design decisions and empower user-centred technology development (Goal D).

Goal D: Evaluate a user-driven, practice-relevant prototype.

Subjective usability was rated as "acceptable" with an average SUS score of 89.2 with the lowest and highest SUS scores of 72.5 and 97.5 translating to a B+ on the grade scale. Mapping these scores onto the adjective ratings as described by [45,46], the majority of usability scores (5/6) therefore fall between "excellent" and "best imaginable". In line with these quantitative results, users commented that: "It's quite intuitive, the key things were easily found", "It's a lot but it's easy to learn and it's colourful", "I'm not technologically inclined, but most things I was able to do intuitively", "I think someone could use this if they were just thrown onto the floor with it."

As highlighted in Table 3, performance was rated comparably with average score of 16.8 and 15.2 for the AFINI-T and current systems, respectively. In the case of mental demand, time demand, effort and frustration, subjective workload ratings were significantly lower for the AFINI-T system than the current system ($p<0.05$). These results suggest the AFINI-T system is perceived to require less effort and lower overall workload than the current system. This is consistent with comments from the participants including: "[This would take a] huge burden off me as a clinician. This is hugely better than paper… there are no guestimates… I don't have to do work.", and "It makes life so much easier".

Table 3. Comparing retrospective perceived users' workload measures of current food/fluid intake system from Stage 1 to the AFINI-T prototype results from Stage 5.a

	System	Mean	Mode(s)	Min	Max	Responses	t-Test
			n	n	n	(N)	t, df (*P*-value)
Mental demand							

	Current	10.2	6	4	19	10	2.56, df = 13.8
	AFINI-T	4.4	3	1	10	6	(*P* = .023)
Physical demand							
	Current	6.4	2	1	15	9	1.41, df = 12.5
	AFINI-T	3.5	1	1	6	6	(*P* = .183)
Time demand							
	Current	16.7	19	5	20	10	4.89, df = 10.8
	AFINI-T	5.5	3	1	12	6	(*P* < .001)
Performance							
	Current	15.2	18, 20	3	20	10	0.722, df = 13.7
	AFINI-T	16.8	20	11	20	6	(*P* = .722)
Effort							
	Current	13.2	6	6	20	10	5.55, df = 13.5
	AFINI-T	3.7	3	1	7	6	(*P* < .001)
Frustration							
	Current	11.5	15	1	20	10	3.80, df = 13.0
	AFINI-T	3	2	1	8	6	(*P* = .002)

[a] Values could take on a range from 0 to 20; 0 implies no workload, 20 implies highest imaginable workload except in the case of performance which is reverse coded.

For the AFINI-T system prototype in Stage 5, receptivity to the prototype was positive with several areas identified for improvement. For example, regarding the general concept for the dietitian interface: "[It] would be good to personalize these specific needs and set it so the flags sent to nursing/PSW for these items based on what dietitian enters …This would save *a lot of time* especially if individualized.", "Capturing [supplement intake] would enable dietitians to monitor intervention adherence … If it shows up that they never have it, then great feedback to change the intervention."

Two technical experts completed a modified Ravden usability checklist evaluation with favourable ratings (Multimedia Appendix 3). Ratings across both raters for sections 1-8 were very satisfactory (7/8 sections), or split between "satisfactory" and "very satisfactory" (1/8 sections) and mode for section 10 on system usability of "no problems". Consistent with comments from user testing, the main suggested area for improvement was to increase customizability options (e.g., sort resident list in multiple ways, allow more flexibility in the order of operations such as allow charting before a picture is taken).

STAGE 6: Final Validation

STAGE 6: Purpose and Objectives

The goal of Stage 6 was to receive additional feedback from a group of RDs, directors and assistant directors of food services to provide a fresh perspective to minimize bias.

