Electronic Cognitive Aid Use in Parkinson Disease: Usability, Feasibility, and Metacognitive Influences

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A dissertation

submitted in partial fulfillment of the

requirements for the degree of

Doctor of Philosophy

University of Washington

2024

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Abstract

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Parkinson disease (PD) is the second most common neurodegenerative disorder. People with PD are prone to a range of cognitive difficulties, and most will eventually progress to dementia. At present, there is emerging evidence for the use of electronic aids in people with PD and mild cognitive impairment, but the benefit of such aids in people with PD and dementia is unknown. The proposed study addressed this gap in two phases by examining the usability and feasibility of an electronic aid, titled IndiAide©, as well as the influence of metacognition on aid use, in persons with PD and a range of cognitive decline. Phase I used a mixed-methods approach to examine ease-of-use and user sentiment and found that people with PD and cognitive decline were able to successfully use the aid when given support and reported generally positive feedback about the app. Phase II assessed global awareness and task-specific awareness. Participants with PD showed patterns consistent with heightened awareness of metacognitive challenges relative to care partners, and they overestimated how much time it would take to complete tasks in IndiAide©. Outcomes include recommendations to ensure IndiAide© is tailored to the needs and preferences of users with PD, as well as clinical recommendations for candidacy for aid use.

Acknowledgments

I would like to thank the following people, without whom I would not have been able to complete this research or the PhD program:

The Motor Speech and Cognitive Laboratory members, especially my mentor Dr. Kristie Spencer. Without her guidance, as well as the support of Tamar Nir, Rojean Janzad, Tejasvi Kameswaran, Kristen Henry, Madison Kendrick, and Hailey Robinson, this project would not have been possible. I would also like to thank Drs. Daniella Kim, Carolyn Baylor, Edyth Strand, and Valerie Kelly for sharing their time and expertise as my committee members.

The statistical consultants who helped develop the analyses, Kenny Zhang and Sara LaPlante.

My fellow PhD students, especially Elise LeBovidge. It’s easy to feel isolated in a PhD program, and I’m so thankful for the community that we’ve built.

The IndiAide© team, especially Alyssa Antcliff, for granting me access to the IndiAide© app, as well as their responsiveness towards the technological issues I experienced.

The organizations that funded my dissertation, the Institute of Translational Health Sciences and the Center for Research and Education on Accessible Technology and Experiences. This project would not have been possible without their financial support.

The local Parkinson disease support groups and the Washington State Parkinson Disease Registry for their immense help with recruitment. Thank you for broadcasting my study.

And lastly, a huge thank you to my family and friends for all the support they have shown me throughout this process. To my husband, Kevin, thank you for being my rock and standing by my side throughout all the smiles, rants, laughs, and tears.

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Preamble

For my dissertation, I conducted two experiments. Phase I was originally designed to examine the usability and feasibility of an electronic cognitive aid, titled IndiAide©, in a small group of individuals with early-stage Parkinson disease dementia. Due to recruitment challenges, as well as an unexpected overhaul of the app, this study was altered to include a wider range of cognitive decline. Phase II, which commenced once changes to the cognitive aid were made based on Phase I outcomes, was similar in nature to Phase I, but it also examined the influence of self-awareness and self-monitoring on the use of the aid. As a foundation to the overall study, I begin with a review of current definitions of cognitive impairment and categories of cognitive treatment. Afterwards, I introduce each Phase. Phases are separated for clarity, with the background literature, methods, results, and discussion for Phase I presented prior to Phase II. At the end, I synthesize findings from both studies, reviewing clinical implications, limitations, and future directions in a general discussion.

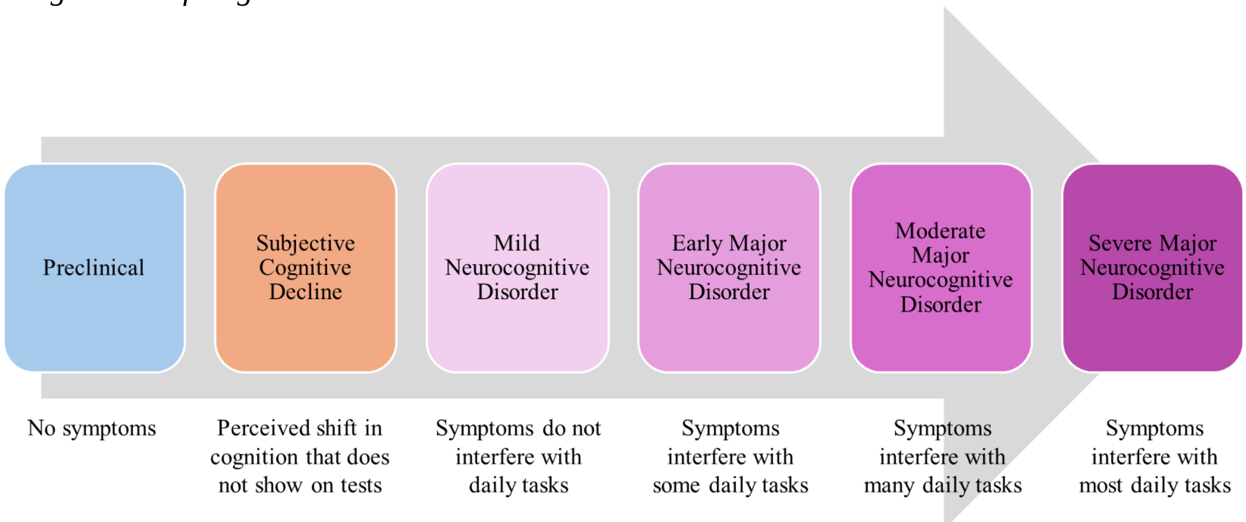
General Introduction

Idiopathic Parkinson disease (PD) is the second most common neurodegenerative disease after Alzheimer's disease (Aarsland et al., 2021), affecting nearly 1 million people in North America and 6 million worldwide (Dorsey et al., 2018; Marras et al., 2018). Although the exact etiology of the disease is unknown, onset has been linked to the spread of Lewy bodies throughout the brain in a caudal-rostral fashion (Del Tredici & Braak, 2016). Historically considered a movement disorder, the cardinal symptoms of PD are bradykinesia/akinesia, rigidity, tremor, and postural instability (Moustafa et al., 2016). In addition to these motor impairments, individuals with PD may develop secondary motor symptoms, such as dysarthria or dysphagia, as well as non-motor symptoms (Marras & Chaudhuri, 2016; Moustafa et al., 2016). The latter is broadly grouped into clusters of related symptoms, including mood disorders, sleep disorders, and autonomic dysfunction (Chaudhuri & Odin, 2010; Marras & Chaudhuri, 2016). One of the most pervasive and debilitating non-motor symptoms in PD is cognitive impairment (Bugalho et al., 2019; Hely et al., 2008; Lawson et al., 2017; Vossius et al., 2011) which is the focus of this study.

Cognitive deterioration in PD encompasses a broad spectrum, from subjective cognitive decline (SCD) to mild or major neurocognitive disorder (Figure 1) (American Psychiatric Association, 2022). Subjective cognitive decline is a self-perceived shift in cognitive ability unrelated to an acute event. Despite self-reported change, performance on neuropsychological tests remains within normal limits (Oedekoven et al., 2022). An estimated 27% of individuals with PD experience SCD early in the disease process (Baschi et al., 2018), with commonly reported alterations in executive functions and attention (Koster et al., 2015). Mild neurocognitive disorder can be likened to mild cognitive impairment (MCI)

Figure 1

Progression of Cognitive Decline in Parkinson Disease



Note. Figure adapted from Alzheimer's Association (2024a). Although progression is presented linearly, the rate at which decline occurs varies, and movement through the milder stages of decline can be fluid and reversable for some.

(Litvan et al., 2012; Sachs-Ericsson & Blazer, 2015), and is defined by a noticeable decrement in cognitive functioning that can be captured on standardized tests (American Psychiatric Association, 2022). Daily functioning is relatively intact, although individuals may need to use compensatory strategies to achieve independence (Black & Grant, 2014). Mild cognitive impairment is relatively common in PD. Approximately 20% of people present with MCI at time of disease diagnosis, with prevalence increasing to 40-50% five years post diagnosis (Broeders et al., 2013; Pedersen et al., 2017). Movement through these milder stages of impairment can be fluid and reversable for some (Chung et al., 2019; J. Jones et al., 2018).

Major neurocognitive disorder is a more severe representation of neurocognitive decline characterized by significant cognitive and functional impairments (Sachdev et al., 2014). This syndrome is synonymous with dementia (Goetz et al., 2009). Although individuals with Parkinson disease dementia (PDD) can experience decline in all cognitive domains (Goetz et al., 2009; Petrova et al., 2012), a 'subcortical' profile characterized by core impairments in attention and executive functions dominates compared to a ‘cortical’ profile represented by primary difficulties in memory (Janvin et al., 2006; Smirnov et al., 2020). This distinction is primarily applicable in the mild and moderate stages of dementia and becomes less relevant in the later stages as impairments become more pronounced across all domains (Goetz et al., 2009).

Several factors are associated with the onset of PDD and the rate at which decline occurs. Frequently reported risk factors include advanced age (Aarsland et al., 2007; Williams-Gray et al., 2009), postural instability and gait disturbance (Alves et al., 2006; Burn et al., 2006; Szeto et al., 2020), and the presence of MCI early in the disease (Nicoletti et al., 2019; Pedersen et al., 2017). Prevalence estimations are impacted by diagnostic criteria, as the criteria employed across studies vary. Aarsland et al. (2021) provide a comprehensive review of longitudinal cohort investigations of PD and suggest that an estimated 17%-28% of individuals develop dementia by year five of the disease, with prevalence increasing to 46% and 60% by years 10 and 12 of the disease, respectively. By year 20 of the disease, approximately 83% of individuals advance to dementia (Aarsland et al., 2021).

Cognitive Interventions in Parkinson Disease Dementia

Cognitive decline is a debilitating consequence of PD. It can lead to social isolation and negatively influence quality of life and risk of mortality in individuals with PD; these outcomes may be exacerbated in those with PDD (Bugalho et al., 2019; Fan et al., 2020; Hely et al., 2005; Suran, 2022). Additionally, care partners for persons with PD and cognitive decline often experience higher levels of distress and financial burden (Lawson et al., 2017; Vossius et al., 2011). Given these adverse outcomes, it is imperative that rehabilitation professionals develop and implement targeted, efficacious interventions for individuals with PD. Broadly, cognitive therapy in PD takes one of two approaches – pharmacological or non-pharmacological.

Cognitive pharmacotherapy, such as the use of cholinesterase inhibitors, is limited in its effectiveness in individuals with PD-MCI or PDD and may be accompanied by adverse side effects (Phillips et al., 2023; Sun & Armstrong, 2021). Non-pharmacological cognitive interventions fall into the general categories of cognitive stimulation, cognitive training, and cognitive rehabilitation. Cognitive stimulation is a restorative remediation that utilizes non-specific stimulation to enhance general cognitive functioning (Cafferata et al., 2021). Cognitive training is another restorative approach that uses repeated execution of cognitive activities to improve related cognitive functions (Biundo et al., 2017). Cognitive rehabilitation is a client-centered approach that aims to maximize previously learned skills and teach compensatory strategies to enhance everyday functioning (Kudlicka et al., 2019). A brief overview of each intervention category is provided, with a focus on evidence from randomized controlled trials in PDD.

Cognitive Stimulation

Based on reality orientation therapy and reminiscence therapy, cognitive stimulation was developed by Spector and colleagues as a psychosocial intervention for dementia (Spector et al., 2001). Since explicit memory is frequently impacted in dementia (Noe et al., 2004; Smirnov et al., 2020), cognitive stimulation aims to improve cognitive and social abilities through implicit learning provided via non-specific stimulation like small group discussions (Cafferata et al., 2021; Spector et al., 2001). Rather than focus on isolated domains, cognitive stimulation targets general arousal with the rationale that individual cognitive functions are not used in isolation (Clare & Woods, 2004). Traditionally, cognitive stimulation is conducted in small groups, with a facilitator leading the group through mentally stimulating group activities (Yates et al., 2014).

Emerging evidence suggests that cognitive stimulation is tolerable, enjoyable, and effective in improving general cognition in individuals with PD and MCI (Farzana et al., 2015; Reitano et al., 2023); yet there is a lack of strong evidence for cognitive stimulation as a behavioral remediation for dementia. Although cognitive stimulation has been found to moderately enhance global cognition immediately following therapy for individuals with non-PD dementia, gains were of borderline clinical relevance and improvements were not maintained at follow-up assessments (Cafferata et al., 2021). A similar theme is seen for PDD. In a trial assessing the effectiveness of cognitive stimulation in PDD, Leroi and colleagues found global cognition did not significantly improve following the intervention (Leroi et al., 2019). In fact, participants who received cognitive stimulation displayed worse neuropsychiatric symptoms than the control group. In contrast, care partners reported reduced care burden and stress and improved quality of life and relationship quality with the care recipient (Leroi et al., 2019). In sum, it appears that non-specific cognitive stimulation is insufficient to induce impactful cognitive change in PDD.

Cognitive Training

Cognitive training differs from cognitive stimulation in that it approaches cognitive decline through a biomedical lens. Interventions couched within the biomedical model of disability are primarily focused on treating deficits in biological systems (Petasis, 2019). As such, cognitive training is a restorative treatment that is founded on the concept that repeated execution of cognitive activities improves related cognitive functions. These activities can be performed using paper and pencil exercises or computerized tasks (Biundo et al., 2017). Usually, exercises are domain specific with the expectation clients will generalize improved abilities to everyday functions (Couture et al., 2019).

An extensive body of literature has examined the effectiveness of cognitive training in various clinical populations with cognitive challenges. Broadly speaking, cognitive training may be moderately effective in improving individual cognitive domains in persons with MCI, but it provides relatively negligible benefits for people with dementia (Hill et al., 2017; Kallio et al., 2017). Initial cognitive gains are weak, and there is often a substantial waning of benefits after training ends (Hill et al., 2017). With respect to PD, cognitive training has been reported to enhance discrete cognitive domains in individuals with MCI (Giustiniani et al., 2022); although, outcomes are mixed, and there is a high degree of methodological heterogeneity across studies (Orgeta et al., 2020; Sanchez-Luengos et al., 2021). To date, only one study has investigated cognitive training in PDD. Van Balkom and colleagues conducted a randomized controlled trial to assess the effectiveness of computerized cognitive training in individuals with PD with and without dementia (van Balkom et al., 2022). Immediately following training, processing speed significantly improved for all participants; however, improvements did not transfer to untrained contexts nor were they maintained at follow-up (van Balkom et al., 2022).

Cognitive training may be marginally effective when combined with other behavioral treatments, such as cognitive stimulation. *NEUROvitalis senseful* is a structured cognitive stimulation intervention that adopts aspects of *NEUROvitalis*, a cognitive training program (Kalbe et al., 2009). The dual approach combines exercises targeting specific cognitive domains, relaxation and mindfulness exercises, and sensory-stimulating procedures (Middelstädt et al., 2016). A randomized crossover trial investigating *NEUROvitalis senseful* in PDD found trends suggesting improved global cognition and neuropsychiatric symptom severity (Folkerts et al., 2018). However, the investigators did not evaluate the impact of each activity type, making it unclear whether gains were driven by cognitive training tasks, relaxation exercises, or cognitive stimulation activities alone or in combination.

Overall, there is a lack of strong evidence for cognitive training as a behavioral intervention for PDD. Cognitive training rests on the dubious assumption that domain specific improvements will generalize to overall cognitive functioning, as well as untrained contexts (Couture et al., 2019). Critics of biomedical therapies additionally argue that these interventions do not holistically consider factors that influence disease presentation and response to treatment (Engel, 1977; Petasis, 2019). Combined, the evidence suggests that cognitive training may not be effective in meaningfully supporting cognition in individuals with PDD.

Cognitive Rehabilitation

The roots of cognitive rehabilitation are embedded in multiple fields, such as behavioral psychology and neuropsychology (B. Wilson, 2002). Therapy is conducted through a biopsychosocial lens, wherein illness is viewed as being driven by physical changes as well as personal, social, and environmental contexts (Engel, 1980). Additionally, it utilizes a person-centered care approach, meaning that clients are viewed as valuable contributors to the healthcare process (Kitwood, 1998). Thus, in cognitive rehabilitation, clinicians collaborate with clients to co-create care plans that holistically shape the disease experience (Clare & Woods, 2004). This is achieved by adopting an individualized approach that uses co-designed, ecologically valid interventions to both retrain previously learned skills and teach compensatory strategies (Kudlicka et al., 2019).

Emerging evidence supports cognitive rehabilitation as a behavioral treatment approach for PD-MCI, particularly when incorporating external support (Foster et al., 2017; Spencer et al., 2020). To date, only one study has investigated cognitive rehabilitation in PDD. Hindle and colleagues conducted a randomized controlled trial investigating cognitive rehabilitation compared to relaxation therapy or treatment as usual for persons with PDD (Hindle et al., 2018). As part of cognitive rehabilitation, participants collaboratively identified problem areas in everyday functioning, chose goals to address these issues, then received training from a therapist on how to use compensatory strategies and restorative techniques to achieve their goals. Following the intervention period, participants who received cognitive rehabilitation exhibited significantly greater goal attainment and satisfaction compared to participants in the control conditions. Effects were maintained at a six-month follow-up assessment. The success of this trial rests in its use of client-centered goals, ecologically valid intervention targets, and compensatory tools.

Indeed, these traits are what make cognitive rehabilitation a promising non-pharmacological intervention for PDD. The person-centered nature of cognitive rehabilitation honors the selfhood of recipients which can lead to numerous benefits, such as enhanced outcomes in quality of life, self-esteem, and neuropsychological symptom severity (Clare et al., 2019; Lee et al., 2022; Tay et al., 2018; Vaartio-Rajalin et al., 2019). Additionally, by targeting challenges in everyday functioning, cognitive rehabilitation mitigates the need to transfer learning across contexts. Lastly, the use of external, compensatory strategies accounts for internal cueing deficits in PD. External cues are known to be particularly facilitative in persons with PD, across functions such as reaction time (Gräber et al., 2014; Scally et al., 2011), gait (Baker et al., 2008; Rochester et al., 2011), speech control (Huang et al., 2019), and cognition (Brown & Marsden, 1988; Hsieh et al., 1995). Cognitive stimulation and cognitive training lack these support structures, as these forms of intervention are not co-constructed with clients, do not target everyday functioning, and do not employ compensatory strategies.

Conclusion

People with PD may experience a broad range of cognitive conditions (Aarsland et al., 2021). While emerging literature suggests that cognitive rehabilitation is a promising behavioral intervention, best practice guidelines remain uncertain, particularly related to the structure and form of compensatory support. Electronic aids are emerging as a viable form of compensatory support for dementia (Shu & Woo, 2021). However, the feasibility of such tools in PDD is little understood in the context of PD-related motor and cognitive challenges. We propose two studies that examine the overall usability and feasibility of a novel electronic cognitive aid in individuals with PD and cognitive decline. The first study primarily aimed to identify the usefulness, clarity, and ease of use of the aid, while the second study aimed to determine the influence of cognitive factors, such as metacognition, on aid use.

Phase I: Usability and Feasibility of IndiAide©

Cognitive rehabilitation is a promising intervention for cognitive decline in Parkinson disease, particularly when external cues and supports are incorporated (Hindle et al., 2018; Spencer et al., 2020). External support can come in a variety of forms, from low-tech (e.g., memory books) to high-tech (e.g., smartphone calendars) options. The effectiveness of such tools may vary as cognition declines. That is, although low-tech aids are a viable way to support cognition in persons with dementia (Chang & Bourgeois, 2013, 2020), high-tech aids have the potential to provide more comprehensive support. Firstly, electronic memory aids may be more effective than low-tech alternatives (Oriani et al., 2003; Woodberry et al., 2015), in part due to their ability to provide automated reminders to use the aid (W. Jones et al., 2021). Additionally, electronic aids can be highly modifiable, as it is possible to adjust the format and functions to the individual user and with disease progression (Lanzi et al., 2017). Lastly, such aids can be cost-effective if the apps can be downloaded onto devices already used within the home, such as smartphones or tablets (Raghunath et al., 2020). Since the number of older adults who use smartphones/tablets has significantly increased in the past decade (Benge et al., 2020), this increases the likelihood of access and exposure to technology when faced with cognitive decline.

Assistive Technology in Dementia

As technology has become more ubiquitous, developers have created a large variety of digital tools to support individuals with dementia, such as smart home devices, sensors and safety monitoring tools, medication adherence aids, and social companion robots controlled by artificial intelligence (Hoel et al., 2021; Lancioni et al., 2021; Shu & Woo, 2021). Following the COVID-19 pandemic, the role of these tools in facilitating psychosocial interventions and telehealth has gained more interest due to their potential to provide remote support (Barbosa et al., 2023). Although the extant literature broadly endorses the benefits of electronic aids (W. Jones et al., 2021; S. Wilson et al., 2022), their role in supplementing cognitive rehabilitation is relatively obscure. Several clinical trials of cognitive rehabilitation have shown that an intervention that integrates external support strengthens goal attainment in persons with Alzheimer's disease (Clare et al., 2010, 2019) and PDD (Hindle et al., 2018); however, these trials did not explicitly assess the impact of electronic aids on therapeutic outcomes.

Øksnebjerg and colleagues conducted a pilot trial to investigate the effectiveness of a novel cognitive rehabilitation program that incorporated a memory-oriented tablet app, titled Rehabilitation in Alzheimer's disease using Cognitive support Technology (ReACT), in early-stage Alzheimer's disease (Øksnebjerg et al., 2020). Participants attended both individual and group sessions. In the individual sessions, they identified meaningful goals, were trained how to use the app, and completed testing to evaluate goal attainment. In the group sessions, participants received education about self-management techniques. Although ReACT was presented as a compensatory tool to use when needed, its use was not mandatory, and participants were allowed to choose whether to use the app outside of sessions. Following the intervention, participants who chose to adopt the ReACT app displayed significantly greater changes in goal attainment scores compared to participants who chose not to use the app (Øksnebjerg et al., 2020).

