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Promoting Autonomy in Older Adults With Cognitive Impairment: Co-Designing an Interactive Calendar for Memory Support

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ABSTRACT

Alzheimer's disease (AD) poses a significant public health challenge necessitating accessible tools to support care recipients and caregivers. Interactive-Care (I-Care) is a web-based remote caregiving platform designed to bridge care gaps and promote independence in individuals with mild AD. This paper focuses on the I-Care Calendar tool, developed through an iterative co-design process to overcome challenges presented by standard digital calendars. The calendar prototype was developed based on cognitive rehabilitation guidelines and refined through three iterative rounds of expert and caregiver- dyad feedback. Further co-design sessions were conducted with older adults with mild dementia. Quantitative evaluation involved counterbalanced A/B testing, comparison to an existing digital calendar (i.e., Google), and a custom Technology Acceptance Model (TAM) questionnaire. The co-designed calendar received high ratings of Perceived Ease of Use, Perceived Usefulness, and Intention to Use. Upon testing, participants could not complete key tasks in the prototype interface or Google Calendar without assistance. In contrast, they completed all tasks independently in the co-designed calendar and with faster speed compared to the other calendars. Further, participants reported significantly higher satisfaction compared to both the prototype and Google calendars. These findings demonstrate that individuals with cognitive impairment can effectively participate in co- design, resulting in a highly usable and accessible calendar.

Keywords: Human-centered design, Human-computer interaction, Co-design, Lived experience, Digital health, Dementia

INTRODUCTION

Alzheimer's disease (AD) is one of the most distressing public health challenges of our time. There is a critical need for tools that serve both care recipients and their family caregivers, especially those providing care from a distance (i.e., remote care). Individuals with AD are impacted by profound memory impairment and executive dysfunction that result in declines in their

ability to manage daily activities. These declines threaten their independence and ability to age-in-place alone, a desire strongly held by a large portion of seniors (Portacolone & Cohen, 2024). Inability to manage daily affairs has serious health consequences including failures to take medication and attend medical appointments, higher healthcare utilization (e.g., avoidable emergency department visits), and increased strain on caregivers (Fonareva & Oken, 2014). Prior research suggests that remote caregivers spend much of their time managing care receiver's daily affairs (Edwards, 2014). As such, caregivers desire digital applications that integrate multiple functions in a single tool and will engage care recipients in management of their own daily activities (Williamson, Gorman, & Jimison, 2014).

Electronic reminder systems provide timely, structured prompts that can foster independence and reduce anxiety associated with forgetfulness in individuals with dementia (El Haj et al., 2017; Meiland et al., 2017; Pimento et al., 2023). Calendar- based reminder systems have the added benefit of orienting a person to the current time/date/year, assisting with future planning and providing a reminder of completed activities. Indeed, digital calendars have been found to be effective at reminding individuals with cognitive impairment to complete tasks independently. For example, after training, individuals with mild cognitive impairment (MCI) were able to use the Memory Support System (MSS), a multifunction tool including a digital calendar (Greenaway et al., 2013).

Another tool, RemindMe, was developed for older adults involved in cognitive rehabilitation secondary to neurological injury/disease (Andreassen et al., 2021). RemindMe involves scheduling activities in a web-based calendar which sends reminders via Short text Message Service to the user's phone at a specified time. Over an eight-week intervention, RemindMe participants showed significant improvements in self-reported ability to manage daily activities. They were also more satisfied with memory support than a control group using standard calendars, like Google Calendar. However, authors in this and other studies acknowledge that success depended on hands-on training and caregiver involvement, reducing the likelihood of scalable remote care (Cahill et al., 2007; Di Campli San Vito et al., 2024; El Haj, 2017).

Qualitative research on digital calendaring consistently emphasizes the role of calendar personalization, accessibility, location, and caregiver synchronization in sustaining calendar use in real-world settings (Evans & Collier, 2017; Zubatiy et al., 2023). Holthe & Walderhaug (2010) also suggest message board integration for those who need support structuring their day. Together, literature on digital calendar systems suggests they can improve daily functioning and independence, but their success depends on thoughtful design choices with users and caregivers, personalized feedback, and integration into everyday life.