STAGE 6: Methods

The RDs, directors and assistant directors of food services from across the Schlegel Villages were invited to participate in a webinar outlining the progress to date along with tandem survey completion for assessing perceived usability and workload. 13 people participated in the webinar (43% participation rate), which is consistent with typical attendance of quarterly dietitian meetings at Schlegel Villages due to scheduling complexities.

STAGE 6: Results

Receptivity of participants in Stage 6 was generally positive. The main reservation pertained to how the system would integrate with the current method and PointClickCare (corroborated in Stages 1, 5 and 6), and workflow more generally. For example, three webinar participant's direct messages were as follows: (1) "I love the idea of this system, we are concerned about workload, as well as if the systems (AFINI-T and PCC) talk to each other.", (2) "Would this be a separate system that would be linked to PCC?", and (3) "I hope a PCC progress note is generated from any notes [a registered dietitian] adds".

Finally, participants expressed reservations regarding the proposed AFNI-T system. One dietitian expressed concern about overemphasizing the importance of nutrition "in a population that should have the main focus of just making sure [residents] are enjoying the food we are serving". There was also concern over how this will translate to Ontario Ministry of Health and Long-Term Care (MOHLTC) inspectors' inspections and the perception that using a system like this will take more time. Additionally, it was stated that there was no perceived value to having access to more detailed nutrient data in the LTC population as, to them, the largest issue contributing to malnutrition is the impact dementia has on calories consumed. However, they did suggest that if there was an ability to screen for residents to focus on only those at greater risk for malnutrition that the AFINI-T system would be helpful while still meeting the MOHLTC standards since only those at risk for malnutrition are mandated to track food and fluid intake. This provides an interesting complementary perspective and warrants further probing and discussion.

Discussion

The overall purpose of this study was to investigate the gap for user acceptance studies and work towards a feasible food and fluid intake tracking solution for use in LTC through a participatory iterative design process and the creation and evaluation of a Goldilocks quality horizontal prototype. Specific contributions of this work were: (1) identify practice-relevant problems and solutions through user-centered participatory design, (2) remove feasibility-related barriers to uptake, and (3) facilitate confidence in design decisions and empower user-centered technology development.

We applied a rapid prototyping methodology via a modified Sprint process [22,28]. For the AFINI-T prototype, the data-collection and design part of our modified sprint took place over six weeks, rather than the suggested five days. This was due to the infeasibility of having an entire team of project advisors dedicated full-time based on volunteered time in addition to project advisors' regular full-time responsibilities. The discussion below is meant to elucidate several challenges applying this framework in the academic research environment. In addition, we deepen our reflection on feedback received on the perception of the necessity of nutrient intake tracking in LTC with particular emphasis on this need within the dementia context.

Challenges of applying the SPRINT framework in academic research

Potential challenges around organising activities

We were fortunate to have had our proposed workshop (Stage 1) accepted by the RIA and SV as part of their annual Innovation Summit. This enabled us to gain momentum and build rapport from the in-person meeting and enabled many perspectives across several homes (within the same organization) to guide the direction for this project. Were this infrastructure not in place, coordinating the initial workshop would have been more challenging, however, not impossible with the following modifications. Initial discussion could have taken place with key stakeholders at targeted meetings (e.g., quarterly dietitian meeting, monthly team meetings etc.). This would have required more travel and more time at the outset. The authors were also fortunate to have experience conducting applied research in the long-term care environment. For others who may be newer to this approach, we recommend arranging a several day observation or volunteer experience to learn what the work environment is like to authentically understand the nuances of the needs and environment. We believe one key factor is to identify a necessary, but highly inefficient and unreliable process.

Addressing the need to connect from a distance

Many of the SPRINT activities were designed to be conducted in-person. This was infeasible given the time, distance, and multiple location constraints of project advisors participation. As a result, many activities required modifications to approximate the intended function of the original activities. For example, the voting exercise and generating heat maps in Stage 2 was meant to be conducted in person with a group discussion. We made modifications by using the Qualtrics system for creating an online survey paired with a Zoom meeting to enable discussion and screen sharing between each advisor and the lead author. In addition, tutorials needed to be developed and built into the online survey (e.g., how to make a vote and practice voting). It was crucial that this data collection tool development go through more than one iteration. We worked with an advisor from support office to ensure the survey made sense, used sensitive language, and was streamlined enough to reduce potential frustration with completion.