In the ReACT trial, participants' goals primarily targeted managing daily tasks or supporting memory (Øksnebjerg et al., 2020). These align with commonly reported goals in other trials of cognitive rehabilitation, such as improving everyday memory functioning, remembering to take medications, and maintaining performance in activities of daily living (Clare et al., 2010; Watermeyer et al., 2016). The broader dementia literature also supports electronic aid use to support everyday functioning. For instance, individuals with dementia of mixed etiologies have used smart home devices to automate everyday tasks to reduce memory and caregiver burden (Dixon et al., 2021). Additionally, tablet and smartphone apps that provide automated reminders have shown notable efficacy in enhancing independence by providing external reminders to support prospective memory (Harris et al., 2021; Lancioni et al., 2017; Oriani et al., 2003; Scullin et al., 2022) and breaking down complex everyday tasks into individual steps (Dixon et al., 2021; Harris et al., 2021). Electronic aids may also benefit other forms of memory, such as autobiographical memory (Dixon et al., 2021; Woodberry et al., 2015). Thus, there is a growing body of evidence to suggest that electronic cognitive aids can lessen the impact of the cognitive challenges associated with dementia.

Assistive Technology in Parkinson Disease

While maintaining independence in the face of a neurodegenerative disease such as PD is challenging, the right supports make this more feasible (Nimmons et al., 2022; Zhao et al., 2015). To date, the focus of clinical and research efforts has largely centered on aids that support motor functioning in PD. While low-tech aids (e.g., grab-rails, canes) are commonly prescribed to address motor needs (Triccas et al., 2019; Zhao et al., 2015), several studies have investigated the effectiveness of electronic aids in improving gait (Ginis et al., 2016; Ivkovic et al., 2016; McAuley et al., 2009), tremor (Bhidayasiri et al., 2022), drooling (McNaney et al., 2019), and speech (Halpern et al., 2012). Motor-focused electronic aids typically consist of a worn device that helps the wearer coordinate their actions through visual or tactile cues, such as smart glasses that project visual lines on the floor (McAuley et al., 2009) or smartphones or watches that provide tactile reminders to initiate movement (Ivkovic et al., 2016; McNaney et al., 2019).

In comparison, the utility of electronic aids in supporting cognition in PD has received little attention, despite the detrimental impact of cognitive decline on quality of life (Lawson et al., 2016) and the successful use of digital aids in other clinical populations with cognitive decline (Harris et al., 2021; Øksnebjerg et al., 2020). Additionally, individuals with PD report that electronic aids are useful in supporting social needs and memory (Ferriero et al., 2012; Zhao et al., 2015). However, the literature in this area remains sparse. Latella and colleagues (2022) examined the effects of home automation on cognitive functions and personal and social autonomy in persons with PD and suspected MCI. Small groups of participants were directed to complete a series of tasks reminiscent of daily life in a room that contained either automated devices or low-tech tools. Global cognitive functioning and instrumental autonomy significantly improved for both groups; however, significant increments in social adaptation, quality of life, and global autonomy were only noted in the group that had access to automated technology (Latella et al., 2022).

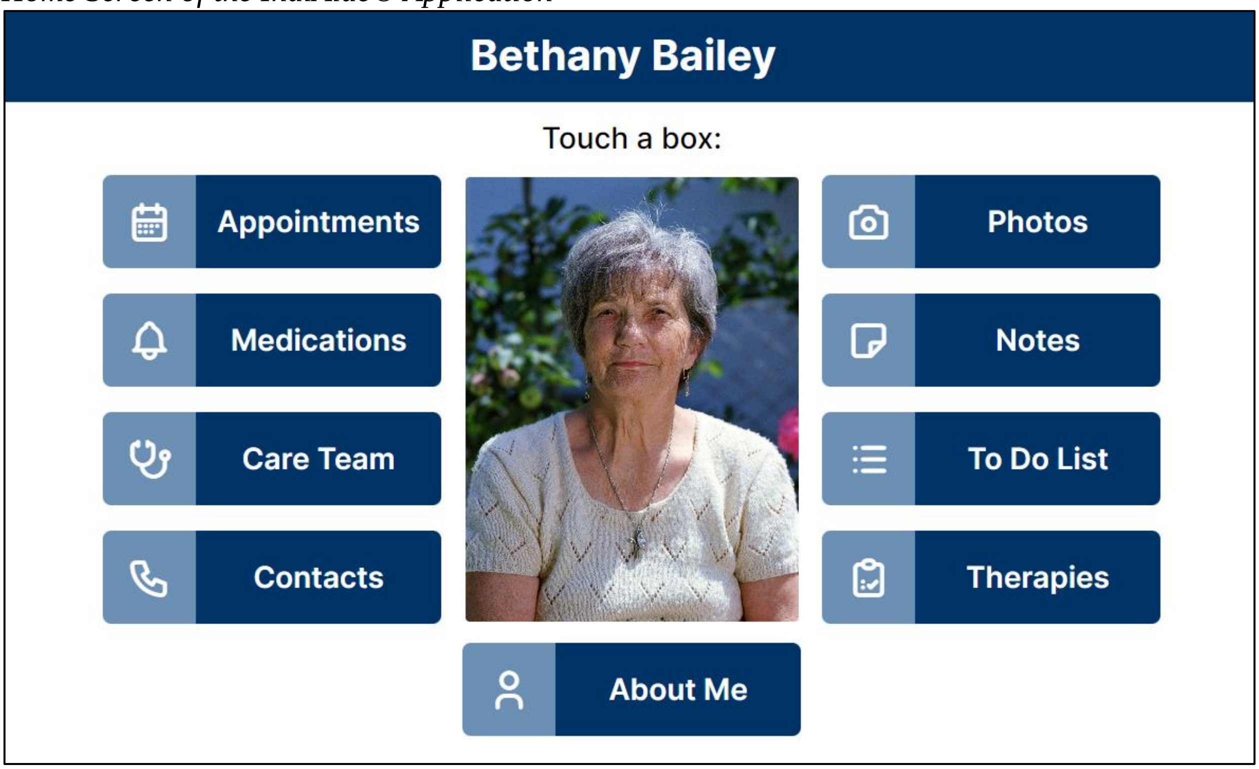
While Latella and colleagues suggested that global cognition and autonomy can be improved with electronic aids, their study ultimately focused on occupational rather than cognitive goals. As discussed, Hindle and colleagues (2018) conducted a pilot trial of cognitive rehabilitation in PDD. Participants co-created personalized objectives, of which learning or re-learning how to use technology was the most cited goal (Watermeyer et al., 2016). A combination of compensatory strategies, such as notebooks, cue cards, and alarms, were employed to help participants attain their goals (Hindle et al., 2016, 2018). The overall success of cognitive rehabilitation compared to the control conditions suggests that individuals with PDD can use external aids despite cognitive and motor concerns. Additionally, it indicates that combining individualized goals with external aids is a viable method of supporting cognition in PDD. However, since high-tech aids were not implemented, additional studies are required to determine the feasibility and impact of electronic aids in supporting cognition in PDD.

While not PDD, Spencer and colleagues examined external aid use in individuals with MCI from PD (Spencer et al., 2020). Three participants co-constructed personalized goals related to external aid use, such as using aids to independently arrive to appointments on time. Then, the researchers trained participants how to achieve each goal using systematic instructional principles, including task analysis, errorless learning, sufficient practice, metacognitive strategies to promote more effortful processing, distributed practice, stimulus variation, and ecological treatment targets (see Ehlhardt et al., 2008). Multiple goals were trained, several of which were related to electronic aids. For instance, participants learned how to schedule appointments in smartphone calendar apps, set smartphone alarms, and use notetaking apps. Following the intervention, the majority of participants' goals were achieved both in structured and unstructured (home) environments, and improvements were maintained at a one-month follow-up (Spencer et al., 2020). This study reinforces the viability of electronic aids as a cognitive support tool in PD. Further, it illuminates the importance of using theoretically grounded principles during training. For example, metacognitive strategies, such as task prediction and effortful processing, may increase the accuracy and efficiency of aid use in individuals with cognitive challenges from PD.

Outcomes from Spencer and colleagues indicate that it is feasible to utilize varying electronic tools readily available in the home to support cognition in PD. However, one concern with this approach is the cognitive burden of managing multiple devices, particularly as cognition declines. IndiAide© is a private start-up company that is developing an integrated, electronic, cross-platform application (titled IndiAide©) that may be beneficial for individuals with PD and cognitive decline, as the program offers flexibility, as well as features that support cognitive abilities that are impacted in PD. For instance, the app can support orientation, executive functions, and memory through a calendar for scheduling appointments, to-do list for daily tasks, and medication organizer for remembering key information (see Figure 2 for an image of the app's homepage). Additionally, the IndiAide© program is customizable, allowing users to modify the interface as their needs change. In turn, this limits the need to learn how to use a novel device and to purchase multiple electronic aids.

Figure 2

Home Screen of the IndiAide© Application



Recently, Nir and colleagues conducted a mixed-methods study to evaluate the usability and feasibility of IndiAide© in 10 neurotypical adults and five individuals with PD and MCI with a range of technology familiarity (Nir et al., 2023). Participants were instructed to complete a series of tasks in the app, from which objective measures of usability were derived. Participants with PD-MCI were successful in navigating the app per time/accuracy metrics. After completing the series of tasks, participants were asked several open-ended and Likert scale questions concerning their overall experience and the app's usability. Participants generally reacted positively towards the app and rated its usability as good-excellent. Of note, ease of use and user satisfaction were driven more by technological familiarity than cognitive status, highlighting the importance of technological comfort in using electronic aids. Overall, outcomes indicated the IndiAide© application was usable and satisfactory for people with PD and MCI.

Conclusions and Research Questions

In sum, although the literature examining electronic aid use in PD is sparse, there is converging evidence for the use of electronic aids as a support mechanism for cognition in persons with PD and varying levels of cognitive decline. First, individuals with PD have an active interest in electronic aids, even as cognition becomes more impaired (Watermeyer et al., 2016). Second, using technology readily available in the home, like smartphones or tablets, is feasible for individuals with PD despite cognitive and motor concerns (Spencer et al., 2020). Third, successful use of such aids in people with MCI from PD (Latella et al., 2022; Nir et al., 2023; Spencer et al., 2020) and in other types of dementia (Harris et al., 2021; Øksnebjerg et al., 2020) suggests it is feasible to implement digital assistive technology with individuals with neurodegenerative cognitive decline. Lastly, while both low-tech and high-tech tools may improve discrete everyday tasks (Hindle et al., 2018; Spencer et al., 2020), electronic aids have more comprehensive capabilities (Latella et al., 2022). However, there remains a critical gap regarding the efficacy of these devices in individuals with dementia from PD. The challenges associated with PDD, such as variable cognitive and motor profiles, and rates at which decline occurs, can make it difficult to develop a product that meets individual users' needs. Thus, technology that is highly customizable to the heterogeneous cognitive and motor challenges of PD is warranted.

IndiAide© has the potential to meet the unique needs of people with PDD, given the program's flexibility, customizability, and range of features that support cognitive abilities that are impacted in PDD. Thus far, product development has been informed by rehabilitation professionals, neurotypical adults, and persons with PD-MCI but has yet to incorporate the input of people with PDD (Nir et al., 2023), making it important to assess whether the aid represents the needs, preferences, and abilities of the latter. Additionally, it is important to reexamine the usability of the aid in persons with milder forms of decline due to recent updates made to the app. Recently, IndiAide© completed an overhaul of the app, changing the layout of existing features and altering the choice of features. Therefore, the purpose of Phase I was twofold. First, it aimed to reassess the usability of the app in people with milder forms of cognitive decline while exploring the usability in persons with more advanced decline. More importantly, however, this Phase aimed to examine the user experience of the IndiAide© app for people with PD and a broad range of cognitive decline. Here, the intent was to collect evaluative feedback which can be utilized to edit the app to better fit the lived experience, preferences, and needs of this population. To this end, the following research questions were addressed in Phase I:

1. How does task accuracy (as measured by number of errors and number and type of cues) and time to complete tasks vary across select features of the IndiAide© app, and how can this inform design adjustment?
2. Which features of the IndiAide© app do users with PD and cognitive decline rank as the easiest and most difficult features to use?
3. Which features of the IndiAide© app do individuals with PD and cognitive decline rank as being the least helpful or most helpful in supporting everyday needs?

4. What aspects of the IndiAide© app are cited by users with PD and cognitive decline as contributing to a positive or negative user experience with the app?
5. What characteristics of the IndiAide© app are most persuasive in motivating a person with PD and cognitive decline to adopt the aid?

Compared to prior evaluations of IndiAide© usability in neurotypical adults and people with MCI secondary to PD, it was anticipated that users with PDD would complete fewer tasks independently, take more time to complete tasks, and produce a greater number of errors (Nir et al., 2023). Features that require greater manipulation of the aid to access (e.g., calendar) were predicted to be ranked as more difficult. Since improved social connection and autonomy are often cited therapeutic goals of persons with PDD (Watermeyer et al., 2016), it was hypothesized that features that foster social connection or autonomy (e.g., medication management) would be ranked as most helpful for everyday functioning and described as motivating characteristics of the app.

Phase I: Methods

Phase I sought to investigate the usability and feasibility of IndiAide© among persons with PD and a range of cognitive decline. To do so, a mixed methods study was conducted to offer quantitative and qualitative insights into ease of use and user sentiment regarding the app.

Phase I: Participants

Participants were recruited using flyers distributed to local PD support groups, hospitals, and clinics. Additionally, an application was submitted to the Washington State Parkinson Disease Registry. Materials and procedures were approved by the Institutional Review Board at the University of Washington.

As the purpose of Phase I was to identify the usefulness, clarity, and ease of use of the IndiAide© application, sample size guidelines for human-centered design were followed. It is commonly accepted that a sample size of five to eight participants can uncover 85% of usability issues (Nielson, 2000); thus, a minimum of seven participants with PD were recruited for Phase I. The same size was deemed sufficient when saturation of user responses was achieved, defined as the point at which additional feedback stopped leading to new insights.

Participant’s level of cognitive functioning was determined through the triangulation of multiple information sources. Participants were included if they (a) were community dwelling, (b) were between the ages of 50-85, (c) had a diagnosis of PD by a neurologist, (d) had self- or informant-reported diagnosis of early dementia or cognitive complaints that interfere with daily living, (e) and had an onset of cognitive complaints and difficulties $\geq$1 year post disease onset. Additionally, they were required to be generally intelligible (i.e., >90% intelligibility) in conversation. Participants were excluded for neurological disorder beyond PD, severe depression (>11 on the Geriatric Depression Scale-Short Form (GDS-SF)) (Yesavage & Sheikh, 1986), a formal diagnosis of a psychiatric disorder (e.g., schizophrenia, bipolar disorder), and significant visual or motor impairments (e.g., severe tremor or freezing episodes) that would impede their ability to use the app. Additionally, individuals who participated in the prior IndiAide© investigation conducted by Nir and colleagues (Nir et al., 2023) were not eligible to participate in the current study.

Phase I: Procedure

Participants were pre-screened for eligibility during the initial contact with investigators. During this call, investigators used clinical judgment and responses from the person with PD and a care partner to triangulate a possible diagnosis of cognitive decline. Appendix A contains the telephone protocol that was used for the pre-screening call (Nir et al., 2023). If an individual was deemed eligible from the pre-screening, an investigator scheduled a time to come to their home or a mutually agreed upon location during optimal medication to complete the remaining screening and experimental procedures. The primary investigator and a research assistant attended the formal session.

During the in-home session, participants were first asked to complete informed consent in the presence of a care partner. Participants were allowed to terminate participation at any point. Next, participants were asked to complete a demographic questionnaire which was used to confirm eligibility criteria (Appendix B), followed by a vision screening requiring participants to read lines at a predetermined font on an iPad. Afterwards, the investigator administered the Parkinson Disease-Cognitive Rating Scale (PD-CRS) (approximately 20 minutes) and GDS-SF (approximately 5-7 minutes). The PD-CRS is a cognitive screening tool designed specifically for PD (Pagonabarraga et al., 2008). It assesses immediate and delayed free recall verbal memory, confrontation naming, sustained attention, working memory, visuospatial functioning, alternating verbal fluency, and action verbal fluency. Scores range from 0-134, with scores <101 suggesting the presence of mild cognitive impairment and scores <73.5 suggesting dementia (Rosca & Simu, 2020). The GDS-SF is a self-report questionnaire that captures the presence and severity of depression. It has a range of 0-15, with scores >11 indicating severe depression (Yesavage & Sheikh, 1986).

Scores for the PD-CRS and GDS-SF were calculated after the session to characterize participants' cognitive status and confirm their eligibility for inclusion. Then, the investigator administered an abridged version of Part III of the Movement Disorder Society-Unified Parkinson Disease Rating Scale (MDS-UPDRS) (Goetz et al., 2008) to determine motor symptom severity as it may relate to aid use (see Appendix C; 3 minutes of direct testing, combined with observation throughout session). The full MDS-UPDRS captures overall motor symptom severity. The abridged version included test items concerned with global motor slowing, postural tremor of the hands, and constancy and amplitude of resting tremor of the hands and legs. A Hoehn and Yahr score was given to participants based on their motor presentation. This measure ranges from 0-5, with higher scores indicating more severe motor involvement (Goetz et al., 2008). Next, participants were asked to complete a technology familiarity questionnaire adapted from Nicosia and colleagues (Nicosia et al., 2022). Scores range from 0-60, with higher scores indicating more familiarity with technology. Participants were then asked to begin task-based testing. Data were analyzed afterwards, and feedback was shared with IndiAide© programmers to incorporate into the app prior to initiating Phase II.

Phase I: Protocol

The procedure for Phase I is depicted in a flowchart in Appendix D. Participants were introduced to the IndiAide© app prior to the usability test, as they had no exposure to the app prior to the session. The investigator provided an overview of the application to clarify the purpose of the app and guided participants through trial tasks to familiarize them with how to access features located on the homepage, select tabs, and scan through information (see Appendix E). Following this, participants were asked to complete a series of tasks using the application on a tablet, as shown in Table 1 (Nir et al., 2023). Tasks were designed to increase in complexity, with the first task requiring a single response and the final task requiring some degree of manipulation. For instance, the first task in a set would require clicking on a single button to open a particular feature, the second task would require finding content on the home landing for that feature, and the third task would require opening additional levels to find information. An exception was made for the Care Team feature, as this feature contains more layers of information than the other features. Due to the added complexity of this feature, task 2 required clicking on a button on the home landing to open another layer of information.

A set of tasks was presented per feature, and the order of features was randomized to control for fatigue effects. Participants were instructed to attempt to complete the tasks independently and that they could receive assistance after completing an initial attempt or after 30 seconds of continued difficulty with task completion. Assistance was hierarchical, beginning with a verbal cue followed by a verbal and gestural cue (e.g., pointing) then a model. This hierarchy was repeated as many times as necessary within a task. The usability test was recorded to allow for offline calculations of performance and reliability. Video recordings were captured via an iPad placed behind users and angled to capture the screen of the tablet running the IndiAide© application.

Table 1
Usability Test Tasks

Program Feature	**User Tasks**
Appointments	• Access "Appointments" • Tell me the appointment Bethany has on [insert date] • Tell me the name of the care team member for the doctor's appointment*
Medications	• Access "Medications" • Tell me the time of day to take Lisinopril • Tell me the side effects of Pramipexole
Care Team	• Access "Care Team" • Tell me the phone number for Amy Washington • Tell me when Bethany has her next appointment with Dr. Rivers
Contacts	• Access "Contacts" • Tell me the phone number for Bethany's spouse • Tell me the email of Bethany's daughter
Photos	• Access "Photos" • Select the last photo and read the text
To-Do List	• Access "To-Do List" • Tell me the first item on the to-do list for this Friday • Tell me Bethany's grocery list when she goes shopping on Friday
Therapies	• Access "Therapies" • Tell me what type of physical therapy exercises Bethany is working on • Tell me how many reps of bird dog Bethany has to do every day
Notes	• Access "Notes" • Read the note for Dr. Rivers

Note. For Phase II, this task was updated to become, "Tell me the name of the care team member for the neurology appointment."

After completing the set of tasks associated with each program feature, the investigator asked the participant to complete two five-point Likert scales. The first scale asked participants to rate how easy or difficult it was to use the feature (1 = extremely difficult, 5 = extremely easy). The second scale asked participants to rate how helpful that feature might be for supporting everyday life (1 = extremely unhelpful, 5 = extremely helpful) (see Appendix F). Participants engaged in a short discussion after providing their rating wherein the investigator asked what aspect of a feature drove a negative or positive response. Additionally, at the end of the session, the investigator guided participants through a semi-structured interview (see Table 2) informed by prior reviews of mobile health usability (Baumel et al., 2017; Nir et al., 2023). To support memory, the investigator provided visual cues of the program features.

Table 2

Guide for Semi-Structured Interview

Topic	**Interview Questions**
General Evaluation	• What was your experience using this app?
Content	• What would you like to see added to or changed on the app?
Therapeutic Persuasiveness	• How motivated would you be to use this app?
Therapeutic Alliance	• How would you use this app to support your everyday needs?

Note. These questions were used to guide the discussion, with the investigator adding more structure as needed depending on the cognitive needs of individual participants.

The session took between 1.5-2 hours to complete, inclusive of breaks. At the end of the session, participants were given a $40 VISA gift card as compensation.

Phase I: Measures

Measures from the demographic questionnaire were used to describe participant characteristics. Total scores from the abridged MDS-UPDRS Part III, PD-CRS, and GDS-SF were collected to characterize disease severity.

Both objective and subjective measures were collected from the usability test, with objective measures chosen to quantify participant performance and subjective measures to qualify participant experience. Combined, these measures allowed for deeper understanding of ease of use and overall user satisfaction. Objectively, the number of tasks completed with or without cues, number of errors, and time to complete tasks was collected for each participant. Subjective measures included Likert ratings for perceived ease-of-use and helpfulness, as well as themes derived from the semi-structured interview.

Phase I: Directional Analysis

Insights from Phase I are directional, meaning they were used to evaluate the existing aid and shape future design considerations. To characterize individual performance, descriptive data (mean, standard deviation, and range) was calculated for number of tasks completed with or without cues, number of errors, and time to complete tasks. Table 3 includes descriptions of these measures and the corresponding calculations (Rubin & Chisnell, 2008). The number of tasks completed with or without cues was tracked online by the investigator via a data collection form (see Appendix G). The number of errors was calculated after the session via the screen recording. Time to complete tasks was calculated manually via screen recordings of the tablet.