The literature on co-design with end-users of digital care technology is extensive (for reviews see Cole et al., 2022; Duffy et al., 2025; Kilfoy et al., 2024). Research in this area suggests that individuals with dementia can meaningfully engage and contribute to the co-design process (Leorin et al., 2019). Importantly, end-user participatory involvement may be

key to uncovering usability and perceived usefulness of application features that would otherwise lead to poor uptake and adherence.

Older adults with dementia use non-digital calendars as compensatory strategies, finding them crucially important to their everyday life, and even personifying their supportive nature as friend-like (Evans & Collier, 2017). Despite positive views of calendar systems, individuals with cognitive impairment sometimes feel that their loss of functioning, age, and level of technology familiarity stop them from using digital calendars. To overcome these barriers, a careful co-design process must be undertaken so individuals in the early stages of AD may reap the benefits of electronic features including customizable alarms, artificial intelligence (AI), and remote caregiver support.

In this paper, we focus on the development of the Interactive-Care (I-Care) calendar to address the challenges presented by commonly used digital calendar platforms which impose high cognitive load and cause confusion among individuals with AD. While other digital calendar systems have been developed, they rely heavily on caregiver involvement. Our goal was to address the remote caregiver need of having individuals with dementia actively involved in their own daily activities to the fullest extent they are able to. Thus, for this project, we focus specifically on designing a calendar system that individuals with mild dementia can use independently as a daily reminder system. This system also integrates a remote caregiving interface allowing caregivers to add calendar entries and provide assistance as needed from anywhere in the world. This paper describes the iterative co-design process through which the I-Care calendar evolved, informed by multiple rounds of feedback and refinement.

METHODS

The I-Care calendar tool was developed using modern web technologies selected specifically for their accessibility features, scalability, and ability to support real- time collaboration between individuals with cognitive impairment and their remote family caregivers. The calendar interface is built using Vue.js 2.x, a progressive JavaScript framework known for its reactive data binding and component-based architecture. Vue.js enables efficient state management and dynamic user interface updates, critical for maintaining responsiveness in interactive calendar applications. The framework's approachable learning curve and excellent documentation facilitated rapid iterative development during the co-design process described below.

System Design and Calendar Architecture

Vuetify 2.x served as the primary user interface (UI) component library, providing Material Design-compliant components that are pre-configured with accessibility features. Vuetify's calendar component (v-calendar) offers built-in support for multiple view types (day, week, month), event rendering, and time-based interactions. The library's customization options allow for

significant modifications to improve usability, including responsive user interface components suitable for older adults with cognitive impairment.

The system leveraged Firebase as the backend infrastructure (see Figure 1) offering: (1) secure user authentication supporting Google OAuth and email/password login methods, enabling secure user management and role-based (caregiver or care receiver) access control; (2) Cloud Firestore, a NoSQL document database for real-time data synchronization and offline support; (3) static web hosting with SSL certification for secure connections; and (4) Firebase analytics for user behavior tracking and engagement metrics. Additional integrated technologies include JavaScript ES6+ for modern and maintainable code; HTML5 and CSS3 for semantic markup and advanced styling; and Babel for JavaScript transpilation ensuring cross-browser compatibility.

The calendar interface supports both care receiver and caregiver views with dynamic role detection. Upon authentication, users are classified based on profile metadata, which determines interface layout, available controls, and data access permissions. This dual-role architecture enables seamless collaboration between care recipients and remote caregivers while maintaining appropriate security boundaries. The codebase is structured using modular JavaScript with separate files for calendar logic, event management, authentication, and utility functions. This separation of concerns facilitates code maintainability and enables multiple team members to work concurrently on different features.