Lessons learned from conducting activities

While Stages 1-6 all informed the design process, one specific opportunity for further enhancement was at Stage 6. We conducted a hybrid webinar survey to connect during a quarterly dietitian meeting. The concept of the AFINI-T system was completely new to the majority of participants which made it difficult to build rapport with this group. However, we believe at this stage of the design process this was a strength; this may have helped participants to provide candid, objective feedback. That said, there were several examples of difficulty in keeping webinar participants engaged. For example, the webinar was run with a brief adjournment for completion of a survey that was then used to encourage group discussion. The ability to take a poll during the webinar may have been more effective at keeping engagement. In addition, the method by which participants attended was inconsistent across locations. For example, most participants joined individually, however at venues where multiple participants joined from one location (e.g., RD, director and assistant director of food services), they filled out the corresponding survey together as well. This may have resulted in bias in some of the feedback collected but also enabled conversation and collaborative thought. Given the exploratory, qualitative nature of the feedback received during this stage, it does not undermine the results of previous stages, and for Stage 6, may have resulted in more critical appraisal from potential group discussion.

Timeliness in the time-constrained dementia care context

One substantial difference between previous work on developing technology for consumer-centred nutrient intake tracking (e.g., [17–20]) and the work presented in this paper is that the purpose of our technology is to support tracking in a regulated LTC environment. This means considerations regarding consumer uptake and use are different than with general consumer market. For example, the novelty does not arise from tracking food and fluid intake per se; this is something that is already mandated for at-risk residents. Instead, the novelty is in improving the method for tracking beyond the current system in place. Other work involving diet tracking apps tend to focus on weight loss and are meant for tracking of an individual's food intake by the individual. Here, we seek to leverage LTC as an infrastructure already in place to conduct more efficient mandated multiperson monitoring.

The role of nutrition as part of a holistic care plan for individuals living with dementia is discussed in the 2015 European Society for Parenteral and Enteral Nutrition (ESPEN) guidelines. They indicate that malnutrition contributes to disease progression and increased caregiver burden and that "non-pharmacological strategies like nutritional interventions are of particular interest as part of disease management" [47]. There is evidence to suggest that adhering to a particular pattern of dietary intake (e.g., the Mediterranean diet) is associated with reduced cognitive decline [48]; however, these authors state "more conclusive evidence is needed to reach more targeted and detailed guidelines to prevent or postpone cognitive decline". Leveraging the necessity to monitor at-risk residents living in LTC through a novel, objective approach to food intake tracking, may be beneficial for gaining new insights for defining guidelines.

Specifically considering the dementia care context and nutrition's role in the process, according to a 2016 systematic review [49], relatively few interventions have been conducted to explore the effect of food intake in mild cognitive impairment or dementia. They conclude that all 43 controlled interventions were at risk of bias and resulted in no consistent evidence either in support or against the effectiveness of nutrition focused interventions [49]. By providing an alternative method for tracking, we seek to improve upon how these allocated resources are used and aim to provide more informative data. One future direction of the AFINI-T system is to use artificial intelligence to learn food preferences. Circling back to feedback we received in Stage 6, we wish to clarify that through this approach, the AFINI-T system may support care givers' efforts in promoting enjoyment of food consumed for residents with communication changes as part of living the dementia journey. Within the scientific community context, additionally, the proposed AFINI-T system may enable knowledge discovery through a thorough automated approach to understanding dietary patterns in the LTC context and beyond.