Table 3
Descriptions and Calculations for Phase I Measures

Measure	**Description**	**Calculation**
Number of tasks completed without cues	The number of tasks (out of 22) associated with each feature that a person completes independently.	Sum of tasks completed without cues
Number of tasks completed with cues	The number of tasks (out of 22) completed with a verbal cue, verbal and gestural cue, or model.	Sum of tasks completed with cues
Number of errors	The number of errors made	Sum of errors
Time to complete task	The time, in seconds, to complete a task.	End time – start time

Likert ratings were used to determine which features users with PD rank as being the most easy/difficult or most unhelpful/helpful. Means were ranked to determine which features are perceived as the most easy/difficult or unhelpful/helpful. Likert ratings were tracked online by the investigator.

To further clarify user satisfaction with the IndiAide© app, the investigator completed a content analysis. A hybrid inductive and deductive approach was used to identify and organize themes. First, four core concepts relating to the user experience were determined *a priori* per Nir et al.'s previous examination of the IndiAide© app, namely, overall experience, content, persuasiveness, and alliance (see Appendix H) (Baumel et al., 2017; Nir et al., 2023). Then, the primary investigator reviewed the transcripts from the Likert discussions and semi-structured interviews to develop codes. Codes were given a classifier of positive, neutral, or negative to better clarify whether participants were providing positive or negative feedback. Next, the primary investigator summarized the codes into emergent themes and grouped the themes under one of the core concepts to highlight which aspect of the user experience was being described (Lester et al., 2020; Nir et al., 2023; Yorkston et al., 2007). Dedoose was used to organize, code, and sort the data (Dedoose, n.d.; Nir et al., 2023).

Phase I: Research Rigor

Video Analysis Reliability

Inter-rater and intra-rater reliability were determined by recalculating the number of errors and time taken to complete tasks for 25% of the tested features (2 randomly selected features per participant/total number of features tested; 14/56) by a novel researcher and the primary investigator, respectively.

Content Analysis Trustworthiness

Several steps were taken to ensure the rigor and trustworthiness of the analysis. First, all interviews were conducted by the same interviewer (i.e., the primary investigator) to ensure consistency. Additionally, the primary investigator kept a diary and reflected on the sessions with a research assistant immediately following the sessions. In terms of positionality, the primary investigator is a certified speech-language pathologist and doctoral candidate in a speech and hearing sciences program, whereas research assistants were undergraduate and postbaccalaureate students in a speech-language hearing program.

An auto-transcriber, Otter.Ai (Otter.ai, n.d.), was used initially to transcribe the interviews. A research assistant listened to all interviews and edited accordingly to ensure the accuracy of the transcripts, and all transcripts were then reviewed by the primary investigator. Once both researchers agreed on the transcripts, the primary investigator read through each transcript several times, iteratively identifying emergent codes (positive/neutral/negative; Appendix H) and updating the application of codes. Then, the lead researcher reviewed the description of each code with a research assistant and showed example quotes exemplifying each code. After this training, the research assistant independently analyzed the transcripts from 2 participants (~29% of the sample). Cohen's kappa was calculated to determine the level of agreement between raters for code application and classification (O'Connor & Joffe, 2020). Subsequent themes were developed by the primary investigator and reviewed for clarity by another member of the research team.

Phase I: Results

Thirteen individuals contacted the primary investigator to express interest in the study. Two did not respond to follow-up attempts to schedule the screening call. Of those who were screened, one retracted their interest in participating, and three were disqualified due to having a neurological disorder beyond PD. The remaining seven were deemed eligible for inclusion and participated in the study. Demographic data, cognitive scores, and other descriptive characteristics are presented in Table 4. Most were white (6 white, 1 Asian) and identified as male (6 male, 1 female). The average age was 68.71 years (range: 62-80 years), and it had been seven years on average since disease diagnosis (range: 2-13 years). All participants were retired, and their average years of education was 17.57 (range: 15-22 years). The mean score on the technology familiarity questionnaire was 40 (range: 26-51), suggesting that, on average, participants considered themselves to be moderately comfortable utilizing smartphones and tablets for a variety of functions (e.g., make phone calls, check email, take photos, record video, etc.; see Appendix I). Two participants demonstrated subjective cognitive decline (cognitive concerns but performance within normal limits on the PD-CRS), three participants presented with MCI (score of <101 on the PD-CRS), and two participants exhibited possible PDD (score of <73.5 on the PD-CRS) (Rosca & Simu, 2020).

Phase I: Research Rigor

Video Analysis Reliability

Offline recalculation of 25% of all the tested IndiAide© features (2 randomly selected features per participant/total number of features tested; 14/56) was completed for both the time to complete task and number of errors. The primary investigator completed all initial offline measurements and then re-calculated these measures for 25% of tasks for intra-rater agreement.

Table 4

Demographic and Clinical Characteristics of Phase I Participants with PD

Participant	Age	Gender	Race	Years of Education	Years Post Diagnosis	PD-CRS	Cognitive Status	GDS-SF	H&Y	Tech Fam.
1	80	Male	White	18	12	92	MCI	7	3	47
2	68	Male	White	15	7	32	PDD	3	2	31
3	69	Male	White	16	5	87	MCI	2	1	39
4	69	Male	White	22	7	90	MCI	4	2	37
5	69	Male	White	18	13	67	PDD	2	3	26
6	64	Male	White	16	2	120	SCD	2	0	51
7	62	Female	Asian	18	3	107	SCD	0	1	49
Mean	68.71	--	--	17.57	7.00	85.00	--	2.86	1.71	40.00
SD	5.71			2.30	4.20	28.64		2.19	1.11	9.47

Note. PD-CRS = Parkinson Disease-Cognitive Rating Scale (range: 0-134; lower scores = more severe decline); MCI = Mild Cognitive Impairment; PDD = Parkinson Disease Dementia; SCD = Subjective Cognitive Decline; GDS-SF = Geriatric Depression Scale-Short Form (range: 0-15; higher scores = more severe depression); H&Y = Hoehn & Yahr score from the abridged version of Part III of the Movement Disorder Society sponsored version of the Unified Parkinson Disease Rating Scale (range: 0-4; higher scores = more severe motor involvement); Tech Fam = Technology familiarity score (range: 0-60; lower scores = less familiar with technology; adapted from Nicosia et al., 2022).

A research assistant completed offline calculations for these measures for the same 25% of tasks for inter-rater agreement. The intra-rater time agreement (α = .99) and error agreement (α = .99) and inter-rater time agreement (α = .99) and error agreement (α = .98) were strong per Cronbach's alpha.

Content Analysis Trustworthiness

The primary investigator and a research assistant reviewed the transcripts for ~29% of the sample (2/7 participants). For these two transcripts, the primary investigator applied 53 codes, and the research assistant applied 59 codes to segments of text. The researchers identified the same segment of text 50 of the total 62 coded segments (50 shared + 3 unshared primary investigator + 9 unshared research assistant). Among the total 62 coded segments, there was substantial agreement between the primary investigator and the research assistant regarding the identified code (κ = .69) and directional classification (i.e., no classification, positive, neutral, or negative) (κ = .61) per Cohen's kappa (Landis & Koch, 1977). Among the 50 shared segments, there was nearly perfect agreement regarding the identified code (κ = .91) and directional classification (κ = .92) per Cohen's kappa. Overall, the content analysis revealed acceptable levels of agreement between raters (McHugh, 2012).

Phase I: Ease of Use

As a reminder, Phase I was designed in part to examine traditional usability measures of usefulness, clarity, and ease of use of the IndiAide© application (Rubin & Chisnell, 2008). To this end, two research questions were developed which broadly sought to objectively describe participant performance and subjectively capture perceived difficulty.

Research Question 1: Quantitative Performance

Research question 1 examined how task accuracy (number of errors and number/type of cues) and time to complete tasks varied across select features of the IndiAide© app. Table 5 reflects the total number of errors made and number of cues provided when completing a list of tasks associated with an app feature. As shown in the table, the highest error count and greatest number of cues required were evident for the Appointments, Care Team, and Therapies features, suggesting these three features were the most difficult to access across participants.

Table 5

Sum of Total Cues and Errors Per App Feature Tested

Feature	Number of Errors	Number of Cues
Notes	0	0
Photos	7	5
Medications	9	5
To-Do List	10	4
Contacts	10	5
Care Team	17	13
Therapies	23	13
Appointments	38	22

Note. Tasks arranged in order of ascending difficulty.

Table 6 provides more specificity, displaying averages for the number of errors, number of cues, and time taken to complete tasks per individual task within each feature. The final requests within the Appointments, Care Team, and Therapies features were associated with relatively increased errors and cues and had the longest time to completion. As noted, each of these tasks was the third task in a sequence of tasks, meaning they had the highest level of complexity. That is, the first task always required clicking on a single button to open a particular feature. The second task required finding content on the home landing for that feature, with the third task requiring opening additional levels to find information. First-, second-, and third-order tasks are compared in Table 7. In general, participants produced more errors, required more cues, and took longer to complete tasks as task complexity increased.

Table 6

Average Time and Accuracy Per Feature and Task

Features & Individual Tasks	Number of Errors (SD)	Number of Cues (SD)	Time in Seconds (SD)
Notes			
1. Access "Notes"	0 (0)	0 (0)	7.17 (6.53)
2. Read the note for Dr. Rivers	0 (0)	0 (0)	8.98 (4.70)
Photos			
1. Access "Photos"	0 (0)	0 (0)	9.29 (7.38)
2. Select the last photo and read the text	1.00 (1.00)	.71 (.76)	26.37 (14.98)
Medications			
1. Access "Medications"	.14 (.38)	0 (0)	5.07 (5.65)
2. Tell me the time of day to take Lisinopril	.29 (.76)	0 (0)	12.93 (11.42)
3. Tell me the side effects of Pramipexole	.86 (1.46)	.71 (.95)	26.11 (20.01)
To-Do List			
1. Access "To-Do List"	.29 (.49)	0 (0)	8.23 (5.54)
2. Tell me the first item on the to-do list for this Friday	.29 (.76)	.14 (.38)	8.72 (6.70)
3. Tell me Bethany's grocery list when she goes shopping on Friday	.86 (1.21)	.43 (.79)	19.95 (19.10)
Contacts			
1. Access "Contacts"	.14 (.38)	0 (0)	7.21 (6.97)
2. Tell me the phone number for Bethany's spouse	.71 (.95)	.43 (0.53)	25.76 (17.51)
3. Tell me the email of Bethany's daughter	.57 (.79)	.26 (.49)	20.78 (9.67)
Care Team			
1. Access "Care Team"	.43 (.53)	.14 (.38)	14.65 (10.97)
2. Tell me the phone number for Amy Washington	.43 (.53)	.43 (.79)	20.25 (22.87)
3. Tell me when Bethany has her next appointment with Dr. Rivers	1.57 (1.27)	1.29 (1.38)	63.23 (54.68)
Therapies			
1. Access "Therapies"	.14 (0.38)	0 (0)	7.79 (6.33)
2. Tell me what type of physical therapy exercises Bethany is working on	1.14 (1.57)	1.29 (1.80)	33.84 (31.67)
3. Tell me how many reps of bird dog Bethany has to do every day	2.00 (1.53)	.57 (.53)	45.19 (23.98)
Appointments			
1. Access "Appointments"	0 (0)	0 (0)	4.95 (3.18)
2. Tell me the appointment Bethany has on [insert date]	.86 (1.57)	1.00 (1.91)	21.03 (27.74)
3. Tell me the name of the care team member for the doctor's appointment	4.57 (1.51)	2.14 (1.21)	67.01 (37.02)

Note. Tasks arranged in order of ascending difficulty.

Table 7
Average Time and Accuracy Per Task Level

Task Order	Number of Errors (SD)	Number of Cues (SD)	Time in Seconds (SD)
Task 1	.14 (.35)	.02 (.13)	8.05 (7.04)
Task 2	.59 (1.02)	.50 (1.06)	19.74 (20.04)
Task 3	1.74 (1.85)	.90 (1.10)	40.38 (35.12)

Research question 2: Ease of Use Ratings

Research question 2 investigated which features of the IndiAide© app users with PD and cognitive decline ranked as the easiest and most difficult features to use. Based on the 5-point Likert scale (1 = extremely difficult to use; 5 = extremely easy to use), the Medications and Notes features were ranked as the easiest features to use with an average ease-of-use score of 4.71 (range: 4-5). Conversely, the Appointments feature was considered the most difficult to use, with an average ease-of-use rating of 3.29 (range: 2-4). These Likert ratings are summarized in Table 8.

When discussing their ratings, the number of interactive elements emerged as a driving factor behind the greater perceived difficulty of the Appointments feature. For example, P2 (PDD) replied that “there’s too much going on on that particular one” when asked about his low rating for the Appointments feature. Personal preferences in terms of layout and organization may have also impacted the lower ease-of-use ratings for this feature, with P7 (SCD) stating, “I guess if I did it for myself, it would be easier. I think I wouldn’t have difficulty finding the information I need. I was just struggling with picking out the wrong thing for this activity.” Participant 4 (MCI) nicely summarized the issue of increased difficulty with increased complexity, stating, “There is probably some sort of threshold where, if you got more things going on, where x is some number you have to figure out, then [the app] would go from being very helpful to being a little confusing.”

Table 8

Perceived Ease of Use of IndiAide© Features

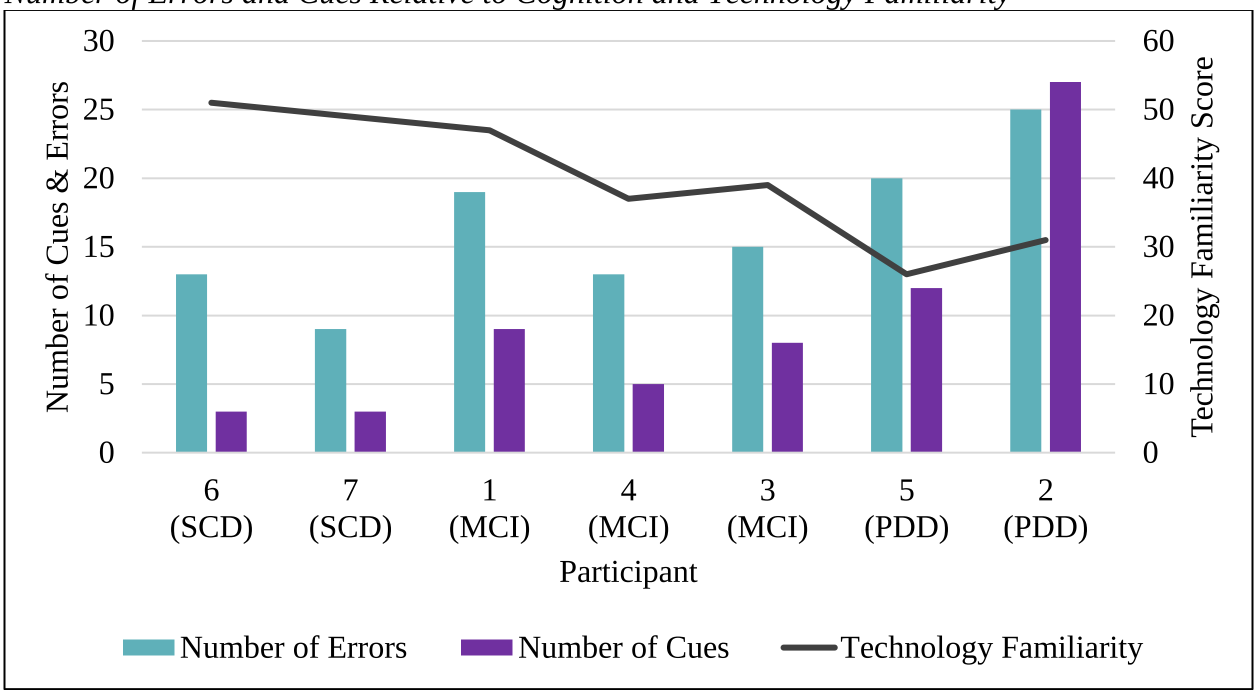
Participant	Appointments	Therapies	Care Team	Contacts	Photos	To-Do List	Medications	Notes	Mean
1 (MCI)	4	4	4	4	4	4	4	4	**4.00**
2 (PDD)	2	4	4	4	4	4	5	5	**4.00**
3 (MCI)	3	3	2	4	4	5	5	4	**3.50**
4 (MCI)	4	5	5	4	5	5	5	5	**4.75**
5 (PDD)	2	2	4	5	4	2	4	5	**3.50**
6 (SCD)	4	5	5	5	5	5	5	5	**4.88**
7 (SCD)	4	5	5	4	4	5	5	5	**4.63**
Mean	**3.29**	**4.00**	**4.14**	**4.29**	**4.29**	**4.29**	**4.71**	**4.71**	

Note. Ratings given on a 5-point Likert scale where 1 = extremely difficult and 5 = extremely easy. MCI = Mild Cognitive Impairment; PDD = Parkinson Disease Dementia; SCD = Subjective Cognitive Decline.

Potential Contributors to Ease of Use. The cognitive status and/or technology familiarity of the participants may have influenced their success with the app navigation. As a whole, participants produced more errors and required more cues to complete tasks as cognitive functioning worsened. Technology familiarity paralleled cognitive function; that is, participants with lower technology familiarity produced more errors and required more cues to complete tasks (see Figure 3). Cognitive status and technology familiarity may have influenced ease-of-use ratings as well. The two participants with SCD and the highest technology familiarity scores also had the highest ease-of-use ratings, whereas the two participants with PDD and the lowest technology familiarity had the lowest ease-of-use ratings.

Figure 3

Number of Errors and Cues Relative to Cognition and Technology Familiarity



Note. Participants are organized in descending order of their score on the Parkinson Disease-Cognitive Rating Scale (Participant 6 = highest score). Technology familiarity shown by the dark grey line (lower scores = less familiar). PDD = Parkinson Disease Dementia; MCI = Mild Cognitive Impairment; SCD = Subjective Cognitive Decline.

Phase I: User Satisfaction

In addition to examining the usability of the IndiAide© application, Phase I aimed to assess user satisfaction with the current prototype of the app. To this end, three research questions were developed which broadly sought to qualify perceived levels of helpfulness of app features, define which aspects of the app contributed to a positive or negative experience using the app, and identify which characteristics of the app were most persuasive in motivating a person to potentially use IndiAide©.

Research Question 3: Perceived Level of Helpfulness

Research question 3 examined which features of the IndiAide© app individuals with PD ranked as the most or least helpful in supporting everyday needs. Based on the 5-point Likert scale (1 = extremely unhelpful; 5 = extremely helpful), the Medications and Appointments features were ranked as the most helpful features to use with an average helpfulness score of 4.57 (range: 4-5) and 4.29 (range: 3-5), respectively. Conversely, the Photos feature was considered the least helpful, with an average helpfulness rating of 3.57 (range: 2-5). These Likert ratings are summarized in Table 9.

When discussing their ratings, the level of perceived helpfulness seemed to depend on whether participants already had a support system in place. For example, when debriefing about the Appointments Feature, P1 (MCI) reflected, “It’s helpful, but what’s on my phone is a pretty well-organized system, so I don’t know if it’d be very helpful to me.” Furthermore, the uniqueness of a feature seemed to affect its perceived helpfulness. When reviewing the Notes feature, P6 (SCD) reflected, “The question is, how does this differ from a to-do list? Or notes on a calendar reminder? …it almost seems redundant.” The Photos feature received similar feedback, with P1 (MCI) and P3 (MCI) likening this feature to an alternative form of social

Table 9

Perceived Level of Helpfulness of Features in IndiAide©

Participant	Photos	Notes	Contacts	Care Team	To-Do List	Therapies	Appointments	Medications	Mean
1 (MCI)	2	2	2	2	2	4	4	5	**2.88**
2 (PDD)	2	4	3	2	3	3	3	4	**3.00**
3 (MCI)	4	4	3	5	4	4	4	5	**4.13**
4 (MCI)	3	3	4	5	4	5	4	5	**4.13**
5 (PDD)	5	5	4	4	5	4	5	4	**4.50**
6 (SCD)	4	3	5	5	5	4	5	4	**4.38**
7 (SCD)	5	5	5	5	5	5	5	5	**5.0**
Mean	**3.57**	**3.71**	**3.71**	**4.00**	**4.00**	**4.14**	**4.29**	**4.57**	

Note. Ratings given on a 5-point Likert scale where 1 = extremely unhelpful and 5 = extremely helpful. MCI = Mild Cognitive Impairment; PDD = Parkinson Disease Dementia; SCD = Subjective Cognitive Decline.

media, and P4 (MCI) saying, “Unless you were supposed to do something with it, I wouldn’t put photos in there cause they’re already in my phone and they’re in my computer. They’re everywhere else.” Lastly, perceived helpfulness seemed to vary depending on participants’ unique life circumstances. When discussing the Care Team feature, P2 (PDD) said that it’s “probably not that helpful now just because I don’t really use that many [care providers].” Similarly, when reflecting on the To-Do List feature, P1 (MCI) said, “I don’t think it’d be helpful. My days [are] not very complicated without working.”

Research Question 4: Factors Contributing to the User Experience

Research question 4 qualitatively investigated which aspects of the IndiAide© app were cited by users with PD and cognitive decline as contributing to a positive or negative user experience. Three themes emerged based on participant feedback, namely, ease of use, layout, and learnability. These themes were grouped under the concept of ‘Overall Experience.’ Table 10 defines each theme and provides example quotes.