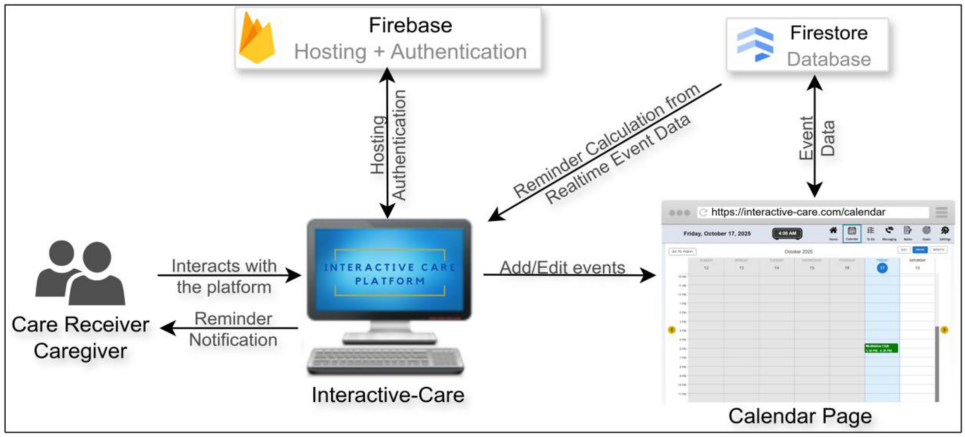

Figure 1: I-Care system design.

Firestore's real-time listeners propagate immediate changes (e.g., edits, created events) instantly across care receiver and caregiver interfaces. Utility functions handle date calculations, recurrence expansions, and reminder scheduling. The calendar leverages optimized Vue reactivity to ensure minimal re-rendering for performance optimization. Firebase's managed

infrastructure auto-scales and guarantees high availability, accommodating variable user loads without performance degradation.

Iterative Refinement Process

First, taking a user-centered approach, we developed a calendar prototype based on cognitive rehabilitation guidelines for individuals with dementia and existing calendar systems for individuals with MCI and other neurological conditions.

The prototype was reviewed by professionals with expertise in AD (4), older adults living alone with cognitive impairment (6), and remote caregivers (7) who provided Usefulness and Satisfaction ratings on a scale from 1–10 (with 10 being very useful/satisfied) and suggested modifications. The prototype was iteratively modified 3 times using this review-feedback-modify process.

Next, in the evolution of our design process, we moved from a user-centered approach to a co-design approach. To accomplish this aim, we worked closely with two female participants (age 84 and 88) with clinical diagnoses of mild dementia (Montreal Cognitive Assessments scores of 19–20) who were living alone in the community but required assistance in at least one instrumental activity of daily living secondary to cognitive decline. One participant was Hispanic White and Spanish/English bilingual and the other was non-Hispanic White and English speaking. Education ranged from 12–18 years, and they had low-moderate comfort with digital technology. Both participants were supported by their adult children who provided remote care.

Participants were provided with an all-in-one-computer to display I-Care, a multifunction daily management web-app designed for collaborative use by individuals living alone with mild-moderate cognitive impairment and their remote caregivers. I-Care includes 6 main functions, referred to as 'pages', and a navigation bar present at the top of each page to provide consistency and ease of use. The navigation bar includes the date and time, buttons to navigate to each page, and personalized user settings. Pages include: (1) a Home page consisting of personal pictures, the current weather, and upcoming events, (2) Calendar page, (3) To-Do page with two customizable lists, (4) Messaging page with simplified synchronous and asynchronous communication options, (5) Notes page for information storage, and (6) Goals page for settings and tracking brain healthy activities (Pimento et al., 2024). Similar to a paper calendar, I-Care calendar is accessible at all times and located in a high traffic area of participants choosing. The computer remains on during the day and displays I-Care in Kiosk mode, specifically on the calendar page. The browser address bar is hidden to prevent users from navigating away from I-Care. This configuration promotes I-Care use, eliminates the need to sign-in/remember passwords, and prevents users from relying on their memory to navigate to I-Care independently.