Limitations

Between workshop participants and project advisors, 27 unique collaborators representing 15 different roles were engaged in this participatory iterative design process. This sample size is consistent with recent analogous health-care-related user-centered design as well as usability and feasibility studies [50–58] with sample sizes ranging from five as in [54] to 32 as in [58]. Between 11 and 13 additional participants were involved in the webinar exercise and contributed to nine survey responses (several individuals filled out a response together). Therefore, the total sample size ranged between 35-40, however, not all collaborators contributed to every aspect of the process (e.g., user testing in Stage 5 was comprised of a subsample of 6 individuals). While this sample size is consistent with early pilot project prototyping [25,50–54,54–58], generalizability remains unclear. As the team of project advisors was relatively small and from the same organization, it will be important for the final product to be tested with a larger sample of users to make sure concepts captured generalize well to users' needs more broadly.

In terms of the physical design requirements, additional discussion is required as the exact location to house the system remains unclear as do size restrictions. What was gleaned, however, is that the AFINI-T system must work on the iPad since this is what is currently in use. The acceptable level of accuracy target was not well defined with project advisors. That said, we can turn to the literature for some insight and important context. There is a tendency for frequent overestimation of food consumption [14,16]; in terms of degree of inaccuracy estimates of food intake are typically over 50% for food items [16,59] with reported over-estimation of food 22% of the time [14]. Furthermore, the source of error is said to be random [59] implying compensation is not possible with current methods. With the AFINI-T system, we should set our targets to be much more stringent because the automated image-based system removes subjectivity. Careful documentation and exploration of the conditions where the system does not perform optimally will be necessary. One challenging situation is plates where the food items get mixed up over the course of the meal. However, even more crude estimates, where we assume equal eating distributions across types of foods for a plate average, would still improve on the current system as it eliminates subjectivity, and reflects relative changes in mass and volume. In terms of time requirements and concerns raised in Stage 6, this is valid and is a next step. When the fully functional prototype is developed, it will be important to evaluate task completion time. Even if the AFINI-T system requires a comparable amount of time, it will yield a trove of powerful nutritional insights so direct comparison of approaches may be more complex than a simple timed trial.

While it was clear that the project advisors were relatively diverse, no demographic information was collected; this should be considered moving forward especially when recruiting for a larger sample for user testing. A larger sample size for the final prototype will help deepen our understanding of usability. Finally, given the stage of this research, qualitative analyses were limited to extracting overarching themes across sources; an additional avenue for future work, pending completion of a high-fidelity prototype is to conduct a more thorough qualitative analysis vetted in an evaluation framework (e.g., grounded theory or narrative content analysis) alongside prototype testing and evaluation.

Conclusions

The purpose of this research was to conduct a multi-stage participatory iterative design sprint of a Goldilocks quality horizontal prototype for the Automated Food Imaging and Nutrient Intake Tracking (AFINI-T) system. Through input from 38 unique collaborators representing 15 distinct roles, design decisions were informed through the application of this user-centered participatory iterative design sprint. Output from these various stages suggest that while careful consideration for integration with the PointClickCare system is needed as well as policy expectations more generally, project advisors are keen to try a technology like this. Advisors seem to be engaging with the AFINI-T prototype, receptive to the idea, and enjoying it. This modified participatory iterative design sprint was effective at understanding the problem space, making informed design decisions, and evaluating receptivity to a novel prototype all within a compressed period of time (i.e., 6 weeks). Next steps for the AFINI-T system include incorporation of learnings from this process, and the development of a fully working prototype for additional user testing. We recommend this approach to others for general technology development.

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Conflicts of Interest

None declared.

Abbreviations

ADFS: Assistant Director of Food Services
AFINI-T: Automated food imaging and nutrient intake tracking
DFS: Director of Food Services
LTC: Long-term care
PSW: Personal Support Worker
RDA: Recommended dietary allowance
RD: Registered Dietitian

Multimedia Appendix 1: Overview of Stages 2 and 3 including purpose, methods, and results.