When reviewing all codes from which the themes were derived, slightly more positive than negative (54% vs. 46%) classifiers were applied to participants’ feedback (see Figure 4). The app’s simplicity was a key aspect contributing to a positive experience. P1 (MCI) called the app “user friendly” and P2 (PDD) said it had a “simple setup” and was “constructed well.” Multiple participants commented on how easy it was to learn how to use the app, with P5 (PDD) labeling the app’s learning curve as “very elementary.” As a general trend, the number of negative comments made regarding the user experience increased as cognitive functioning and technology familiarity declined (see Figure 4). For instance, despite considering the app easy to learn how to use, P5 (PDD) expressed low self-efficacy, stating, “I didn’t have the confidence I

Table 10

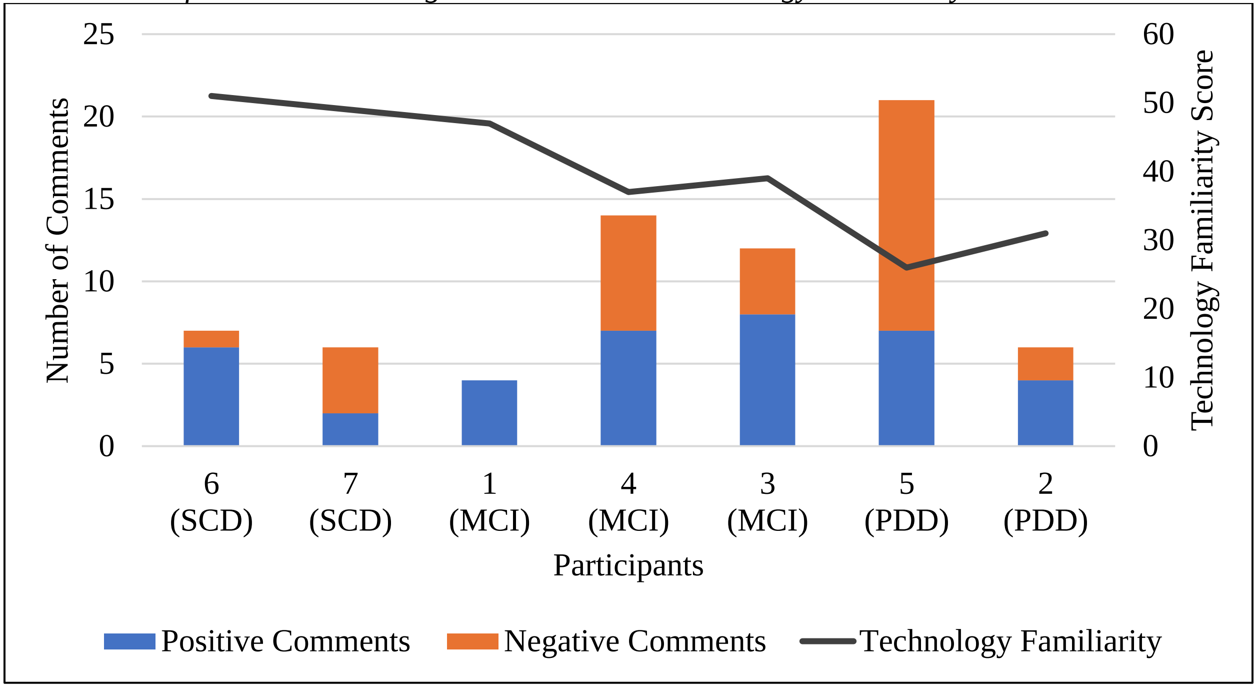
Summary of Themes Related to the Overall Experience

Themes	Classification	Explanation	Sample Quotes
Ease of use	Positive	Participants report that the structure of the app is easy to use or well thought out	"…there's something to be said for a very simple [layout]. You go to the home button, and everything is accessible from [there]. And if it sounds like what you're looking for it probably is because it's been simplified to the maximum point" (P4, MCI)
	Negative	Participants report difficulties finding information in the app	"I wasn't sure where the text was for [the photo], but I figured it must by the picture" (P7, SCD)
Layout	Positive	Participants report positive thoughts about the app's layout	"This works I think because it's simple" (P2, PDD)
	Negative	Participants report negative thoughts regarding the layout of the app	"I feel like the person doing this breakdown of the information thinks a little bit different than I do. Just the way they organize some of the things" (P5, PDD)
Learnability	Positive	Participants report positive experiences about learning how to use the app	"I've only used [the app] for a couple of minutes, but I know where the care team is on the homepage, so I know that gets me the doctors and so on" (P4, MCI)
	Negative	Participants report negative experiences about learning how to use the app	"I was a little frustrated that I couldn't find things as quickly as I would like, but I think that's really a function of the use of practice and getting used to it" (P3, MCI)

Note. The additional classification of themes as positive or negative was utilized to further clarify actionable insights to share with the app development team. MCI = Mild Cognitive Impairment; PDD = Parkinson Disease Dementia; SCD = Subjective Cognitive Decline.

Figure 4

Distribution of Feedback Per Cognitive Status and Technology Familiarity



Note. Participants are organized in descending order of their score on the Parkinson Disease-Cognitive Rating Scale (Participant 6 = highest score). Technology familiarity shown by the dark grey line (lower scores = less familiar). MCI = Mild Cognitive Impairment; PDD = Parkinson Disease Dementia; SCD = Subjective Cognitive Decline.

was going to get all the entries from my query.” Participant 4 (MCI) brought up additional concerns of age, expressing, “I’d think that old geezers and old ladies like us would have some problem[s].”

Research Question 5: Factors Contributing to App Persuasiveness

Research question 5 qualitatively investigated which characteristics of the app were most persuasive in motivating a person with PD and cognitive decline to adopt the app. Three themes emerged based on participant feedback, namely, integration, transferability, and motivation. These themes were grouped under the concept of ‘Persuasiveness.’ Table 11 defines each subtheme and provides example quotes.

Table 11

Summary of Themes Related to Persuasiveness

Theme	Classification	Explanation	Sample Quote
Integration	Positive	Participants like having multiple features all in one place	"The fact that you have them all in one spot is very helpful because I got stuff spread all over the place" (P4, MCI)
Transferability	Positive	Participants like the mobility of the app	"If it's a phone-based app, I would probably use that because it's with you all the time" (P3, MCI)
Motivation	Positive	Participants state why they would be motivated to use the app	"…having control of your meds, appointments, things like that is really important. It's empowering" (P1, MCI)
	Neutral	Participants are motivated to use the app if another condition is fulfilled	"…it would be highly motivating to use it if the data was transferred in. If I had to load everything that I have in there now that is and will probably be a disincentive" (P3, MCI)
	Negative	Participants do not see themselves using the app	"But I probably wouldn't use it as is because it'd feel like I was duplicating processes that I've already worked out" (P6, SCD)

Note. The additional classification of themes as positive, negative, or neutral helped to further clarify actionable insights to share with the app development team. MCI = Mild Cognitive Impairment; SCD = Subjective Cognitive Decline.

Feedback related to the integration and transferability themes was generally positive. Participants considered the integration of multiple features to be one of IndiAide©'s strengths, as exemplified by P7 (SCD) stating, "I think the advantage of this [is that] several aspects are all in one app." Additionally, participants reacted positively towards the mobile nature of the app, with three specifically commenting on how helpful it would be to bring the tablet to doctor's appointments. Despite these positive reactions, participants were relatively split on how motivated they would be to adopt the app. Overall, 32% of codes contributing to the motivation theme were positive, 32% were neutral, and 36% were negative. Unsurprisingly, many of the factors that appeared to influence perceived helpfulness (research question 3) also affected motivation. First, participants seemed to be less motivated to use the app if they already had a cognitive support system in place. During the interview, P1 (MCI) said "Well, it kind of duplicates what I already have for myself," and P5 (PDD) stated, "The stuff we already have is, may be sufficient." Similarly, the level of feature overlap between the IndiAide© app and other tools seemed to dampen participant's enthusiasm towards the app. As quoted in Table 11, P6 (SCD) felt as though the IndiAide© app duplicated processes they already have worked out.

Several requests and suggestions were made to improve the uniqueness and functionality of the app (see below), and it appeared that participants would be more persuaded to adopt the app if their suggestions were to be realized. When asked if they would use the app if their suggestions were implemented, P6 (SCD) eagerly responded, "Oh my gosh. I'd be all over it. Oh wow, yeah, this would be my go-to central."

Phase I: Actionable Insights

As part of research question 1, feedback from the usability study and interviews was synthesized to identify areas of improvement. Specifically, participant feedback was summarized, and a list of actionable insights were generated and shared in a high-level report with the IndiAide© development team (see Appendix J for the full report). Table 12 lists the key requests organized by level of importance, where high indicates most participants requested a particular change, medium that some participants requested a change, and low that one participant requested a change. The development team took note of this feedback and considered the feasibility of adding these alterations to their roadmap. Additionally, there were several immediate technical concerns that were noted during the completion of Phase I, namely, the checkboxes in the Medications feature were permanently checked, the presentation of the medication schedule was reported as confusing, and the font size was reported as being slightly too small for text in lower levels of the hierarchy of content. Prior to initiating Phase II, the development team was able to uncheck the checkboxes and alter the wording of the medication schedule; font size was not able to be adjusted at the time.

Table 12

Summary of Actionable Insights Organized by Importance

Finding	Recommendation
High Importance (requested by majority)	
• Care partner access is a high priority	• Give care partners access to the app
• Integration with healthcare app affects adoption	• Allow for IndiAide© to integrate with other healthcare apps like MyChart
Medium Importance (requested by some)	
• Notifications may support memory	• Add notifications or alerts to the medications, notes, appointments, and to-do list features
• Sorting could support navigation	• Add a grouping or sorting feature to the contacts and to-do list features
• Simplicity is good, but some customizability is better	• Allow users to customize their font size, turn features on and off depending on their needs, re-label features to personally meaningful titles, and/or re-organize features on the home page
• Check boxes are helpful for more than just medications	• Add check boxes to the notes and to-do list features
Low Importance (requested by one)	
• Financial support was requested by one	• Add a finances feature where users can track whether they have paid co-pays and/or can monitor their running balance for medical bills
• Archiving information may help maintain simplicity	• Add an archive ability to the notes feature
• Integration with Zoom could support telehealth	• Integrate the app with Zoom so that users with mobility limitations can use the app to contact healthcare providers

Phase I: Discussion

Phase I sought to understand the usability and feasibility of a novel electronic cognitive aid, IndiAide©, in individuals with PD and cognitive decline. To this end, five research questions were proposed which examined: 1) how task accuracy and time to complete tasks vary across select features; 2) which features of the app users rank as the easiest and most difficult features to use; 3) which features of the app users rank as being the least helpful or most helpful in supporting everyday needs; 4) what aspects of the app users cite as contributing to a positive or negative user experience; and 5) what characteristics of the app are most persuasive in motivating someone to adopt the aid.

It was hypothesized that participants with PDD would require more support and make more errors compared to users with PD-MCI; more complex features of the app would be perceived as more difficult; and features that foster social connection or autonomy would be viewed positively. These hypotheses were partially supported. User performance tended to decline as cognitive functioning decreased and feature complexity increased, which may have been associated with level of technology familiarity. However, more socially oriented features were not considered highly motivating or supportive for everyday functioning relative to organizational features.

Objective and Subjective Ease-of-Use

As a reminder, objective indicators of ease-of-use were collected from the moderated usability test, using task accuracy and time to complete tasks. Accuracy was examined via the total number of errors made and the number of cues provided. User sentiment regarding ease-of-use was captured via Likert ratings. Overall, participant accuracy was lowest for the Appointments, Care Team, and Therapies features; tasks associated with these features also took the longest to complete. User sentiment aligned with their performance, as participants scored these three features as having the lowest ease-of-use. User performance and sentiment may reflect feature complexity. That is, these features are more visually complex and include more interactive components compared to the other features, potentially making them more difficult to navigate.

Of note, performance and ease-of-use ratings declined as cognitive functioning and technology familiarity decreased. It was not surprising that performance degraded with cognitive decline, as the onset of dementia can be accompanied by slower processing speed and increased challenges in cognitive domains relevant to aid use such as memory, attention, and executive functions (Smirnov et al., 2020). Furthermore, the impact of reduced technology familiarity on aid use was expected; it is also not uncommon for technology literacy to diminish as cognition declines (Liappas et al., 2018; McLaren et al., 2023). While performance with an aid may be impacted by both factors, the influence of technology familiarity may be stronger in the milder stages of decline. For example, Nir and colleagues found that technology familiarity influenced usability more than cognitive decline in their investigation of IndiAide©'s usability in persons with PD-MCI (Nir et al., 2023). Technology familiarity may also mitigate the impact of cognitive decline (Cho et al., 2023) and create a cognitive reserve (Liang et al., 2023). However, as cognition continues to decline, the possible protective effect of technology familiarity may wane due to the increasingly higher cognitive load required for use of electronic aids. That is, previously automatic skills may require more intention and attention due to the competition for limited cognitive resources (MacAulay et al., 2017).

Perceived Level of Helpfulness

User sentiment regarding the level of helpfulness of each feature was examined via Likert ratings. The Medications and Appointments features were ranked as the most helpful features for everyday functioning, while the Photos feature was considered the least helpful. It was hypothesized that the Medications and Appointments features would be well-received since prior studies have indicated that improving autonomy in organization, scheduling, and planning is desired by persons with PD (Spencer et al., 2020; Watermeyer et al., 2016), and the Medication and Appointments features support functioning in these areas. However, the lack of perceived helpfulness regarding more socially oriented features, such as the Photos feature, was unexpected.

Prior work suggests that people with various forms of dementia seek to maintain social connections and endorse tools that offer opportunities for social engagement (Turner & Berridge, 2023; Watermeyer et al., 2016). However, the Photos feature was populated by generic photos which may not cultivate as strong of a positive response (Tan et al., 2023). Additionally, the majority of participants indicated that they already had a system in place for storage of photos (e.g., their smart phones). Options to upload videos, audio messages, or more personal photos may be perceived more favorably as they offer more salient opportunities for social connection. It is well known that social engagement may have a protective effect against cognitive decline, as loneliness has been linked to increased dementia risk (Penninkilampi et al., 2018), and in some cases, mortality (Lamar et al., 2022; Pastor-Barriuso et al., 2020).

Differences in populations and symptom severity may additionally explain the reduced interest in the Photos feature. The majority of studies exploring technology use in persons with cognitive decline focus on Alzheimer’s disease, where memory loss is a defining feature (Smirnov et al., 2020). Given the negative impact of memory loss on interpersonal relationships and overall quality of life (Powers et al., 2016), people with Alzheimer's disease may uniquely benefit from devices that foster remembrance of shared connections. Compared to Alzheimer's disease, cognitive decline in PD is characterized by core impairments in attention and executive functions (Smirnov et al., 2020). While concerns surrounding social engagement and memory may increase with the onset of PDD (Watermeyer et al., 2016), the current self-reported concerns generally surrounded challenges with multitasking, attention, or following multistep directions.

Describing the User Experience

A content analysis was utilized to identify themes surrounding the IndiAide© user experience. Participants provided slightly more positive than negative feedback regarding the app's ease of use, layout, and learnability. They liked how simple the app was, and they generally felt the app was easy to learn how to use. Negative feedback was more frequently reported by participants with lower cognitive functioning or technology familiarity. This is unsurprising, as individuals with cognitive decline or low technological comfort may be less confident with technology and may experience greater challenges utilizing aids (Gedde et al., 2021). Despite this, many adults with cognitive decline continue to show an interest in learning how to use new technology (Cherian et al., 2024; Liappas et al., 2018), and treatment studies have found the implementation of electronic aids in daily life to be feasible and beneficial (Dowell-Esquivel et al., 2024; Oriani et al., 2003; Scullin et al., 2022).

Functional success with cognitive aids can be supported via education about the benefits of technology (Kaser et al., 2024), structured, systematic training (Dowell-Esquivel et al., 2024; Ehlhardt et al., 2008), and adherence to app designs that are intuitive (Mao et al., 2015). To this end, customizability is an integral part of making an app that works for this population, as it is common for people with dementia to report varying experiences with and exposure to technological devices (Di Campli San Vito et al., 2024; Turner & Berridge, 2023). Continued effort should be made to include people with cognitive decline from PD and other neurological conditions in the design process of IndiAide© to ensure high fidelity between app design and the lived experiences and needs of this population.

Factors Contributing to App Persuasiveness

A content analysis was utilized to identify which characteristics of IndiAide© were most persuasive in motivating a person with PD and cognitive decline to potentially adopt the app in the future. Although participants gave positive feedback about IndiAide©, they were relatively split in how persuaded they were to adopt the app. Some foresaw less of a need for the app due to already having a cognitive support system in place or overlap between IndiAide© and other, existing cognitive support tools. While individuals with dementia can successfully use novel devices (Scullin et al., 2022), they are generally drawn towards tools that are familiar (Mao et al., 2015). Given this context, it is understandable that participants would prefer existing support systems with which they are already familiar compared to a novel device.

For potential users who already have a cognitive support system in place, IndiAide© may not be additive to their existing system due to the level of overlap between IndiAide©'s offered features and other apps that can be accessed on mobile devices, tablets, or computers. For these users, the benefit of IndiAide© may not arise until later in the disease course wherein impairments in attention, memory, or executive functions make it cumbersome to manage multiple apps or devices. When making the shift to IndiAide©, allowing users/care partners to upload existing information, such as medications or scheduled appointments, from other apps may support the transition between cognitive support systems. Furthermore, allowing users/care partners to customize certain feature titles or icons, if desired, to align as much as possible with the layout of familiar systems may enhance aid adoption. For potential users who are less familiar with technology, it may be helpful to introduce IndiAide© early in the disease course given the aid's simplicity and 'one-stop-shop' design. This would allow for familiarization with and integration of IndiAide© into everyday activities while cognition is less impacted.

Care partner encouragement is another factor that can facilitate aid adoption, especially if a user has dementia. Evidence suggests that the degree to which individuals with dementia are interested in an aid is influenced by care partner perceptions (Di Campli San Vito et al., 2024; Turner & Berridge, 2023). This is particularly relevant given that individuals with dementia may experience diminished insight into the role in which technology can play in supporting their needs (McLaren et al., 2023). For instance, persons with dementia may not feel the need for an aid but will entertain the idea of using one if their care partner expresses interest (Turner & Berridge, 2023). Care partners were not included in the current study; however, several participants commented on how helpful certain features would be in supporting their care partners. Perhaps, participant perceptions would differ if their care partners expressed that the aid would reduce their day-to-day care demands. This could have positive downstream effects, as caregiver mental health has been linked to positive shifts in the well-being of the patient, such as improved quality of life (Litzelman et al., 2016) as well as reduced risk of hospitalizations (Levoy et al., 2022), depression and anxiety (Semere et al., 2021; Sink et al., 2006), and mortality (Lwi et al., 2017). Given that the IndiAide© developers have already added care partner access to the aid, the influence of care partner 'buy-in' on perceived persuasiveness could be an area of future investigation.

Phase I: Conclusion

In sum, the IndiAide© app appears to be usable by people with PD and a range of cognitive decline when given the proper support. App persuasiveness, perceived helpfulness, and overall user buy-in may improve in future iterations if targeted changes are made, such as adding notifications, and users and care partners are introduced to the full complement of IndiAide© features. When identifying who would be a good fit for the aid, specific consideration should be given to intra-individual factors such as the severity and nature of cognitive decline and the level of technology familiarity. To ensure success in individuals with PD and greater cognitive challenges or less technology literacy, structured training to ensure app adoption and utilization in naturalistic settings may be necessary, and it should include a care partner when available. Additionally, users with PDD may benefit from education surrounding how IndiAide© could be utilized to supplement everyday functioning given that individuals with dementia may experience diminished insight into the benefits of technology. This is particularly relevant for the next phase of this study, Phase II, which delves more deeply into the role of metacognition on aid use.

Phase II: Metacognitive Contributions to IndiAide© Use

Developing an electronic aid for persons with Parkinson disease dementia (PDD) requires a clear understanding of the cognitive challenges that might impede success and/or prevent adoption of the technology. Individuals with PDD can experience a broad range of cognitive challenges that may impact aid use. Attention, working memory, visuospatial function, memory, and processing speed are often reported as challenges in PDD (Goetz et al., 2009; Smirnov et al., 2020). Most prominent, however, is executive dysfunction which reflects the cognitive skills underlying goal-directed behavior (Smirnov et al., 2020). Central to this concern, and foundational to successful aid use, is metacognition and insight. These cognitive abilities facilitate learning as well as participation in cognitive rehabilitation (Hartman-Maer et al., 2003; Winkens et al., 2014). The following sections define key terms related to these complex cognitive constructs, provide theoretical models of awareness, and explicate the rationale for why these functions are important to electronic aid use in PDD.

Awareness in Parkinson Disease Dementia

People who experience PDD may have deficits in multiple cognitive domains (Smirnov et al., 2020), yet they may not be fully aware of their impairments. An estimated 16% of people with PD-MCI and 36% of those with early-stage PDD have diminished awareness of their cognitive challenges, with the prevalence increasing as cognition deteriorates (Orfei et al., 2018). In the broader dementia literature, this phenomenon has been examined through the lens of cognitive psychology and neuropsychology (Chapman et al., 2020). In cognitive psychology, awareness falls within the purview of metacognition. Broadly, metacognition is the ability to 'think about thinking,' and it encompasses beliefs about one's cognition as well as self-monitoring and control (Kennedy & Coelho, 2005). In contrast, neuropsychologists have primarily focused on clinical representations of reduced awareness (Chapman et al., 2020). The term anosognosia has historically been used to refer to reduced awareness following brain injury or stroke (Markova et al., 2005), although it is now used to describe diminished awareness across clinical populations.

Models of Awareness

By itself, the term ‘awareness’ is relatively broad. To conceptualize awareness, researchers have proposed multiple models that differ in their scope and purpose. Two key theoretical models related to awareness in the context of this study, and the relevance of this information to PDD, are discussed below and summarized in Table 13.

Levels of Awareness Framework

Proposed by Clare and colleagues, the Levels of Awareness Framework delineates awareness into four levels of increasing complexity, namely, sensory registration, performance monitoring, evaluative judgment, and meta-representation (Clare et al., 2011). Although the framework presents each level independently, they may interact, and the root of reduced awareness may span several levels. Beyond defining these levels, the Levels of Awareness Framework proposes that awareness is uniquely influenced by intraindividual factors, such as individual, social, cultural, and environmental idiosyncrasies and thus may present differently in each person (Clare et al., 2011).