Following basic training on how to use I-Care, we engaged our lived-experience participants in an iterative, co-design process that occurred over

several sessions. During each session, examiners would carefully observe how participants naturally engaged with the different I-Care components. To further elucidate participants' approach to I-Care, examiners engaged participants in a think-aloud process (Ichsani, 2017). These steps were taken with as little examiner guidance, training, and support as possible given that cognitive deficits would likely interfere with retention of information and thus would not reflect future engagement patterns. In addition to behavioral observation, we requested that participants provide recommendations for modifications. After individual sessions with both participants, a team consisting of software engineers/web developers, examiners, and subject matter experts met to discuss possible modifications/refinements. These were then executed and evaluated by participants in a subsequent session. We repeated this process over the course of several weeks until both users endorsed satisfaction with the I-Care calendar and were observed to consistently use the various functions independently.

Evaluation

We conducted counterbalanced A/B testing comparing the prototype to the co-designed calendar. Participants were asked to complete the following tasks in each version: (1) with your mouse, click on the calendar page; (2) with your mouse, point to today on the calendar; (3) create a new event for Friday from 9:00-10:00 am, label the event "test," set a reminder for 10 minutes before the event; (4) show me where the newly created event is; (5) using your mouse, navigate to next week, and then back to the current week; and (6) delete the Friday "test" event you just created. Instructions could be repeated as many times as needed. Time (in seconds) to complete each task was recorded as well as omissions, inefficiencies, and errors. For additional usability benchmarking, we also requested that participants complete the same tasks in Google Calendar except for "click on calendar." Rather, examiners navigated to the Google Calendar on behalf of the participants who carried out the remainder of the tasks. Participants also completed a custom Technology Acceptance Model (TAM) questionnaire for the co-designed I-Care calendar that included Likert ratings (1-5, with 5 being the highest) of Perceived Ease of Use, Perceived Usefulness, and Intention to Use (Davis, 1989).

RESULTS

Prototype

The prototype was first evaluated by professionals with expertise in neurodegenerative diseases. They rated I-Care as a useful tool both for individuals with cognitive impairment ($M = 8.33$, $SD = 1.53$) and remote caregivers ($M = 9.33$, $SD = 1.15$). Recommended improvements included minor modifications to the user interface and functionality (e.g., text contrast, medication tracking). These modifications were completed, and I-Care was subsequently evaluated by individuals with cognitive impairment and caregivers who provided high ratings for both usefulness

($M = 10.00$, $SD = 0.00$; $M = 9.67$, $SD = 0.58$, respectively) and satisfaction ($M = 10$, $SD = 0.00$; $M = 9.00$, $SD = 1.00$, respectively). Recommended improvements included the ability to create and collaborate on text documents, which was implemented and evaluated in a final round of reviews. Round 3 care receivers again had high ratings for both usefulness and satisfaction ($M = 9.40$, $SD = 1.41$). Caregivers provided a perfect 10/10 ratings for caregiver and care receiver usefulness and satisfaction.

Co-Design

During the co-design process, the I-Care calendar underwent several enhancements based on user feedback and examiner observation. For example, the prototype presented today's date with a vertical bar separating time and date that interfered with ease of locating the current time. Following several suggestions, users identified that a familiar alarm clock icon would improve rapid recognition of the current time, while also adding a touch of levity. The calendar also defaults to displaying the time slots from 8:00 AM to 8:00 PM, thus showing the most relevant daytime hours and minimizing the need for scrolling through infrequently used empty time slots. High-contrast styling, enlarged fonts, and increased spacing between words further improved readability, ensuring key interface elements remain prominent and easily distinguishable.

Temporal orientation was also improved to guide users to identifying the current day. We initially followed conventional (e.g., Google calendar) styling by using a blue circle over the current date. However, upon testing, we discovered that users were not able to reliably identify "today" and could not describe what the blue circle indicated. The new co-designed interface highlights the entire current day column in blue, while prior days are greyed out and future days are in white. This modification allowed users to focus their attention on the current day and upcoming events (see Table 1 for additional comparisons).

Table 1: Comparing the I-Care calendar to google's conventional calendar.

Feature	Google Calendar	I-Care Calendar	Co-Design Outcomes
Current Day	Represented by a blue circle on the current date and blue text on day of the week.	Full day highlighted with prior days grayed out. Date also present in the navigation bar.	Improved identification. Users didn't know what the unlabeled circle represented.
Current Time	Represented by a red time line on the current date.	The time line was found to be confusing. Time is clearly labeled in the navigation bar.	Time tracking was simplified with a familiar alarm clock icon - no confusing indicators.