STAGE 2: Reflect and Storyboard

STAGE 2: Purpose

The purpose of Stage 2 was to use storyboarding to generate solution concepts of the user interface and system output that reflect Stage 1's identified needs and priorities for project advisors' critique in Stage 3.

STAGE 2: Methods

The data from Stage 1 design ideation was combined with the heuristics outlined below to create a series of storyboard solution concepts. Each storyboard was designed using Balsamiq and included tailored concepts developed for three types of primary users identified in Stage 1: a PSW, registered team, and RD. As the system is expected to run on iOS based software and hardware to mesh with the current charting practice on iPads, storyboards were loosely based on iOS Human Interface Guidelines [29]; general iOS expectations will need to be balanced with the current electronic health record system in place (i.e., PointClickCare).

Usability was considered from two perspectives; the designer perspective (Stage 2) and the user perspective (Stages 5 and 6). In Stage 2, we explored usability from the designer's perspective by applying the heuristics outlined by Shneiderman's 8 golden rules [33] and Nielsen and Molich's 10 user interface design heuristics [32] as well as considering heuristics to support trust cues and credibility [60,61] while adhering to best practices for user interface design [28–31]. For example, as shown in Figures 2-3, buttons were designed in accordance with the affordance principle where visual cues act as clues to suggest how an object might be used [28,30] and informative labels [31] were included to reinforce affordances. Colour was used to make the buttons appear actionable [30,31] and users were "rewarded with visual feedback" [31] in the form of confirmation pop-ups, as well as warning and success screens. Finally, inspiration was drawn from three healthcare record systems (e.g., PrognoCIS EHR, ChiroSpring, and Aprima EHR [62–64]) noted as the top electronic medical records software from 2018 online reviews [65,66].

STAGE 2: Results

Design decision inspirations were drawn from PrognoCIS EHR, ChiroSpring, and Aprima EHR [62–64] (see Multimedia Appendix 1 for more detail). These inspirations led to a full, yet organized screen for each of the three interfaces (Figures 2, 3). Many of the inspiration examples and informed design decisions described in Table 2 are illustrated as the output from Stage 2's storyboard critiques (Figures 2, 3). These figures also depict how Stage 2 output informed Stage 3 (including the heatmap overlay in the Stage 2 panes) and Stage 4 (discussed further in subsequent stages).

STAGE 3: Storyboard Critiques

STAGE 3: Purpose

The purpose of Stage 3 was to use the storyboards created in Stage 2 to collaborate with experts to establish design directions and to finalize solution concepts for incorporation into Stage 4's design of the Goldilocks quality prototype.

STAGE 3: Methods

Five participants self-selected as project advisors during Stage 1's workshop from the perspectives of

PSW, dining lead, LTC RD, food and nutrition consultant, and food/dietary aide. Similar to the sprint process described by [22], storyboard critiques were conducted with each participant. Feedback was gathered through in-person meetings or over a virtual screen sharing teleconference (a Zoom meeting) when it was infeasible to meet in person on areas of interest, utility, or needing improvement using a wire diagram prototype mockup developed in Stage 2. The first author transcribed feedback in real-time with on-going participant clarification and confirmation. The outputs from Stage 3 included spatial heatmaps on preferred design elements and qualitative feedback for additional consideration. These heatmaps provided feedback similar to the vote with dots exercise described in Stage 1 where more popular concepts received more votes.

STAGE 3: Results

In Figures 2-4, the heatmap overlaid on the Stage 2 pane illustrates the most promising concepts voted by project advisors (e.g., drop-down items and meal-specific tabs). The lower left-hand pane depicts additional considerations captured through discussion. For example, on the PSW interface, building a database of pre-meal images to save time along with the domain knowledge that this solution would work for around 90% of the population (i.e., 10% may require special pre-meal images due to residents receiving non-standard portion sizes).