Sensory registration is considered the fundamental building block for all other forms of awareness. It consists of the ability to direct attentional resources toward an object, allowing for internal appraisals and behavioral responses. This level of awareness is minimally affected by intraindividual factors, although the magnitude of response may be influenced by social and environmental contexts (Clare et al., 2011). It is usually assessed via self-reports or subjective

Table 13

Summary of Models of Awareness

Model	Field of Origin	Summary
Levels of Awareness Framework (Clare et al., 2011)	Neuropsychology	• **Sensory registration** consists of the ability to direct attentional resources toward an object. • **Performance monitoring** is represented by online monitoring of performance wherein a person identifies errors and compares them with expected performance. • **Evaluative judgment** reflects a person's general awareness of symptoms and their implications. • **Meta-representation** incorporates self-reflection and the ability to consider other people's perspectives.
Cognitive Awareness Model (Morris & Mograbi, 2013)	Cognitive Psychology	• **Cognitive Comparator Mechanisms** compare expected performance with actual performance by using the Personal Database as a reference. When these mechanisms malfunction, a person may display **executive anosognosia**. • The **Personal Database** contains a person's representations of conceptual knowledge, such as their understanding of their abilities. This system should be updated when mismatches between expected and actual performance are noted. If this does not occur, a person may display **mnemonic anosognosia**. • The **Autobiographical Conceptual Memory System** receives input from episodic and working memory, and it contains information regarding experienced events. • The **Metacognitive Awareness System** is an emergent form of awareness that is built from connections between systems. A failure to integrate systems can result in **primary anosognosia**.

accounts (Clare et al., 2005), although non-verbal indicators may be used in severe dementia (O'Shaughnessy et al., 2021). Performance monitoring is the next level of awareness, and it is represented by online monitoring of performance which allows a person to identify errors and compare expected performance with actual outcomes (Clare et al., 2011). This type of awareness may be influenced by personal beliefs and expectations, prior knowledge of the task, and the availability of feedback (West et al., 1996), and it is typically measured by asking individuals to estimate their performance on a task and comparing their estimations with behavioral outcomes (Clare, 2004).

Evaluative judgment, the third level of awareness, reflects a person's general awareness of symptoms and their implications. This level of awareness is more complex, as the individual must make judgments of a more diverse and composite nature. For example, evaluative judgments may draw upon the ability to concurrently consider multiple mental representations and their relationship, such as one's current and past cognitive capabilities and the impact of noted discrepancies. These judgments are more heavily affected by intraindividual factors such as beliefs and self-attributions, personal expectations, social stereotypes, and emotions (Clare et al., 2011; Martyr et al., 2022). Typically, this form of awareness is assessed by comparing ratings between an individual and a knowledgeable informant such as a care partner (Clare et al., 2005). The final, and most complex, level of awareness is meta-representation. It incorporates self-reflection and the ability to consider other peoples' perspectives, such as the awareness of having a disorder and the impact of this diagnosis on the current and future self and friends and family. This level of awareness is heavily shaped by individual, cultural, experiential, and educational factors (Clare et al., 2011), and it is often measured by in-depth interviews (Clare et al., 2005).

Cognitive Awareness Model

Proposed in 1998 and updated in 2013, the Cognitive Awareness Model is a neurocognitive model of awareness that explains how breakdowns in cognitive domains affect awareness (Agnew & Morris, 1998; Morris & Mograbi, 2013). It is compatible with the Levels of Awareness Framework, as it can be used to explain how cognitive impairments influence the framework's proposed levels of awareness (Clare et al., 2011). Per the Cognitive Awareness

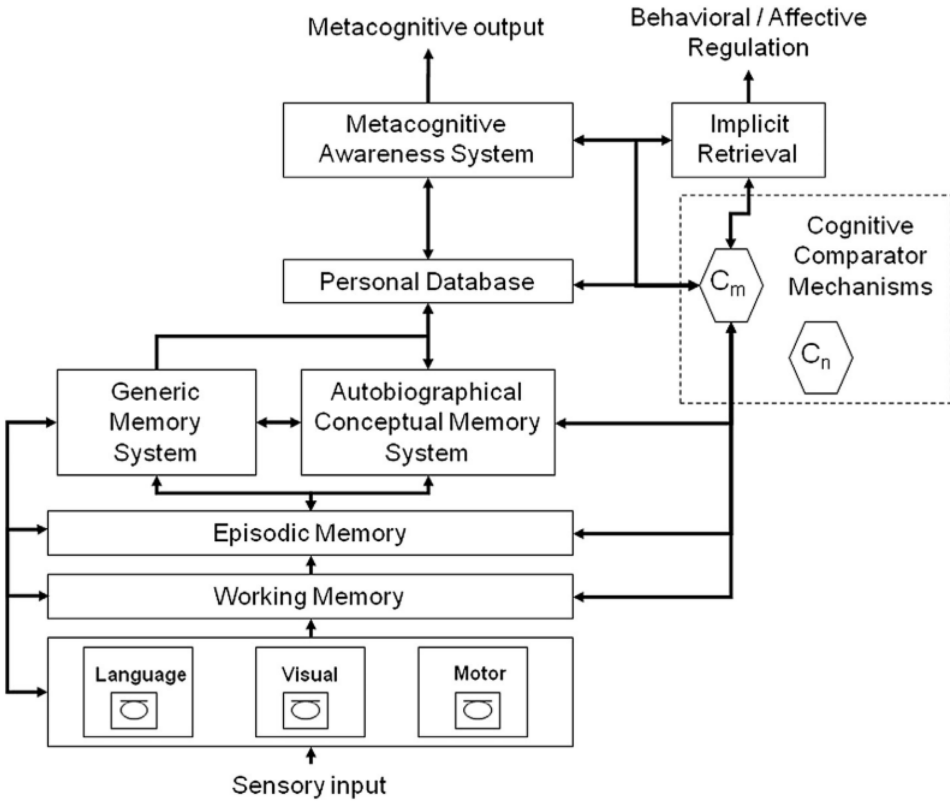
Model, awareness emerges due to the combined efforts of executive functions, memory, and metacognition.

Executive functions contribute to awareness by regulating Cognitive Comparator Mechanisms. These mechanisms are required for performance monitoring, as their role is to identify errors in current behavior and compare them with expected performance. Emotional responsiveness is considered essential for accurately appraising situations. The role of memory is more complex, as the model proposes several circuits that are regulated by various memory systems. The Personal Database is closely related to semantic memory. This database contains representations of conceptual knowledge, such as one's understanding of their abilities, and it is formed by performing tasks and through social and cultural experiences. The Autobiographical Conceptual Memory System receives input from episodic and working memory, and it contains information regarding experienced events. Both systems provide the basis of awareness for evaluative judgments and meta-representation. Other aspects of memory unrelated to the self are stored in the Generic Memory System. The Metacognitive Awareness System is the highest order construct in this model, and it can be viewed as an emergent process rather than a standalone system. The Metacognitive Awareness System reflects nascent awareness that is derived from widespread connectivity among multiple systems (Agnew & Morris, 1998; Morris & Mograbi, 2013).

Each of these systems are interconnected and work together to develop awareness (see Figure 5). When a person receives sensory input, the information is first processed in the relevant sensory circuits. Next, it is transferred to working memory then either to the Autobiographical Conceptual Memory System or General Memory System, depending on the relevance of the information to the self. This information is then shared with the Personal Database to enrich the

Figure 5

The Reformulated Cognitive Awareness Model (Morris & Mograbi, 2013)



mental representation of the self. While this occurs, Cognitive Comparator Mechanisms assess whether the input matches what is expected by using the Personal Database as a reference. If a mismatch is noted, the database is updated. Similarly, discrepancies feed into the Metacognitive Awareness System to generate a phenomenological sense of failure (Morris & Mograbi, 2013). Given the complex nature of this process, it is possible for breakdowns to occur at one or more levels.

Disruptions to executive functions can negatively affect Cognitive Comparator Mechanisms. When these mechanisms malfunction, a person may experience executive anosognosia. With this type of anosognosia, a person is made aware of an error, but the error is not compared with existing knowledge in the Personal Database. Thus, the person is unaware of any mismatches that may exist between actual behavior and expected performance. Individuals with executive anosognosia may display confabulation as they attempt to process contradictions between failed experiences and their expectations (Morris & Mograbi, 2013).

When the Personal Database fails, people may experience mnemonic anosognosia. Here, the Cognitive Comparator Mechanisms accurately identify errors, but this information is not encoded in semantic memory to update the Personal Database. Thus, the individual retains an outdated representation of their abilities. While this form of anosognosia is primarily related to memory impairments, it can negatively affect metacognitive functioning, as breakdowns in the Personal Database undermine the ability to self-reflect. Lastly, impairments at the level of the Metacognitive Awareness System can lead to primary anosognosia. In primary anosognosia, individual systems regulating awareness are spared, yet there is a failure in integration between systems that prevents the person from developing conscious awareness. In these cases, errors are only perceived and experienced implicitly (Agnew & Morris, 1998; Morris & Mograbi, 2013).

Models of Awareness: Applications to Parkinson Disease

To date, reports of diminished awareness in PD align with the Levels of Awareness Framework. Individuals with PD have shown reduced accuracy in estimating performance on a task immediately after task completion, suggesting diminished performance monitoring. This has been reported across both motor and cognitive functioning, with persons with PD displaying reduced recognition of motor symptoms (Maier et al., 2012, 2016; Pietracupa et al., 2013; Vitale et al., 2001) and overestimation of performance on cognitive tasks (Kudlicka et al., 2013; S. Smith et al., 2011; Souchay et al., 2006). Evaluative judgment may also be altered in PD, although its presentation is more variable. Compared to informants, individuals with PD and executive dysfunction may (Lanni et al., 2014; Sitek et al., 2013) or may not (Kudlicka et al., 2013) overestimate their cognitive functioning. Conversely, people with PD-MCI may underestimate the presence of cognitive challenges, with the prevalence of reduced awareness increasing following dementia onset (Orfei et al., 2018). People with PD have also been found to underestimate the severity of motor (Seltzer et al., 2001), speech (Pawlukowska et al., 2018), and neuropsychiatric (McKinlay et al., 2008) functioning. Perhaps, whether evaluative judgments are altered in PD is dependent on the overall severity of cognitive decline and the domain being examined.

The Cognitive Awareness Model may help explain noted variability in evaluative judgments. While the Cognitive Awareness Model has not been directly tested in PD, it can enrich understanding of the Levels of Awareness Framework by explaining neurocognitive mechanisms that contribute to functioning (see Table 14). For instance, Kudlicka and colleagues found performance monitoring accuracy was diminished in participants with PD and executive dysfunction compared to those with PD without executive dysfunction. In contrast, judgments of executive functioning were comparable between informants and both PD groups. Of note, neither PD group displayed memory impairments (Kudlicka et al., 2013). These findings support an association between Cognitive Comparator Mechanisms and performance monitoring due to noted breakdowns in performance monitoring only in the PD group with executive dysfunction. Similarly, findings support a connection between evaluative judgments and memory circuits, as evaluative judgments in both PD groups were accurate despite the presence of cognitive challenges in executive functions. Thus, evaluative judgments may be spared in persons with isolated executive dysfunction; however, once cognitive decline impacts memory (e.g., the onset of multidomain MCI or dementia), individuals may begin to underestimate their functioning.

While the study by Kudlicka and colleagues highlights the proposed synergy between models, the association between Cognitive Comparator Mechanisms and performance monitoring, as well as the relationship between memory circuits and evaluative judgment, may not be so clearly defined. Evaluative judgments of motor symptom severity have been found to relate to performance on tests of executive functions (Amanzio et al., 2014; Palermo et al., 2017) and memory (Seltzer et al., 2001) in persons with PD and normal cognition. Similarly, processing speed may impact evaluative judgments of executive dysfunction in people with PD and mild cognitive difficulties (Lanni et al., 2014). This suggests that executive functions, and by extension Cognitive Comparator Mechanisms, are involved in the formation of evaluative judgments. Perhaps, this reflects interactions among the levels of awareness proposed in the Levels of Awareness Framework.

Table 14

Neurocognitive Processes Implicated in Levels of Awareness

Level of Awareness	Relevant Neurocognitive Modules	Example Cognitive Processes
Sensory registration	• Local sensory or motor comparators	• Feedforward and feedback
Performance monitoring	• Cognitive comparator mechanisms	• Error detection
Evaluative judgment	• Episodic memory • Personal database • Autobiographical conceptual memory system	• Integrating memory representations
Meta-representation	• Personal database • Autobiographical conceptual memory system • Metacognitive awareness system	• Belief instantiation • Perspective taking • Personal agency

Note. Adapted from Morris & Mograbi (2013).

Working Definition of Awareness

As seen in this review, there is a degree of overlap in models of awareness and related constructs. Indeed, the terminology used in the broader literature can be confusing, as studies encompassing awareness often fail to define the concept being tested or use the terms awareness, insight, and anosognosia interchangeably (Markova et al., 2005). To reduce confusion, a working definition of awareness is offered, informed by the above models. For this proposal, awareness will be broadly defined as ‘an accurate appraisal of a given aspect of one’s situation, functioning, or performance, or of the resulting implications’ (Clare et al., 2008), with a focus on self-awareness and self-monitoring (see Table 15 for a summary). Here, self-awareness is defined as a person’s knowledge of their abilities, and it may manifest as knowledge of how an impairment or disease impacts functioning (Chudoba & Schmitter-Edgecombe, 2020). It can be operationalized as the discrepancy between self-ratings and informant-ratings of functioning (Lanni et al., 2014), or as the difference in perceived ability to complete a task and actual performance (Chudoba & Schmitter-Edgecombe, 2020). Self-monitoring refers to tracking one’s performance during or immediately after a task. It can be operationalized as the difference between observed and estimated performance on a task (Chudoba & Schmitter-Edgecombe, 2020).

As indicated, common methods for measuring these metacognitive constructs are patient-informant discrepancy and performance discrepancy. Patient-informant discrepancy involves comparing a self-report of abilities to an informant’s report on a parallel form. These are sometimes referred to as “offline” assessments and are particularly useful for measuring global self-awareness, such as a person’s general understanding of having a disease or the effects of the disease on everyday life. In contrast, performance discrepancies allow for the assessment of both self-awareness and self-monitoring and are commonly defined as “online” assessments (Chudoba & Schmitter-Edgecombe, 2020). Online assessments are task-specific, as individuals are asked to make predictions about their performance during and after a task. The difference between predictions made before the task and actual performance provides a measure of self-awareness (i.e., how accurate is the person's mental representation of their skillset), and the difference between estimations of performance made after the task and actual performance provides a measure of self-monitoring (i.e., how accurate is the person in assessing their performance in real time). Of note, these expressions of online awareness are not mutually exclusive. Errors identified through self-monitoring can be contrasted with a person's conceptual knowledge of the task to update their self-awareness.

Table 15
Definition of Self-Awareness and Self-Monitoring

	Definition	**Measurement**	**Measurement Type**
Self-awareness	Knowledge and prediction of abilities	Global: Self versus informant rating	Offline
		Task specific: Prediction of performance versus actual performance	Online
Self-monitoring	Tracking performance during/after task	Task specific: Error detection, estimation of completed task performance versus actual performance	Online

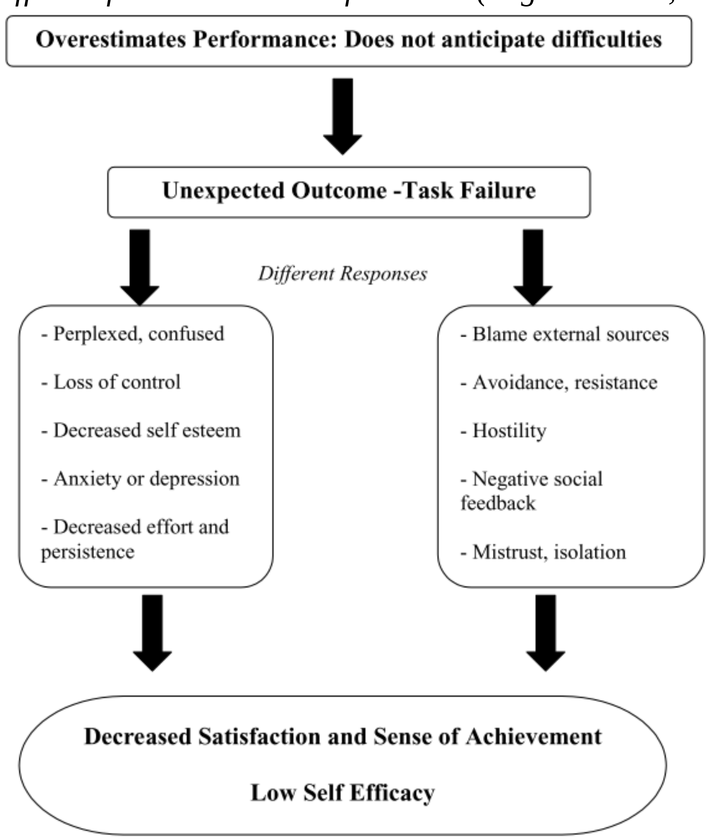
The Role of Awareness in Electronic Aid Use

As discussed, individuals with cognitive impairment, particularly dementia, are prone to experiencing reduced awareness (Orfei et al., 2018). This may negatively impact electronic aid use in several ways. First, a person with diminished global (offline) self-awareness may be less likely to engage in rehabilitation. They may display low motivation and poor acceptance of compensatory aids due to reduced recognition of the need for such services (Cosentino et al., 2011). A person with impaired task-specific (online) self-awareness, may not have an accurate mental representation of their ability to use an aid which may cause them to overestimate their abilities. When a person overestimates their performance, they may experience a range of negative emotions when unsuccessful with use of the aid, which may lead to decreased satisfaction and low self-efficacy (see Figure 6) (Toglia & Kirk, 2000). Low functional use of an aid may occur if this happens consistently.

The ability to accurately self-monitor performance during a task is also important. When learning how to use an aid, a person with reduced self-monitoring may have difficulty making online adjustments and detecting or learning from errors. Subsequently, the user may experience frustration if they are unable to recognize and adjust to errors. Additionally, users with reduced self-monitoring may require additional support from care partners to guide them through use of the aid (Rymer et al., 2002; Tsai et al., 2021). Thus, it is important to understand the constructs of self-awareness and self-monitoring in relation to aid use when examining the usability of electronic aids in PD, as well as the potential for inclusion of electronic aids in cognitive rehabilitation for people with early-stage PDD.

Figure 6

Effects of Overestimation of Abilities (Toglia & Kirk, 2000)



Conclusions and Research Questions

In sum, PD is a multifaceted disease in which cognitive decline is a common and challenging symptom. While electronic cognitive aids are a promising treatment mechanism for dementia, there are elevated challenges in using such devices in PDD. Diminished awareness, which may emerge with dementia onset, may negatively impact aid adoption, and subsequent use, as individuals with reduced self-awareness may not fully recognize the need for an aid. Moreover, individuals who experience difficulties self-monitoring may develop frustration with recurrent failures using or learning how to use an aid. Thus, it is important to consider the presence and influence of these metacognitive factors when considering the feasibility of electronic cognitive aids. The purpose of Phase II was to examine whether individuals with PD and cognitive decline experience diminished global self-awareness and task-specific self-awareness and self-monitoring related to aid use. The following research questions were addressed:

1. To what extent do self- and informant-ratings of global behavioral regulation and metacognition differ between individuals with PD and cognitive decline and their care partners?
2. How accurately do pre-experience predictions align with participants' true performance for (a) the level of help needed to use the app and (b) the time taken to complete the tasks?
3. How accurately do post-experience estimations align with participants' true performance for (a) the level of help needed to use the app and (b) the time taken to complete the tasks?

4. Is there a relationship between global (offline) self-awareness of metacognitive capabilities and task-specific (online) self-awareness or self-monitoring?

Prior literature has found discrepancies between informant reports and self-ratings of cognitive functioning in PD, with discrepancies becoming greater as cognitive difficulties become more severe (Lanni et al., 2014; Orfei et al., 2018). Thus, it is hypothesized that people with PD will report significantly different severities of behavioral and metacognitive challenges compared to care partners. Similarly, it is hypothesized that individuals with PD will provide inaccurate pre-experience predictions and post-experience estimations, as evaluative judgments and performance monitoring have previously been found to be inaccurate in people with PD (Kudlicka et al., 2013; Maier et al., 2021). Additionally, it is hypothesized that global self-awareness of metacognitive abilities will significantly relate to pre-experience predictions and post-experience estimations, since metacognitive abilities have been associated with performance monitoring (Amanzio et al., 2014; Palermo et al., 2017), and pre-experience predictions have been related to post-experience estimations of accuracy (Chudoba & Schmitter-Edgecombe, 2020).

Phase II: Methods

Phase II sought to investigate the influence of metacognition on aid use among persons with PD and a range of cognitive decline. To do so, a multipronged assessment examining global (offline) self-awareness, task-specific (online) self-awareness and self-monitoring, and the relationship between global and task-specific awareness was conducted.

Phase II: Participants

Participants were recruited via the Washington State Parkinson Disease Registry. A sample comprised of 15 caregiver dyads (15 individuals with PD and cognitive decline, 15 care partners) were recruited for Phase II. Dyads were included if the individual with PD (a) was community dwelling, (b) was between the ages of 50-85, (c) had a diagnosis of PD by a neurologist, (d) had self- or informant-reported diagnosis of early dementia or cognitive complaints that interfere with daily living, (e) had an onset of cognitive complaints and difficulties ≥1 year post disease onset, and (f) was generally intelligible (i.e., >90% intelligibility) in conversation. Additionally, the person with PD needed to have a consistent main care partner, defined as "any person who, without being a professional or belonging to a social support network, usually lives with the patient and, in some way, is directly implicated in the patient's care or is directly affected by the patient's health problem" (Martínez-Martín et al., 2007). Care partners were asked to provide verbal consent during the telephone screening. Dyads were excluded if the person with PD reported a neurological disorder beyond PD or had a formal diagnosis of a psychiatric disorder (e.g., schizophrenia, bipolar disorder), displayed evidence of severe depression (>11 on the Geriatric Depression Scale-Short Form (GDS-SF) (Yesavage & Sheikh, 1986), or had significant visual or motor impairments (e.g., severe tremor or freezing episodes) that would impede their ability to use the app. Additionally, individuals who had participated in a prior IndiAide© study were not eligible to participate in Phase II.

Phase II: Procedure

Participants were pre-screened for eligibility during the initial contact with investigators. During this call, investigators used clinical judgment and responses from the person with PD and a care partner to triangulate a possible diagnosis of cognitive decline (see Appendix A). If an individual was deemed eligible from the pre-screening, an investigator scheduled a time to come to their home during optimal medication to complete the remaining screening and experimental procedures. The primary investigator and a research assistant attended the formal session. Eligibility and descriptive measures were collected first, followed by the metacognitive protocol.