Continued

Table 1: Continued

Feature	Google Calendar	I-Care Calendar	Co-Design Outcomes
Calendar View	Drop down with multiple options. View automatically adjusts depending on time of day.	Present all options above the calendar and current view is highlighted. View default is 8 AM - 8 PM.	Drop-down options eliminated. Time view default reduced the need for scrolling up/down when creating events.
Time Selection	Times are listed to the left of the calendar.	Time shown when hovering over cell	Improved selection of correct event time.
Creating an Event	Many concurrent input options (Title, location, guests).	Stepwise questions with minimal inputs. Only one possible flow.	Reduces cognitive load and simplified event creation.
Recurring Event	Multiple drop-down options.	Limited options presented linearly.	More intuitive, avoiding unnecessary complexity.
Navigation Buttons	Buttons located at top among several other controls. Return to today by clicking on the "Today" button.	Carousel-style navigation buttons on calendar sides. "Go to Today" button to return to current date.	Carousel navigation eased scrolling between views. Further, "Go to Today" enhanced clarity vs. "Today."
Video Link	Supported.	Not Supported.	A desired feature.
Syncing and Sharing	Both supported.	Caregivers access to view and schedule events.	Calendar syncing is desired, particularly among caregivers.

The event creation process underwent significant redesign based on participant feedback and examiner observation. The original implementation presented users with a single-form pop-up containing all input fields simultaneously (e.g., event name, date/time, reminders), which overwhelmed users and caused confusion. Feedback led to the development of a step-by-step guided workflow that breaks complex tasks into manageable components through progressive responses to posed questions, thereby reducing cognitive load (see Figure 2). Date and time are prepopulated based on the calendar cell users clicked on and plain language prompts confirm information (e.g., "you chose May 15, is that correct?"). Once an event is saved, a short flash animation draws immediate attention to the new entry, helping users with memory challenges confirm their action was successful without being overly distracting.

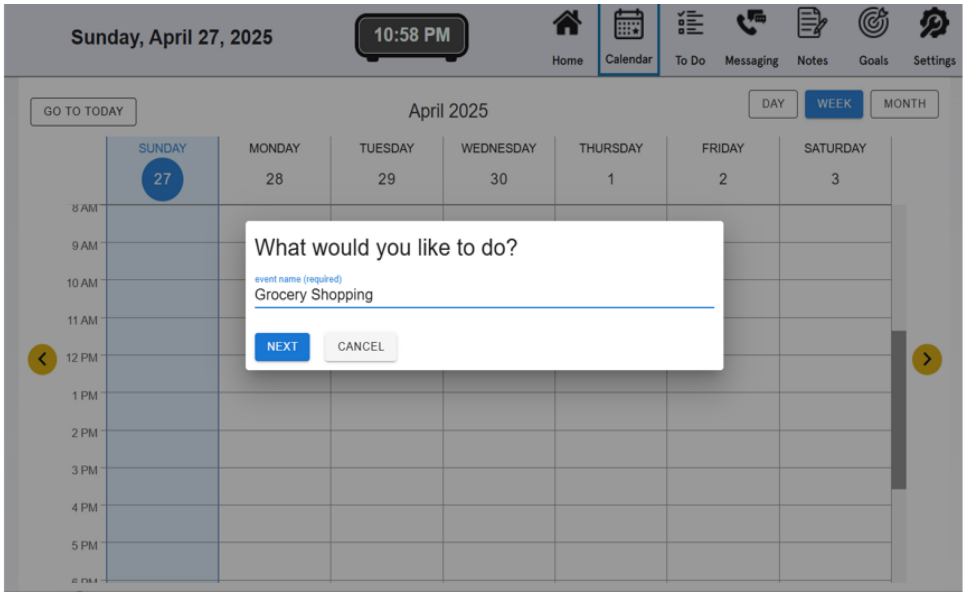

Figure 2: I-Care calender event creation.