When design decisions were made, the advisor's perspective was considered and weighed accordingly. As the team of project advisors was relatively small, it will be important for the final product to be tested with a larger sample of users to make sure concepts captured generalize to users' needs more broadly. Generally, the project advisor feedback on storyboard solution concepts (Stage 3) were well received with project advisors actively engaged (e.g., "this system will give me confidence on neighbourhoods I don't know."). Regarding the solution concepts considered together, one advisor said, "This is a fantastic tool for dietitians to use. I can see it is needed. It will advance the profession and advance quality of care for residents. And it will happen in my lifetime". There were no negative comments.

Multimedia Appendix 2. Summary of key inspiration concepts from commercially available online healthcare tools. Numbers in brackets correspond to corresponding design decisions; many are highlighted in Figures 2-3.

	Inspiration Example	AFINI-T Prototype Design Decision
PrognoCIS EHR [63]		
	Click saving features (1)	Smart tabs opening based on time of day.
	Tap on name (2)	Tap on a name to open the profile for loading a resident profile.
	Clinical snapshot (3)	“Today’s Intake Summary” clinical snapshot pane.
	One check default clicks (4)	“select all” capability for registered nursing team referral.
	Input and edit notes (5)	Ability to add and edit notes
ChiroSpring [64]		
	Customizability (6)	Planned: panes to be moved, expanded, minimized.
	Solution from scheduling to billing to claims to task management (7)	Supports the process from intake tracking to referrals to further investigation.
	Ability to skip questions (8)	Incomplete data can be entered and edited later or skipped (with a warning).
	Last and current visit notes visible(9)	RD pane (not shown) has “Notes History” right beside “Today’s Notes”
Aprima EHR [62]		
	Hand off from one person to the next (7)	Supports the process from intake tracking to referrals to further investigation.
	Adaptive learning capabilities with intelligent navigation (10)	Planned: smart food suggestion/selection based on learned preferences and already selected items. Automatically highlighting/changing focus after sub-tasks completed (e.g., progress note pane becomes in-focus after intake completed)

Multimedia Appendix 3. A summary of the Ravden usability checklist evaluation conducted by two technical experts; section 9 was removed as it was not applicable to this version of the prototype.

Section	Mode Rating	Expert 1	Expert 1	Expert 2	Expert 2
		% of valid "Always" ratings (n/N)	% of valid "Most of the time" ratings (n/N)	% of valid "Always" ratings (n/N)	% of valid "Most of the time" ratings (n/N)
Section 1: VISUAL CLARITY	Very Satisfactory	73% (11/15)	27% (4/15)	50% (7/14)	50% (7/14)
Section 2: CONSISTENCY	Very Satisfactory	91% (10/11)	5% (1/11)	73% (8/11)	27% (3/11)
Section 3: COMPATIBILITY	Very Satisfactory	79% (11/14)	21% (3/14)	64% (9/14)	36% (5/14)
Section 4: INFORMATIVE FEEDBACK	Very Satisfactory	75% (9/12)	25% (3/12)	69% (9/13)	31% (4/13)
Section 5: EXPLICITNESS	Very Satisfactory	91% (10/11)	9% (1/11)	83% (10/12)	17% (2/12)
Section 6: APPROPRIATE FUNCTIONALITY	Very Satisfactory	100% (8/8)	0% (0/8)	88% (7/8)	13% (1/8)
Section 7: FLEXIBILITY AND CONTROL	Satisfactory/ Very Satisfactory	56% (5/9)	22% (2/9)	89% (8/9)	11% (1/9)
Section 8: ERROR PREVENTION AND CORRECTION	Very Satisfactory	89% (8/9)	11% (1/9)	100% (7/7)	0% (0/7)
Section 10: SYSTEM USABILITY PROBLEMS[a]	No Problems	71% (15/21)	29% (6/21)	81% (17/21)	19% (4/21)

[a] Section 10 was reverse coded. Instead of % of valid "always" and "most of the time", these columns refer to "% of valid no problems" and "% of valid minor problems".

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