Phase II: Protocol

The procedure for Phase II is represented by the flowchart in Appendix D. Following informed consent and descriptive measures, participants were asked to complete a technology familiarity questionnaire adapted from Nicosia and colleagues (see Appendix I) (Nicosia et al., 2022) to account for variations in technology comfort that may influence mental representations of one's ability to use an aid. A lower score suggests a person is less familiar with technology, whereas a higher score indicates they are more familiar with technology. Next, executive functions were assessed using the Behavior Rating Inventory of Executive Function-Adult (BRIEF-A) (10-15 minutes administration time) (Roth & Gioia, 2005). This is a 75-item questionnaire designed to capture higher-order cognitive processes necessary for engaging in real-world, goal-directed behaviors. It can be subdivided into two indexes, namely, a Behavioral Regulation Index (BRI) and Metacognition Index (MI). The BRI is composed of the Inhibit, Shift, Emotional Control, and Self-Monitor scales, and it measures the ability to properly regulate behavioral and emotional responses. The MI is compiled from the Initiate, Working

Memory, Plan/Organize, Task Monitor, and Organization of Materials scales, and it measures the ability to organize information and solve complex problems (Lanni et al., 2014).

Both members of the dyad were asked to complete this questionnaire (using the self-report and informant-report forms) yielding self- and informant-ratings of executive functions. Next, participants were introduced to the IndiAide© application using the familiarization protocol (see Appendix E). New to this phase was the metacognitive component. For each feature of the app, participants were shown a set of tasks (see Table 1). Prior to completing the tasks, participants were asked to predict how much help they will need to complete the tasks (pre-experience prediction) using an ordinal scale ranging from no help, a little help (verbal cue), some help (verbal + gestural cue), to a lot of help (model). Additionally, participants were asked to predict how long it will take them to complete the tasks. Then, participants were asked to complete the tasks. After finishing, participants were asked to estimate how much help they needed using the same ordinal scale and how long it took them to complete the tasks (post-experience estimation).

To orient participants to this process, a set of practice tasks was completed first. The investigator gave examples of each level of help to define the ordinal scale. Additionally, the true time taken to complete the tasks was measured with a stopwatch and shared with the participant after they finished the practice tasks to anchor their sense of time. After this practice, participants were presented with the experimental tasks. Feature presentation was randomized to address fatigue effects. The examiner tracked the number and level of cues provided online using the data collection form (see Appendix G). For the level of help, the investigator gave participants a score between 0-3 (0 = no help, 3 = a lot of help) depending on the level of help required. Sessions were video recorded to allow for offline calculations of task time and reliability.

It took participants between 1.5-2 hours to complete Phase II, inclusive of breaks. At the end of the session, participant dyads were given a $40 VISA gift card as compensation for their time.

Phase II: Measures

Self- and informant-ratings from the BRIEF-A were collected and transformed into *T*-scores. *T*-scores (M = 50, SD = 10) are used to interpret a respondent's level of functioning on the BRIEF-A by comparing their scores to the standardization sample. A score $\geq$65 is considered clinically significant (Roth & Gioia, 2005). *T*-scores were used for all analyses incorporating BRIEF-A ratings. Offline self-awareness of executive abilities was operationalized as the difference between self-ratings and informant-ratings for the BRI and MI indexes (Clare et al., 2005; Lanni et al., 2014). Online measures of self-awareness and self-monitoring were operationalized as the difference between pre-experience predictions and true performance and post-experience estimations and true performance, respectively. This difference was calculated for each feature, resulting in eight measures of self-awareness and eight measures of self-monitoring. The median level of help and mean time were calculated across features and used in the analyses.

Phase II: Statistical Analysis

Paired *t*-tests were used to differentiate self- and informant-ratings of behavioral regulation and metacognition, as they allow for comparisons of ratings about the same group. Specifically, a paired *t*-test was used to compare self- and informant-ratings on the BRI index, and a paired *t*-test was used to compare self- and informant-ratings on the MI index. The signed difference (self-rating – informant-rating) was calculated for each index to determine whether the person with PD under or overestimated functioning, while the absolute difference (|self-rating –

informant-rating|) was calculated to show the magnitude of difference in responses per index (Chudoba & Schmitter-Edgecombe, 2020).

Paired *t*-tests were also used to evaluate how accurately pre-experience predictions for the level of help and time aligned with participants' true performance. Signed difference scores (predicted performance outcome – true performance outcome) were calculated to describe whether participants under or overpredicted their performance, while absolute difference scores (|predicted performance outcome – true performance outcome|) were calculated to describe the magnitude of difference. Similarly, paired *t*-tests were used to evaluate how accurately post-experience estimations for the level of help and time aligned with participants' true performance. Signed difference scores (estimated performance outcome – true performance outcome) were calculated to describe whether participants under or overestimated their performance, while absolute difference scores (|estimated performance outcome – true performance outcome|) were calculated to describe the magnitude of difference.

Spearman's rank order correlations were used to determine if there is a relationship between global (offline) self-awareness of metacognitive abilities and task-specific (online) self-awareness or self-monitoring. Specifically, the absolute rater difference for the MI index was correlated with the absolute difference for pre-experience predictions of help/time versus true help/time and post-experience estimations of help/time versus true help/time.

Analyses were conducted in R version 4.4.2 (The R Foundation, 2024). For all analyses, the alpha level was set to .05.

Phase II: Reliability and Validity

Video Analysis Reliability

Inter-rater and intra-rater reliability were determined by recalculating the level of help provided and time taken to complete tasks for 25% of the tested features (2 randomly selected features per participant/total number of features tested; 30/120) by a research assistant and the primary investigator, respectively.

Self and Informant Validity

To account for bias in participants' responses on the BRIEF-A, within-person validity was assessed by calculating the negativity, infrequency, and inconsistency scores (Roth & Gioia, 2005). The negativity score measures the extent to which respondents respond to questions in an unusually negative manner. A score $\geq$6 indicates there were a concerningly high number of negative responses. The infrequency score assesses the extent to which participants atypically endorse items. A score of $\geq$3 indicates that items were endorsed in an atypical manner. The inconsistency score indicates the extent to which participants respond inconsistency across items. A score of $\geq$8 suggests that respondents were not consistent in their responses (Roth & Gioia, 2005).

Additionally, multiple regressions were conducted to examine the degree to which self-reports and informant-reports of executive dysfunction align with objective decline. Specifically, four multiple regressions were conducted with either the self- or informant-reported *T*-score from the BRIEF-A BRI or MI as the dependent variable. Objective decline was captured using the PD-CRS scores, and this was used as the predictor variable. Scores on the GDS-SF were included as a covariate to account for the influence of depression on perceptions of cognitive functioning (Løvstad et al., 2016).

Phase II: Results

Twenty-four individuals contacted the primary investigator to express interest in the study. Five did not respond to follow-up attempts to schedule the screening call. Of those who were screened, one was disqualified due to participating in a prior IndiAide© study, one retracted their interest in participating, one was disqualified due to advanced age, and another was disqualified due to having a neurological disorder beyond PD. The remaining 15 were deemed eligible for inclusion and participated in the study. Demographic data, cognitive scores, and other descriptive characteristics are presented in Table 16. Most participants were white (14 white, 1 mixed race) and identified as male (12 male, 3 female). The average age was 72.2 years (range: 59-84 years), and it had been 7.2 years on average since disease diagnosis (range: 1-15 years). Average years of education was 15.8 (range: 12-24 years); two participants worked part-time while the rest were retired. The average score on the technology familiarity questionnaire was 39.33 (range: 12-60), suggesting that, overall, participants considered themselves to be moderately comfortable utilizing smartphones and tablets for a variety of functions (e.g., making phone calls, checking email, playing games, etc.; see Appendix I). Ten participants presented with MCI (score of <101 on the PD-CRS), and five participants exhibited possible PDD (score of <73.5 on the PD-CRS) (Rosca & Simu, 2020). The majority (13/15) of care partners were spouses of the participant with PD. Of the remaining two care partners, one was a longtime friend of the participant, and the other was a live-in son.

Table 16

Demographic and Clinical Characteristics of Phase II Participants with PD

Participant	Age	Gender	Race	Years of Education	Years Post Diagnosis	PD-CRS	Cognitive Status	GDS-SF	H&Y	Tech Fam.
1	84	Male	White	14	1	86	MCI	5	4	33
2	74	Male	White	12	15	75	MCI	4	4	34
3	60	Male	White	18	5	84	MCI	4	2	46
4	74	Female	White	14	6	98	MCI	2	1	50
5	77	Male	White	18	2	53	PDD	9	3	26
6	75	Male	White	15	5	71	PDD	2	3	44
7	70	Male	White	16	7	76	MCI	4	2	43
8	77	Female	White	16	11	101	MCI	1	1	60
9	82	Male	White	20	8	96	MCI	3	2	12
10	70	Male	White	24	4	64	PDD	3	2	50
11	74	Female	Mixed	13	10	91	MCI	1	3	49
12	59	Male	White	12	6	64	PDD	5	3	30
13	63	Male	White	16	9	76	MCI	9	3	39
14	67	Male	White	17	5	74	MCI	3	3	47
15	77	Male	White	12	14	73	PDD	5	3	27
Mean	72.20	--	--	15.80	7.20	78.80	--	4.00	2.60	39.33
SD	7.40			3.32	4.02	13.72		2.42	.91	12.30

Note. PD-CRS = Parkinson Disease-Cognitive Rating Scale (range: 0 – 134; lower scores = more severe decline); MCI = Mild Cognitive Impairment; PDD = Parkinson Disease Dementia; SCD = Subjective Cognitive Decline; GDS-SF = Geriatric Depression Scale-Short Form (range: 0 – 15; lower scores = no or less severe depression); H&Y = Hoehn & Yahr score from the abridged version of Part III of the Movement Disorder Society sponsored version of the Unified Parkinson Disease Rating Scale (range: 0 – 4; lower scores = less severe motor involvement); Tech Fam. = Technology familiarity score (range: 0 – 60; lower scores = less familiar).

Phase II: Reliability and Validity

Video Analysis Reliability

Offline recalculation for the level of help and time to complete task was conducted for 25% of all tested IndiAide© features (2 randomly selected features per participant/total number of features tested; 30/120). The primary investigator completed all initial offline measurements and then re-calculated 25% of the measures for intra-rater agreement. A research assistant completed offline calculations for these measures for the same 25% of tasks for inter-rater agreement. For the level of help, intra-rater agreement (α = .98) and inter-rater agreement (α = .94) were highly reliable per Cronbach's alpha. Similarly, intra-rater time agreement (α = .99) and inter-rater time agreement (α = .99) were highly reliable per Cronbach's alpha.

Self and Informant Validity

Participants with PD and their care partners were determined to be reliable and valid responders on the BRIEF-A. That is, negativity, infrequency, and inconsistency scores were below the cut-off for all self and informant reports, indicating that bias levels were within acceptable limits.

Neither participants' cognitive decline per the PD-CRS nor their severity of depression per the GDS-SF predicted self- or informant-ratings on the BRIEF-A subscales, indicating that perceptions of everyday functioning may not have been driven by objective functioning. Specifically, neither the model containing self-ratings on the BRI as the dependent variable, $F(2, 12) = .26$, $p = .78$, $R^2 = .04$, nor the model containing self-ratings on the MI as the dependent variable, $F(2, 12) = .55$, $p = .59$, $R^2 = .08$, were significant. Similarly, neither the model containing informant-ratings on the BRI as the dependent variable, $F(2, 12) = 1.51$, $p = .26$,

R^2 = .20, nor the model containing informant-ratings on the MI as the dependent variable, $F(2, 12) = 1.58$, $p = .25$, $R^2 = .21$, were significant.

Phase II: Global Awareness and Task-Specific Awareness

Phase II was designed to examine global (offline) self-awareness and task-specific (online) self-awareness and self-monitoring in PD. To this end, four research questions were developed which examined these aspects of awareness and their relationship to each other.

Research Question 1: Global (Offline) Self-Awareness

Research question 1 examined the extent to which self- and informant-ratings of global behavioral regulation and metacognition differ between individuals with PD and cognitive decline and their care partners. To this end, a comparison of self- and informant-ratings from the BRIEF-A was conducted, using both the Behavioral Regulation Index (BRI) and Metacognition Index (MI). Table 17 displays self- and informant-ratings on these indexes, while Figure 7 visually depicts dyad responses.

Self and informant group ratings for the BRI were not significantly different ($t(13) = 1.93$, $p = .08$, $d = .52$) when analyzed with removal of one outlier dyad[1] (see Table 17 and Figure 8). For the MI, there were significant differences between self-ratings and informant-ratings ($t(14) = 3.00$, $p = .01$, $d = .77$). As a group, participants with PD perceived themselves as experiencing significantly more challenges with metacognition than their care partners (see Figure 9). For 11/15 dyads, the person with PD reported greater MI challenges; for 3 dyads, the difference between ratings for the person with PD and care partner was negligible ($\leq$2 points) and for only one dyad, the care partner reported greater challenges.

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[1]P10 presented with the largest rater discrepancy on the BRI compared to the other dyads. Boxplot visualization revealed an outlier that was >1.5 times the interquartile range away from the first quartile.

Table 17

Comparisons of Self- and Informant-Ratings on BRIEF-A Indexes

		Behavioral Regulation Index					Metacognition Index				
		Self		Informant		T Score Diff.	Self		Informant		T Score Diff.
ID	Cog. Stat.	Raw	T	Raw	T		Raw	T	Raw	T	
1	MCI	52	**66**	60	**65**	1	77	**74**	112	**88**	-14
2	MCI	32	40	38	46	-6	53	49	55	51	-2
3	MCI	62	**74**	55	**69**	5	96	**86**	71	61	25
4	MCI	35	44	32	41	3	67	62	42	42	20
5	PDD	43	53	53	59	-6	84	**78**	88	**72**	6
6	PDD	46	57	54	60	-3	82	**76**	97	**78**	-2
7	MCI	47	58	37	46	12	88	**82**	89	**73**	9
8	MCI	45	56	39	47	9	60	56	51	48	8
9	MCI	34	43	30	40	3	72	**69**	50	47	22
10	PDD	49	61	38	46	15[a]	74	**69**	64	56	13
11	MCI	41	51	38	46	5	76	**71**	72	62	9
12	PDD	53	62	43	50	12	96	**84**	83	**69**	15
13	MCI	49	59	53	59	0	68	62	76	64	-2
14	MCI	36	44	32	41	3	60	55	53	49	6
15	PDD	38	47	35	44	3	68	63	63	56	7
Mean[b]	--	44.13	54.33	42.47	50.60	5.73	74.73	69.07	71.07	61.07	10.67
SD		8.31	9.58	9.83	9.31	4.38	12.79	11.15	19.85	13.03	7.33

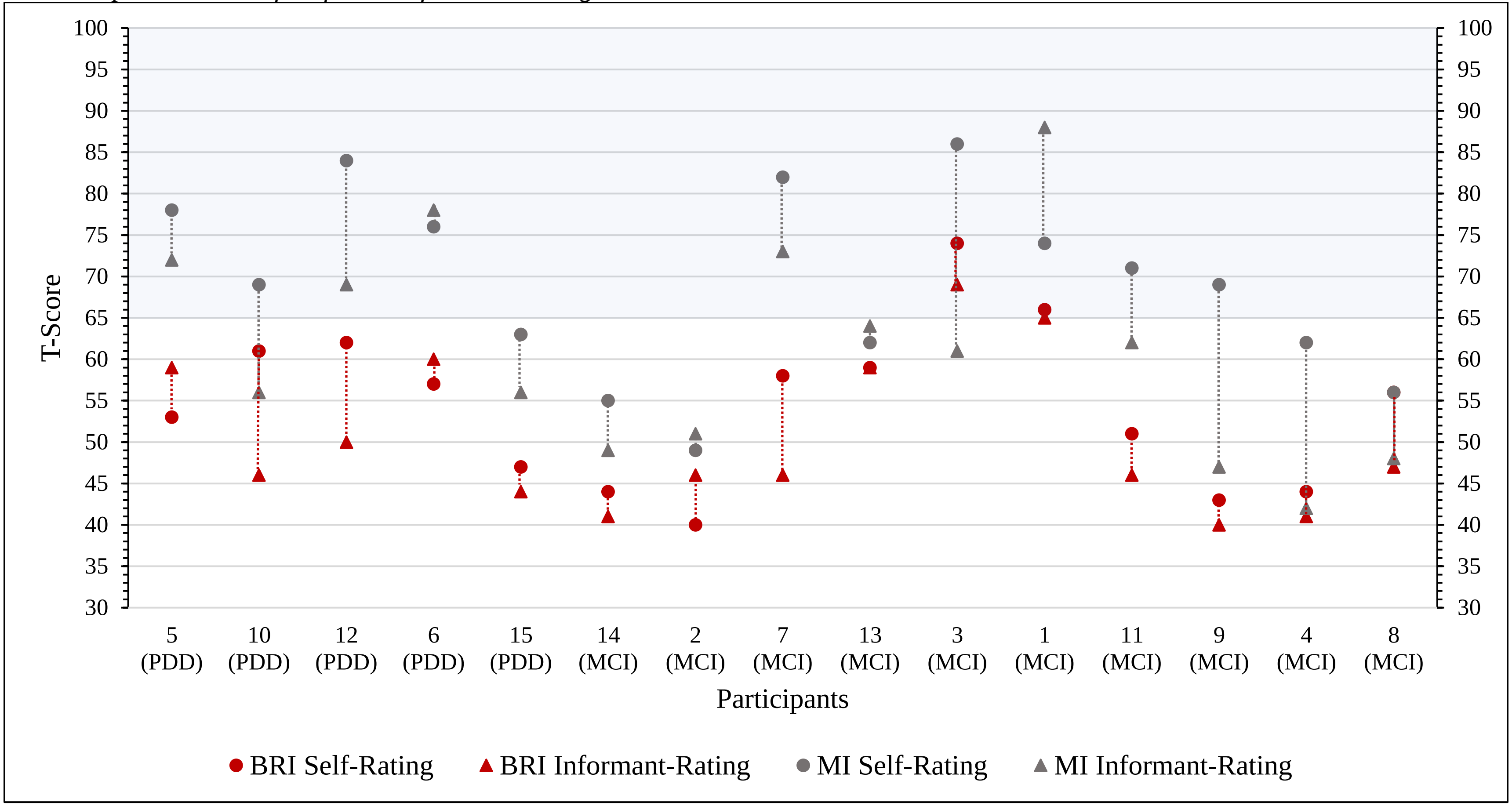
Note. T-scores >65 (bolded) indicate significantly elevated levels of perceived dysfunction (Roth & Gioia, 2005). BRIEF-A = Behavior Rating Inventory of Executive Function-Adult; ID = Participants' identification number; Cog. Stat. = Cognitive status as indicated by the Parkinson Disease-Cognitive Rating Scale; MCI = Mild cognitive impairment; PDD = Parkinson disease dementia; T Score Diff. = the difference between self vs. informant *T*-scores (negative value = person with PD underreported difficulties compared to care partner; positive value = person with PD overreported difficulties compared to care partner)

[a]The BRI *T*-score difference for P10 was deemed an outlier, and thus this participant was removed from the BRI comparison

[b]Absolute values used to calculate the means and standard deviations for difference scores

Figure 7

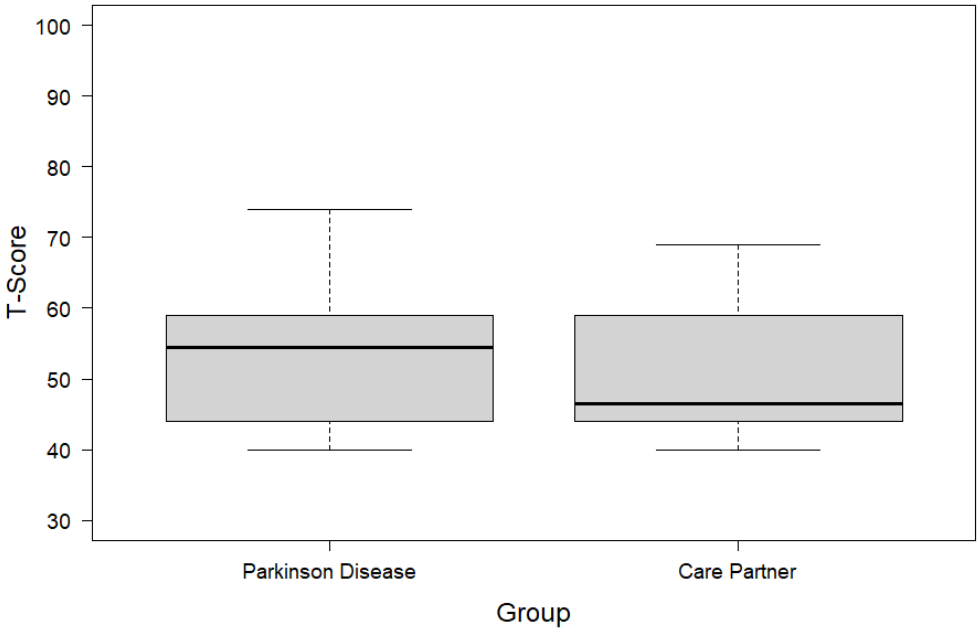
Visual Representation of Self- and Informant-Ratings on BRIEF-A Indexes



Note. Participants are organized in ascending order of their score on the Parkinson Disease-Cognitive Rating Scale. *T*-scores above 65 indicate significantly elevated levels of perceived dysfunction (Roth & Gioia, 2005). BRIEF-A = Behavior Rating Inventory of Executive Function-Adult; BRI = Behavioral Regulation Index; MI = Metacognition Index; PDD = Parkinson disease dementia; MCI = Mild cognitive impairment

Figure 8

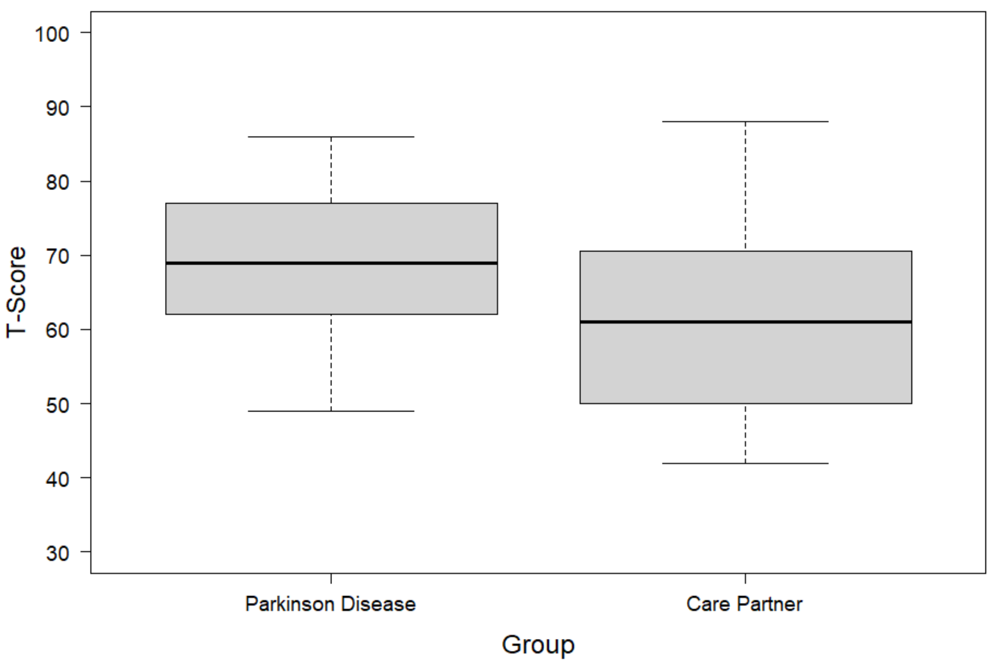
Group Comparison of the Behavioral Regulation Index (BRI) Ratings



Note. *T*-scores above 65 indicate significantly elevated levels of perceived dysfunction (Roth & Gioia, 2005). Shown here is the group comparison with the P10 outlier removed.