The prototype calendar permitted only a single reminder per event, limiting flexibility for users who might need multiple, layered memory cues. The redesigned system now supports multiple reminders. Regarding reminder alarms, the prototype system played a continuous audio alert that persisted until manually dismissed. This approach caused distress and confusion when participants returned from being out of the house. The redesigned alarm system now employs a graduated notification approach: an initial audio alarm rings for 5 minutes, followed by a clear verbal message (i.e., "you have a missed alarm") every 5 minutes until acknowledged. There is also a 5-minute snooze button feature.

Evaluation

Testing revealed improvements in terms of time and ability to complete tasks for the co-designed calendar compared to both the prototype and Google calendars (see Table 2). Of note, the prototype also had clear advantages over the more conventional Google calendar interface but challenges with independent event creation remained. Participants reported substantially higher satisfaction with the co-designed calendar compared to the prior version, citing ease of navigation and clarity of visual cues. In contrast, Google Calendar task completion elicited poor satisfaction ratings, with one participant discontinuing testing due to frustration. Regarding co-design calendar TAM ratings, participants provided exceptionally high average ratings of Perceived Ease of Use = 5.0, Perceived Usefulness = 4.8, and Intention to Use = 5.0. These ratings indicate strong acceptance and usability.

Table 2: Calendar evaluation.

Task	Completion Time in Seconds (sd)		
	Prototype	Co-Designed	Google
Go to calendar page	13.65 (12.66)	3.69 (2.28)	N/A
Point to today	15.97 (3.90)	4.24 (1.39)	26.13
Create a new event	Unable	78.23 (22.13)	151 (41.01)
Navigate to next week and back to today	11.30 (0.65)	12.87 (0.14)	102
Delete the new event	90.28 (46.70)	15.15 (3.08)	15.51
		Satisfaction	
Rating Average	7 (4.24)	10 (0)	0 (0)
Quotes	"Gives basic information but doesn't pinpoint specific stuff."	"Today's day is pleasantly shown." "Highest I can rate, it's got everything."	"This wasn't designed for people like me." "The font is too small."

DISCUSSION

The development and evaluation of the I-Care calendar, informed by iterative co- design with older adults living alone with cognitive impairment, successfully addressed critical design barriers present in conventional digital calendars. The results strongly support our human-centered approach, demonstrating that purposeful design can drastically reduce cognitive load and enhance independent use of a digital calendar. Importantly, each iteration addressed small but critical usability challenges, demonstrating that even seemingly minor design details can have a substantial impact on user confidence in using the system independently.

The most significant finding is the superior usability of the co-designed calendar over both the initial prototype and Google Calendar. Task completion times were dramatically lower for the co-designed calendar and participants reported higher levels of satisfaction. Further, participants provided exceptionally high TAM ratings of perceived ease of use and intention to use. In stark contrast, participants were unable to complete the crucial task of event creation in the prototype and expressed high frustration with the conventional Google interface, with one participant discontinuing testing.

These findings directly support the cognitive rehabilitation literature, which emphasizes that tools for individuals with cognitive impairment must minimize complexity and ambiguity. Our key design modifications including the progressive event creation workflow, multi-modal notifications, and the use of enhanced visual cues were instrumental. These features worked together to address the cognitive limitations experienced by our participants, proving far more effective than concurrent input models and abstract visual indicators. The final result is a system that allows older adults to perform

complex daily management tasks independently, upholding their strong desire to age-in-place, and remote caregivers need for less oversight of daily activities.

While the co-design process yielded a usable and accepted tool, this study has limitations. Notably, our study was limited to 2 lived-experience participants. That said, this small sample allowed for deep, case study level insights into usability challenges and user preferences. These observations provide a critical foundation tightly aligned with user needs and cognitive accessibility requirements for the next stage of research which include broad testing.

CONCLUSION

The I-Care calendar is a comprehensive reminder system designed to support independence in users with mild-moderate cognitive impairment. The development process demonstrated that individuals with cognitive impairment can effectively engage in co-designing digital tools resulting in a calendar they can use independently. High satisfaction ratings highlight its clarity, intuitive design, and accessibility, emphasizing the value of tailoring digital tools to the cognitive needs of older adults.

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