Figure 9

Group Comparison of the Metacognition Index (MI) Ratings



Note. *T*-scores above 65 indicate significantly elevated levels of perceived dysfunction (Roth & Gioia, 2005)

Factors Driving Rater Differences. Post-hoc paired *t*-tests examining the subscales that comprise the MI revealed that self- and informant-ratings significantly differed only for the Working Memory subscale ($t(14) = 3.29$, $p = .01$); two other subscales approached significance (Initiate subscale, $p = .08$; Organization of Materials subscale, $p = .06$).

Cognitive Status Comparison. A second post-hoc analysis was conducted using Mann Whitney U Tests to compare self- and informant-ratings on the BRI and MI between participants with MCI and PDD. The discrepancy between self- and informant-ratings did not significantly differ between groups for the BRI ($p = 1$) or MI ($p = .90$) suggesting that level of cognitive impairment was not driving the differences between PD and care partners.

Research Question 2: Task-Specific (Online) Self-Awareness

Research question 2 examined how accurately pre-experience predictions align with participants' true performance for the level of help needed to use the app and the time taken to complete a set of tasks. As an indicator of self-awareness (Chudoba & Schmitter-Edgecombe, 2020), participants' pre-experience predictions were compared with their true performance for the level of assistance needed ("how much help do you think you'll need?") and time required ("how much time do you think it will take?") to complete the IndiAide© tasks. Table 18 displays participants' predictive ratings for the level of help and time, their true performance outcomes, and the difference between each.

Table 18

Pre-Experience and Post-Experience Participant Ratings for the IndiAide© Tasks

Participant	Cognitive Status	Median Level of Help					Mean Time (Seconds)				
		Pre	Post	True	Diff (Pre)	Diff (Post)	Pre	Post	True	Diff (Pre)	Diff (Post)
1	MCI	1	2	1	0	1	60.00	68.13	97.25	-37.25	-29.13
2	MCI	.5	1	1	-.5	0	60.00	56.88	50.80	9.21	6.08
3	MCI	0	0	0	0	0	53.75	33.13	29.67	24.08	3.45
4	MCI	0	0	0	0	0	42.50	28.75	27.46	15.04	1.29
5	PDD	1	1	1	0	0	101.25	112.50	85.44	15.81	27.06
6	PDD	2	1.5	1	1	.5	116.25	76.88	94.84	21.41	-17.97
7	MCI	1.5	1	1	.5	0	236.25	210.00	84.84	151.41	125.16
8	MCI	1	1	.5	.5	.5	82.50	90.00	38.98	43.52	51.02
9	MCI	0	0	0	0	0	60.00	63.50	43.62	16.38	19.88
10	PDD	0	1	1	-1	0	43.13	41.25	40.75	2.37	0.50
11	MCI	0	0	0	0	0	15.63	15.63	45.04	-29.42	-29.42
12	PDD	1	1	2	-1	-1	315.00	330.00	111.60	203.40	318.40
13	MCI	2	1	1	1	0	54.38	45.63	54.11	0.27	-8.48
14	MCI	1	0	0	1	0	76.88	65.63	45.03	31.85	20.58
15	PDD	1	2	1.5	-.5	.5	360.00	270.00	128.45	231.55	141.55
Mean[a]	--	.80	.83	.73	.47	.23	111.83	100.53	64.91	55.53	53.33
SD		.70	.70	.62	.44	.37	104.91	93.79	31.68	74.97	84.82

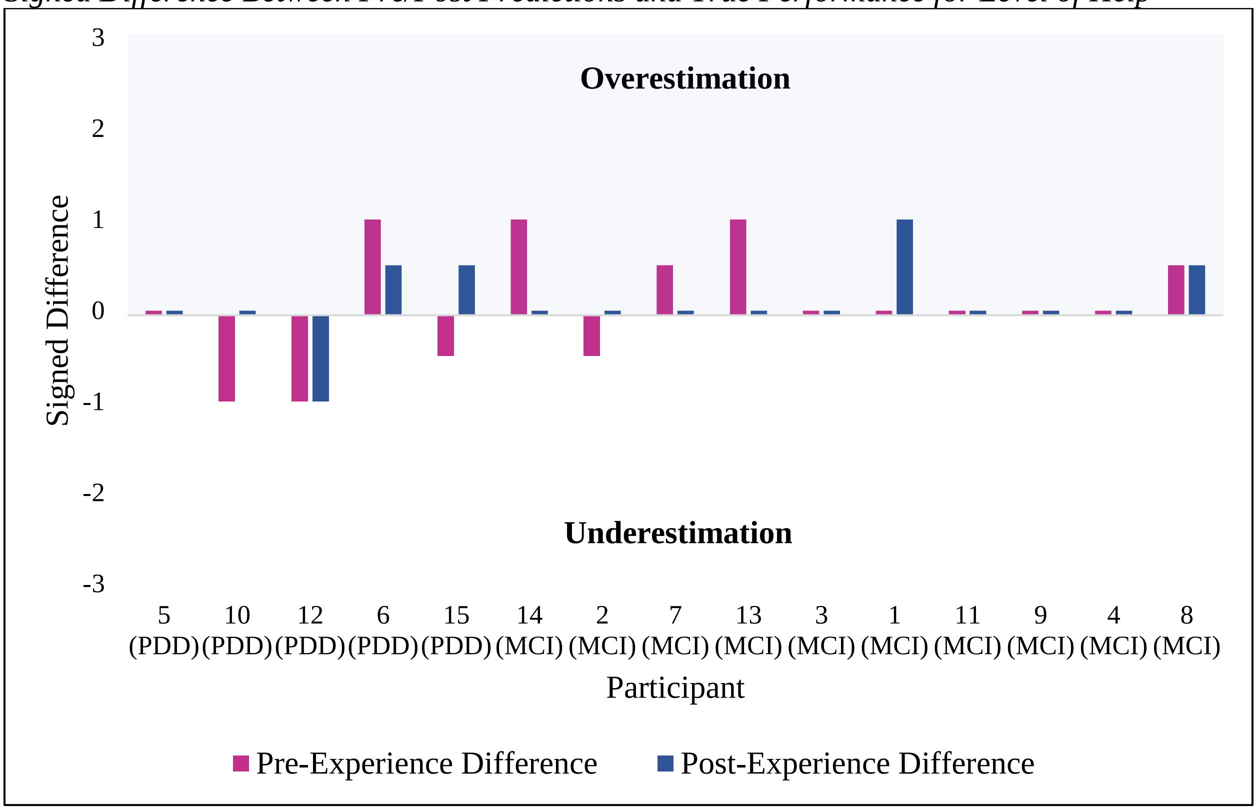
Note. Scores for Level of Help reflect the median level across all 8 IndiAide© features tested on a 0-3 ordinal scale: 0 = 'no help'; 1 = 'a little help' (verbal cue); 2 = 'some help' (verbal + visual cue); 3 = 'a lot of help' (model). Mean time in seconds was determined from performance across all 8 IndiAide© features tested. MCI = Mild cognitive impairment; PDD = Parkinson disease dementia; Diff = the difference between pre/post ratings and true performance, where negative = underestimate and positive = overestimate

[a]Absolute values used to calculate the means and standard deviations for difference scores

There was not a significant difference between participants' predicted level of help and the true level of help provided ($t(14) = .40$, $p = .70$, $d = .10$). Conversely, there was a significant difference between participants' time predictions and the true time taken to complete tasks ($t(14) = 2.22$, $p = .04$, $d = .57$). That is, participants significantly overestimated the amount of time it would take to complete the IndiAide© tasks. Figures 10 and 11 display the signed difference between participants' pre-experience predictions and true performance for the level of help and time estimations, respectively.

Figure 10

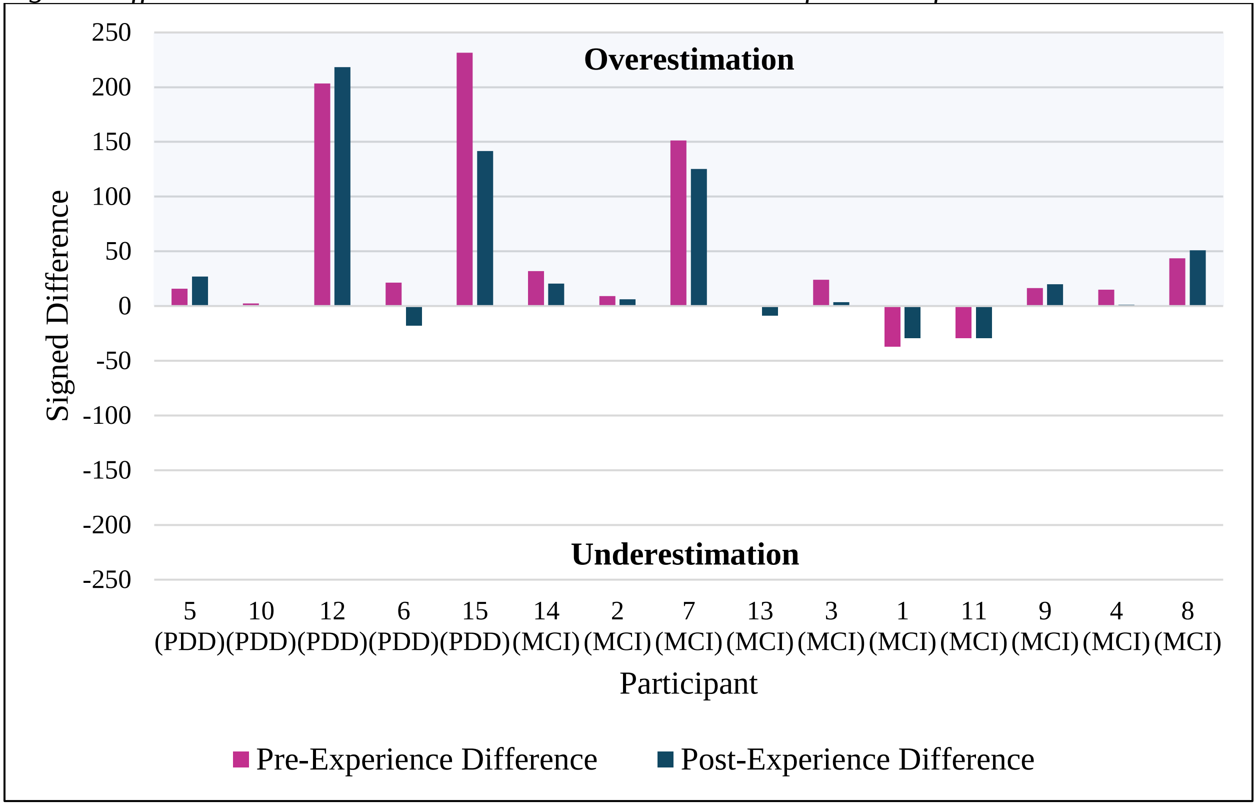
Signed Difference Between Pre/Post Predictions and True Performance for Level of Help



Note. Participants are presented in ascending order of cognitive decline (P5 = lowest score on the cognitive screener). MCI = Mild Cognitive Impairment; PDD = Parkinson Disease Dementia

Figure 11

Signed Difference Between Pre/Post Predictions and True Performance for Time



Note. Participants are presented in ascending order of cognitive decline (P5 = lowest score on the cognitive screener). MCI = Mild Cognitive Impairment; PDD = Parkinson Disease Dementia.

Accounting for Practice Effects. A post-hoc paired *t*-test was conducted comparing the difference between pre-experience time estimates and the true time taken to complete tasks for the first and final set of IndiAide© tasks. The difference in participant predictions for the time needed to complete tasks and the true time taken to complete tasks did not significantly differ between the first or final set of tasks ($t(14) = .04$, $p = .97$), suggesting that participants' time accuracy did not change as they became more familiar with the app.

Cognitive Status Comparison. A second post-hoc analysis was conducted using Mann Whitney U Tests to compare pre-experience predictions and true performance between participants with MCI and PDD. The discrepancy between scores did not significantly differ between groups for the level of help ($p = .14$) or time ($p = .31$).

Research Question 3: Task-Specific (Online) Self-Monitoring

Research question 3 examined how accurately post-experience estimations align with participants' true performance for the level of help needed to use the app and the time taken to complete a set of tasks. As an indicator of self-monitoring (Chudoba & Schmitter-Edgecombe, 2020), participants' post-experience estimations were compared with their true performance for the level of help needed ("how much help did you need?") and time required to complete tasks ("how much time did it take?"). Table 18 displays participants' ratings of the level of help and time, their true performance outcomes, and the difference between each.

There was not a significant difference between participants' post-task estimates of help and the true level of help provided ($t(14) = .90$, $p = .38$, $d = .23$). Similarly, there was not a significant difference between participants' post-task time estimations and the true time taken to complete tasks ($t(14) = 1.92$, $p = .08$, $d = .50$), despite the moderate effect size and trend towards overestimating how long it took to complete the tasks. Figures 10 and 11 display the signed difference between participants' post-experience estimations and their true performance for the level of help and time estimate, respectively.

Cognitive Status Comparison. A post-hoc analysis was conducted using Mann Whitney U Tests to compare post-experience estimations and true performance between participants with MCI and PDD. The discrepancy between scores did not significantly differ between groups for the level of help ($p = 1$) or time ($p = .37$).

Research Question 4: Relationship Between Offline and Online Awareness

Research question 4 examined whether there is a relationship between global (offline) self-awareness of metacognitive abilities and task-specific (online) self-awareness and self-monitoring. Global self-awareness was defined as the absolute difference between self- and informant-ratings on the BRIEF-A MI (Lanni et al., 2014), where 0 = complete agreement. Task-specific self-awareness was defined as the absolute difference between predictions of help and time versus true performance, while self-monitoring was defined as the absolute difference between estimations of help and time versus true performance (Chudoba & Schmitter-Edgecombe, 2020). The relationship between MI differences and app-based performance differences was examined using four Spearman's rank order correlations. There were no significant correlations between the absolute rater difference on the MI and the absolute difference for pre-experience predictions for the level of help (r = -.51, p = .053) and time (r = .20, p = .48) or post-experience estimations for the level of help (r = .02, p = .95) or time (r = -.04, p = .87).

Metacognitive Status Comparison. Because of challenges inherent in interpreting rater differences, a post-hoc analysis was conducted to determine whether the global measure of metacognition, i.e., the BRIEF-A scores, were related to task-specific perceptions of performance. Taking a conservative approach, impaired metacognitive functioning was defined as *T*-scores $\geq$65 (Roth & Gioia, 2005) for *both* the self- and care partner-ratings. Five dyads endorsed levels of clinically significant metacognitive impairment (participants 1, 5, 6, 7, 12). Table 19 reflects differences in pre/post estimations of help and time relative to metacognitive impairment per the BRIEF-A. The gap between estimated help/time and true level of help/time was greater for participants with metacognitive impairment, as indicated by the larger difference scores for the MI impaired group. While group comparisons using Mann Whitney U tests were not significant for pre-experience predictions of help versus true help (p = .85) and predictions of time versus true time (p = .68) or post-experience estimations of help versus true help (p = .83) and estimations of time versus true time (p = .68), the analyses were likely underpowered.

Table 19

Participant Performance Divided by Dyad Endorsement of Metacognitive Challenges

Task-Specific Metacognition	**Global Metacognition**	
	Impairment (n = 5)	**Other (n = 10)**
Level of Help		
Median Pre-Difference (SD)	0.50 (0.50)	0.45 (0.44)
Median Post-Difference (SD)	0.50 (0.50)	0.10 (0.21)
Time (Seconds)		
Mean Pre-Difference (SD)	85.86 (85.93)	40.37 (68.52)
Mean Post-Difference (SD)	103.54 (127.81)	28.23 (42.79)

Note. Dyad division for global awareness determined by whether both members endorsed significantly elevated metacognitive challenges on the BRIEF-A MI. Difference scores are absolute values where 0 = perfect agreement.

Phase II: Discussion

The purpose of this study was multifold. Phase II examined whether individuals with PD and cognitive decline experience diminished awareness related to their overall functioning and task-specific functioning. To this end, four research questions were proposed which examined: 1) the extent to which self- and informant-ratings of behavioral regulation and metacognition differ between persons with PD and cognitive decline and their care partners; 2) how accurately pre-experience predictions align with true performance during use of a cognitive aid for the level of help provided and time taken to complete tasks; 3) how accurately post-experience estimations align with true performance during use of a cognitive aid for the level of help provided and time taken to complete tasks; and 4) whether there is a relationship between global (offline) self-awareness and task-specific (online) self-awareness or self-monitoring.

It was hypothesized that participants with PD would report significantly different degrees of metacognitive dysfunction than their care partners, and that their perceptions of app performance would differ from their true performance. Lastly, it was hypothesized that global awareness would relate to task-specific awareness. These hypotheses were partially supported. For global awareness, participants reported experiencing significantly more metacognitive challenges relative to their care partners. However, for online awareness measures, only pre-experience time predictions were significantly elevated from the true time taken to complete tasks, with post-experience predictions trending in the same direction. Furthermore, there was not a statistically significant relationship between global awareness, as originally defined, and task-specific awareness.

Global (Offline) Self-Awareness

Global self-awareness was assessed by examining discrepancies between self- and informant-ratings on the BRIEF-A. As discussed, the BRIEF-A is a measure of executive function that is divided into a Behavioral Regulation Index (BRI) and Metacognition Index (MI). Self- versus other ratings on the BRIEF-A have been commonly used to gauge overall levels of awareness (Rabin et al., 2006; Scholz & Donders, 2024), including for individuals with cognitive impairments from PD (Kudlicka et al., 2013; Lanni et al., 2014). When comparing individuals with PD and their care partners, BRI ratings were relatively comparable. However, MI ratings were significantly different, that is, participants with PD perceived themselves as experiencing more metacognitive challenges compared to their care partners' perception.

The BRI and MI each capture different aspects of executive functions. Specifically, the BRI measures the ability to maintain appropriate regulatory control over behavior and emotional responses. Disruptions in these behaviors may be more overt, such as impulse control and regulating emotions. In comparison, the MI measures the ability to initiate activity, sustain working memory, and generate, initiate, and monitor problem-solving plans (Roth & Gioia, 2005). These behaviors may be more subtle for observers to detect or attributed to other aspects of PD. For instance, impairments in initiation could be perceived as a byproduct of motor slowing, a common motor symptom in PD (Lanni et al., 2014). Indeed, post-hoc analyses indicated that participants with PD were endorsing significantly more covert metacognitive challenges compared to their care partners, particularly for behaviors related to working memory.

The discrepancy between self- and care partner-ratings can be interpreted in numerous ways. Often, the care partner is used as the standard for accuracy (Scholz & Donders, 2024; Seltzer et al., 2001), as it is assumed that accuracy of self-ratings will diminish with onset of cognitive decline (Orfei et al., 2018). However, in some circumstances, self-ratings can perhaps be more accurate predictors of the current level of functioning among individuals with neurodegenerative diseases (Garcia-Willingham et al., 2018) and MCI (Rabin et al., 2006; Rike et al., 2018). Self-ratings tend to be more accurate in the absence of depression or other neuropsychiatric symptoms (Lanni et al., 2014; Scholz & Donders, 2024; Sitek et al., 2011; Wang et al., 2024), as well as the absence of memory impairments (Ivory et al., 1999; Kudlicka et al., 2013; Seltzer et al., 2001; Sitek et al., 2011). Given that group ratings were similar for more overt behaviors yet different for less overt behaviors, particularly those captured by the MI, the patterns of performance suggest that participants with PD were more sensitive to their cognitive changes. Differences between raters for the MI were almost exclusively in the direction of greater endorsed difficulty by the person with PD.

Another possible contributor to the self- versus other performance discrepancy in the current study could be overall severity of cognitive decline. That is, discrepancies between raters typically increase as cognitive functioning declines (Orfei et al., 2018). However, the discrepancy between self- and care partner-ratings for the BRI and MI in the current study was similar between participants with MCI compared to early-stage PDD. As a reminder, cognitive designations were based solely on PD-CRS scores and should be viewed with that caveat in mind. While this screener has high sensitivity and specificity (Pagonabarraga et al., 2008), it is not a comprehensive assessment.

Similarly, emotional factors such as anxiety, depression, or apathy may contribute to self- versus other rating discrepancies (Mograbi & Morris, 2014; Scholz & Donders, 2024; Starkstein et al., 2010). Depression ratings, as captured by the GDS-SF, do not suggest an influence of depression on the current findings. Most participants scored themselves as experiencing normal to mild levels of depression (Yesavage & Sheikh, 1986). Two participants presented with moderate depression, yet their BRIEF-A discrepancy scores were minimal, with both members of the dyads in agreement as to the presence of executive challenges. Future examinations of global awareness should consider including a measure of anxiety and apathy, given the potential impact of both on self-perception of cognitive abilities (Bălăeţ et al., 2024; Mograbi & Morris, 2014).

As mentioned, one way to enhance the interpretation of self- versus other ratings of cognition is to examine the findings relative to a neuropsychological test battery (Scholz & Donders, 2024). The present study was limited in this respect as the PD-CRS screener was the only additional cognitive measure employed. Future studies in this area would benefit from a more in-depth neuropsychological assessment. This would potentially allow for better contextualization of BRIEF-A responses, as well as a more comprehensive view of overall cognitive decline. Key candidates include the Color-Word Interference Test, California Verbal Learning Test, and Symbol Digit Modalities Test, as these tests have previously been found to be significantly correlated with the BRIEF-A (Kudlicka et al., 2013; Lanni et al., 2014; Scholz & Donders, 2024); the Wisconsin Card Sorting Test also has overlap with the executive abilities captured by the BRIEF-A (Kopp et al., 2021; Roth & Gioia, 2005).

Task-Specific (Online) Awareness

Online self-awareness was assessed by examining discrepancies between pre-experience predictions and true performance for the level of help and time, while self-monitoring was assessed by examining discrepancies between post-experience estimations and true performance for the level of help and time. As a reminder, the level of help was measured on a 4-point ordinal scale ranging from no help, a little help, some help, to a lot of help, and time was measured in seconds.

Task-Specific (Online) Self-Awareness

The current study revealed that the discrepancy between participants' pre-experience predictions for help aligned with true performance; however, predictions for time were significantly overestimated relative to actual performance. Time predictions did not improve as participants completed more tasks using the app, suggesting that the findings were not simply related to familiarity and experience with the app. It may also suggest that the sense of time to complete certain functions in the app was not being retained and used to update mental representations of one's skillset in subsequent trials. Help and time discrepancies were also similar for participants with MCI and PDD, suggesting that self-awareness of the ability to complete novel tasks with an aid was similar across stages of cognitive decline.

Time overestimations seemingly align with BRIEF-A performance. On the BRIEF-A MI, participants showed heightened endorsement relative to care partners of metacognitive challenges related to working memory, initiation, planning, and organizational abilities. Participants' assessment of functioning relative to care partners on the BRIEF-A MI suggests that they were sensitive to the cognitive changes affecting everyday functioning and were, subsequently, overestimating the time it would take to conduct tasks on the IndiAide© app.

Alternatively, overestimations could be interpreted as disruptions to one's internal clock. There is a broad body of literature examining the phenomenon of an internal clock in PD (e.g., Honma et al., 2016, 2018; Kim et al., 2024; Terao et al., 2021; Torta et al., 2010). Converging evidence indicates that the internal clock is slowed in PD for tasks with a short duration (e.g., a few seconds or less), with individuals overestimating time (Y. Kim et al., 2024; Terao et al., 2021). As durations shift from short to long (e.g., >10 seconds), the internal clock appears to shift, with individuals beginning to underestimate time intervals (Y. Kim et al., 2024; Terao et al., 2021). Given the group trend towards overestimation of time for longer duration IndiAide© tasks, results better align with the hypothesis that hyper-awareness of metacognitive challenges mediated self-predictions of time.

Models of awareness may also help to contextualize current findings. As a brief recap, the Levels of Awareness Framework was currently used to define task-specific awareness, i.e., online self-awareness and self-monitoring (Clare et al., 2011). In the current study, online self-awareness was operationalized as the difference between pre-experience predictions and true performance (Chudoba & Schmitter-Edgecombe, 2020). Performance monitoring, to be discussed in the following section, is awareness that allows a person to monitor their behavior to identify errors and compare expected performance with actual outcomes. In the current study, this level of awareness was labeled online self-monitoring and was measured by comparing post-experience estimations to true performance (Chudoba & Schmitter-Edgecombe, 2020).

This model is particularly helpful in considering the lack of a significant finding for the help metric, as it additionally proposes that awareness is influenced by intraindividual factors, such as the availability of feedback, personal beliefs and expectations, and self-attributions (Clare et al., 2011). Key here is the availability of feedback. Prior to the test session, participants had not seen or interacted with the IndiAide© app. While feedback was not explicitly provided beyond the familiarization tasks, the level of help metric inherently provides feedback in the form of cues during task completion. The cues themselves may have helped participants make evaluative judgments about their performance, particularly given known benefits of external cues in PD (Gräber et al., 2014; Hsieh et al., 1995). Overall, the provision of cues may have given participants sufficient information to reflect on their performance relative to the level of help received and make appropriate evaluative judgments in subsequent trials. Alternatively, it is possible that the limited ordinal scale used for the level of help was not sensitive enough to detect more subtle shifts in the perception of needed support.

The Cognitive Awareness Model is another model of awareness that may be useful in interpreting findings. This model proposes a series of neurocognitive modules that underlie self-awareness and monitoring. Two particularly relevant modules include the Personal Database and Cognitive Comparator Mechanisms. The Personal Database is closely linked to memory as it contains representations of conceptual knowledge, and it supports self-awareness. Cognitive Comparator Mechanisms are regulated by executive functions, and they support self-monitoring by acting as error identifiers (Clare et al., 2011; Morris & Mograbi, 2013). These modules work together to cocreate awareness; that is, during active behavior, the Cognitive Comparator Mechanisms assess whether the input matches the expected outcome using the Personal Database as a reference. If a mismatch is noted, the Personal Database is updated (Morris & Mograbi, 2013). Presumably, impairments in memory will lead to breakdowns in the Personal Database, whereas executive dysfunction can result in breakdowns in Cognitive Comparator Mechanisms. Depending on where a breakdown occurs, the presenting awareness impairment may differ. For example, when the Personal Database fails, errors identified by Cognitive Comparator Mechanisms may not be encoded to update a person's mental representation of their abilities. This may behaviorally present as diminished self-awareness, and it has been referred to as mnemonic anosognosia (Morris & Mograbi, 2013).

Viewing the current findings through the lens of the Cognitive Awareness Model, the lack of improvement in time predictions across trials could indicate that new experiences were not being encoded in the Personal Database. This would indicate that participants were experiencing mnemonic anosognosia. However, performance on the PD-CRS and BRIEF-A suggest pronounced executive dysfunction with limited memory impairments. According to the model, memory is integral to the Personal Database and would need to be impaired for disruptions to occur in this module. Instead, the current presentation of cognitive impairments among participants better aligns with impaired Cognitive Comparator Mechanisms. Overall, current findings suggest that the grouping of specific cognitive domains with relevant neurocognitive modules may not be straightforward and that executive functions mediate task-specific self-awareness.

Task-Specific (Online) Self-Monitoring

Participants with PD were fairly accurate in conveying how much help was needed during the IndiAide© tasks, which is perhaps not surprising given the basic ordinal scale (a little help, a lot of help, etc.) as well as the relatively mild or early-stage cognitive decline. As with predictions of time, post-experience judgments of time tended to be overestimations. The discrepancy between time estimations and true performance approached significance (p = .08) and had a medium effect size (d = .50).

Diminished performance monitoring in PD was expected as it has been reported for both cognitive and motor tasks (Maier et al., 2012; Pietracupa et al., 2013; S. Smith et al., 2011; Souchay et al., 2006; Vitale et al., 2001), as well as for time estimation tasks (Honma et al., 2016; Koch et al., 2008; J. Smith et al., 2007). Furthermore, performance monitoring has been found to be diminished in persons with PD and executive dysfunction (Kudlicka et al., 2013). Several factors could have influenced current findings. For instance, it is possible that the severity of executive dysfunction among participants was not pronounced enough to robustly affect self-monitoring. Furthermore, the process of providing cues may have unintentionally supported monitoring for the level of help, as proposed by the Levels of Awareness Framework.

Performance monitoring is thought to be influenced by the availability of feedback (Clare et al., 2011), and external cues are thought to improve performance on both cognitive and motor tasks (Gräber et al., 2014; Hsieh et al., 1995). Lastly, it is possible that post-experience estimations of time were more accurate due to participants' use of dopaminergic medications, as there is some literature to suggest that time estimations are improved by such medications (Torta et al., 2010). However, the direction of this relationship is questionable, with medications potentially reducing the accuracy of time estimations (Cameron et al., 2016).

Associations Between Global and Task-Specific Awareness

Previous studies of cognitive functioning in PD have suggested a link between global (offline) self-awareness and task-specific (online) self-awareness and self-monitoring (Amanzio et al., 2014; Palermo et al., 2017). In the present study, there was not a significant association between global and task-specific awareness. The lack of a strong correlation between offline and online awareness could be due to several factors. First, using rater discrepancy as the primary indicator of global awareness can be challenging to interpret, as previously discussed, because the ground truth is unknown. Additionally, the milder cognitive impairment in the current study relative to other studies (e.g., Kudlicka et al., 2013), as well as the high degree of variability in app-based ratings, may have limited the sensitivity of this approach. Task differences may have also contributed to the current findings. That is, previous studies finding an association between global and task-specific awareness examined online awareness of motor symptoms (Amanzio et al., 2014; Palermo et al., 2017), whereas the current study examined online awareness of functional metrics relevant to aid use; the relationship between global and task-specific awareness can vary across domains (as discussed below).

An alternative approach to understanding global and task-specific awareness was to use the BRIEF-A as a proxy for representing global awareness. That is, would participants with clinically significant metacognitive impairment (defined conservatively as impaired scores from both members of the dyad; n = 5) have more difficulty with the task-based estimations? There was indeed a trend for poorer task-specific time predictions (MI impaired 86 seconds on average versus 40 seconds for others) and post-experience estimations (MI impaired 104 seconds on average compared to 28 seconds for others), despite the lack of a significant statistical association in this small group. This approach to understanding global and task-specific awareness warrants further investigation.

While several theoretical models posit an association between global and task-specific awareness (Clare et al., 2011; Morris & Mograbi, 2013), other models argue for a distinction between global awareness and task-specific awareness. For example, the Dynamic Comprehensive Model of Awareness (Toglia & Goverover, 2022) discusses the divergence between these forms of awareness, stating that general acknowledgment of difficulties in everyday functioning may not transfer to monitoring of performance during actual task completion, a claim that has been supported by neuroimaging showing different neuroanatomical activation areas related to each type of awareness (Plutino et al., 2020). The model also postulates that self-awareness can vary within and across domains (e.g., cognitive, social, functional), level of awareness, and the specific cognitive, task, contextual, personal, and psychological variables. Thus, the authors suggest that self-awareness deficits may be observed in some tasks or situations and not in others and can be expressed differently in two clients with similar cognitive profiles depending on psychological, task, or contextual variables (Toglia & Goverover, 2022).

Phase II: Conclusion

In sum, participants with PD and cognitive decline displayed evidence of heightened sensitivity of metacognitive challenges relative to their care partners. While findings describe the influence of metacognition and awareness on IndiAide© use, they may also be relevant for broader electronic aid use in PD. For example, findings suggest that users with PD and mild cognitive decline or early-stage dementia are sufficiently aware to recognize the need for an aid. However, there was evidence of diminished task-specific awareness of the time it takes to complete tasks in IndiAide©, with participants consistently overestimating time. In relation to aid use, this indicates that users with PD and mild cognitive decline or early-stage dementia may perceive usage of an aid as being more cumbersome or time consuming than actual performance would suggest. Awareness assessments should be conducted when considering candidacy for IndiAide©, with a particular focus on task-specific self-awareness and monitoring, as users with PD and cognitive decline may need targeted training to enhance online awareness.

General Discussion

The current study sought to examine the usability and feasibility of the newest prototype of IndiAide©, as well as the influence of metacognition on aid use, in persons with PD and a range of cognitive decline. Phase I used a mixed-methods approach to examine ease-of-use and user sentiment and found that people with PD and cognitive decline gave generally positive feedback and were able to successfully use the aid when given support, though technology familiarity and cognitive decline appeared to mediate outcomes. Phase II assessed global (offline) awareness and task-specific (online) awareness. Overall, participants with PD perceived significantly more global metacognitive challenges than their care partners and overestimated how much time it would take them to complete tasks in the IndiAide© app.

Usability, Feasibility, and Awareness Across Stages of Cognitive Decline

When co-designing electronic cognitive aids, individuals with dementia are often overlooked due to perceived barriers regarding their ability to consent to and actively engage in research (Hirt et al., 2024). As such, this study was intentionally developed to invite individuals with PDD into the IndiAide© design space to determine how development can progress so as to better match their needs, preferences, and lived experiences. Unexpected study challenges (e.g., unanticipated major update to the app, recruitment difficulties) prompted an expansion of inclusionary criteria. That is, people with SCD and MCI were included in Phase I, and those with MCI were included in Phase II. While this allowed for observations of ease of use, sentiment, and awareness across different levels of cognitive decline, it was more difficult to draw conclusions about the PDD-specific experience.

The inclusion of a wider range of cognitive status in Phase I had possible benefits. Namely, a relatively even spread of cognitive statuses were present which allowed for a cursory comparison of ease of use and sentiment as cognition declined. Relatively clear trends emerged, showing that objective performance with the aid tended to worsen and user sentiment tended to become more negative as cognition declined. Specifically, participants with PDD made more errors and required more cues compared to participants with MCI or SCD, and more statements were classified as ‘negative’ among participants with PDD or MCI compared to those with SCD. Assertations based on cognitive status remain speculative given the very small sample size; however, the trends align with findings across the broader digital assistive technology literature (Talbot & Briggs, 2022). Overall, Phase I outcomes suggest that IndiAide© would be usable by people with early-stage PDD with proper scaffolding and support. As always, an individualized approach to aid introduction and instruction is recommended (Sohlberg & Turkstra, 2011), given the many cognitive, language, motor, environmental, etc. factors that influence cognitive aid use and adoption (De Vleeschhauwer et al., 2021; Dixon & Lazar, 2020; Talbot & Briggs, 2022).

In Phase II, cognitive status was more unevenly distributed, with only 5/15 (33%) participants showing evidence of dementia per the PD-CRS. The small subset of participants with early-stage dementia, as well as the nature of their impairments, may have impacted current findings, particularly that of global and task-specific self-awareness. That is, diminished self-awareness tends to be most prominent in advanced stages of decline, and in dementias with a primary disruption to memory, language, and visuospatial functioning (i.e., ‘cortical’ profile) than attention and executive functions (i.e., ‘subcortical’ profile) (Castrillo Sanz et al., 2016; Orfei et al., 2018; Turró-Garriga et al., 2016). While participants with PDD in the current sample did display some memory challenges per the PD-CRS, these impairments may not have been severe enough, or the subset of participants with PDD too small, to reflect markedly diminished self-awareness.

Relative to task-specific self-monitoring, comparable performance between participants with MCI and PDD was unexpected. Executive functions have been linked to performance monitoring in PD (Kudlicka et al., 2013), and presumably a worsening of symptom severity would result in worse self-monitoring. However, several participants with MCI were experiencing considerable challenges to executive functioning per the PD-CRS and the BRIEF-A and were overestimating time for task completion in a similar manner to the participants with PDD. The departure from the extant literature, which endorses diminished task-specific awareness with cognitive decline, may have been influenced by methodological factors, such as the modality in which awareness was assessed (Amanzio et al., 2014; Palermo et al., 2017), specific tasks being performed (Kudlicka et al., 2013), or provision of cues (Cassimatis et al., 2016) alongside intraindividual factors like medication status (Swainson et al., 2000; Torta et al., 2010).

Recruitment Challenges Following the Onset of Dementia

As stated, recruitment difficulties contributed to the alteration of inclusionary criteria related to cognitive functioning. Recruiting people with dementia has historically been challenging (Davis & Bekker, 2022; Hirt et al., 2024). Given known challenges with recruitment, best practices for recruiting persons with dementia were employed. For example, recruitment efforts were conducted in collaboration with community partners, the principal investigator provided information about the study to both the participant and their care partner during the recruitment phase, the protocol was conducted within the home, sessions were scheduled outside of typical working hours as needed, and financial incentive was offered for participation (Davis & Bekker, 2022; Hirt et al., 2024). Despite these endeavors, recruitment of people with dementia remained a challenge.

Some key lessons were learned and can be applied to future studies that aim to recruit individuals with PDD. First, assessing MCI versus early-stage dementia during the initial telephone screening call is understandably challenging; adding a cognitive screener such as the Montreal Cognitive Assessment 5-minute protocol to the screening call may help in identifying ideal study candidates (Wong et al., 2015). Second, mobility and technology comfort may be lower in persons with dementia (Cerff et al., 2017; McLaren et al., 2023), which may create physical or technological barriers that make it challenging to connect with potential participants. In addition to recruiting via local support groups, and email/mail, future studies may consider expanding to alternative avenues that may be more accessible and appealing to an older audience (e.g., TV commercials, radio ads, newspaper ads, etc.) (Davis & Bekker, 2022). Additionally, seeking input from persons with MCI or dementia regarding the design of recruitment flyers would be informative (Bouranis et al., 2023). Lastly, the recruitment process itself may be biased against individuals with more advanced cognitive challenges, including diminished awareness. Individuals who are uncertain or unsure of their diagnosis may be less likely to participate in research (Hirt et al., 2024). Expanding recruitment in care partner circles and partnering directly with healthcare professionals might help circumvent this issue.

Supporting Aid Use Among Users with Neurodegenerative disease

Given the neurodegenerative nature of PD, it is important to consider how motor changes may influence aid use, and prompt changes to the aid itself. These considerations extend to other neurodegenerative conditions with a related motor and cognitive component, such as Dementia with Lewy Bodies and Parkinson Plus syndromes (e.g., multiple system atrophy, progressive supranuclear palsy, and corticobasal degeneration). In the present sample, the most severe motor symptoms related to gait disturbance, while hand and upper limb movement were mildly to mild-moderately impacted. To reduce the impact of tremor on performance, a stylus was offered to all participants which most chose to use. However, the stylus could not account for general slowing of movement or rigidity, two symptoms which can impact movements necessary for aid use (De Vleeschhauwer et al., 2021; Yu et al., 2017). Time to complete tasks may have been particularly impacted by these symptoms.

Given that IndiAide© is a web-based app that can be accessed on any device with internet access, it is important to consider motor accommodations that support computer, tablet, or smartphone access channels. Computer access can be supported with tremor-suppressing computer mice (Bani Hashem et al., 2014; Levine & Schappert, 2005) or movement prediction software (Loukas & Brown, 2012; Youngmann et al., 2019). The situation is more complex when it comes to devices with touchscreens. As stated, a stylus may help support fine motor control for tablets. However, smartphones provide additional complexity given that the smaller size of their screen often leads to more dense targets (Zhong et al., 2015). Designers may attempt to increase target size, hitbox size, and space between targets, but the extent to which these modifications can be made is limited by the size of the screen (Wacharamanotham et al., 2011). Variability among screen sizes further increases the difficulty in designing universally accessible layouts. As such, smartphones are not recommended as an access channel for IndiAide© for users with PD.

Considering the impact of motor symptoms on touchscreen access, users of touchscreen devices may benefit from alternative access modalities, such as speech-to-text. While the accuracy of speech recognition and speech-to-text technology is impacted by speech changes in PD (Moro-Velazquez et al., 2019; Rahman et al., 2021), deep learning models can be trained to detect speech in PD (K. Kim et al., 2024). There is room for improvement, of course, particularly in naturalistic settings (Goudarzi & Moya-Galé, 2021). At present, speech-to-text may be most accurate for users with minimally impacted speech. However, there is potential for this approach to apply to speakers with more moderate dysarthria in the future. Speech recognition has been a growing area of interest, and the accuracy of deep learning models is likely to continue improving in coming years (van Gelderen & Tejedor-García, 2024).

Swabbing may be an alternative approach to interacting with touchscreens for users with more pronounced tremor and speech impairments. Swabbing is a touchscreen input technique where users drag their finger across a screen to the intended target and select the target by lifting their finger (Mertens et al., 2012). This approach has been found to reduce error rates in individuals with tremor (Mertens et al., 2012; Wacharamanotham et al., 2011). However, swabbing may be susceptible to other PD motor symptoms, such as akinesia. For individuals with severe global motor challenges, alternative access channels include switches and eye-tracking (Koch Fager et al., 2019). Across all users with concomitant motor and cognitive challenges, it is important to consider the potential for cognitive fatigue. Leaning how to use a novel device is demanding and requires the allocation of attention to both physical movement and cognitive processing. Best practices for limiting cognitive fatigue include using a set of consistent, contrasting colors to group relevant content (Gordon, 2021; Hung et al., 2017; Marquardt et al., 2014), adding descriptive imagery (Astell et al., 2010), and including error messages that appear adjacent to the location of an error and are noticeable, redundant, and timely (Neusesser & Sunwall, 2023).

The Influence of Demographic Factors on Aid Use

Demographic factors, such as race/ethnicity, education level, and socioeconomic status, have a known influence on cognitive task performance and aid use (Chan & Marsack-

Topolewski, 2022; Rexroth et al., 2013). In the present study, 91% (20/22) of participants were white and had at least 12 years of education. Additionally, all participants had internet access and reported owning a smartphone for 10 or more years. While socioeconomic status was not directly measured, participants' education level, access to technology, housing type, and neighborhood suggest basic financial security (Oakes & Andrade, 2017). Thus, the outcomes of the present study are relatively limited in transferability in that they capture ease-of use, user sentiment, and the impact of awareness on aid use in a relatively narrow subset of the PD population. It is possible that participants belonging to other racial/ethnic or socioeconomic backgrounds have different needs and perspectives that would impact their experience with IndiAide©.

Through a broader lens, there is a growing body of literature examining health disparities across demographic variables. For instance, dementia prevalence and incidence may vary substantially among racial and ethnic minority groups, such as African Americans, Hispanics, and Native Americans, compared to non-Hispanic Whites (Kornblith et al., 2022; Moon et al., 2023; Nye et al., 2022). Members of these communities may also be disproportionately impacted by low health literacy (Lor et al., 2019; Muvuka et al., 2020), which may decrease the likelihood of seeking a medical diagnosis and rehabilitative resources in a timely manner (Chakawa & Shapiro, 2022). Even when engaging with healthcare professionals, underrepresented groups may never receive a diagnosis or receive a delayed diagnosis of dementia (Lin et al., 2020, 2021). Cultural differences in how dementia is perceived may further shape the dementia experience. For instance, more than half of non-Hispanic White Americans consider severe cognitive decline to be a normal part of aging and may feel insulted if medical doctors recommend neuropsychological testing (Alzheimer's Association, 2024b).

These differences elevate the need for inclusive recruitment practices and study designs that reflect key stakeholders from underrepresented communities. Additionally, it is important to address access and usage barriers related to IndiAide©. For instance, members of underrepresented racial/ethnic groups may be disproportionately impacted by the digital divide. That is, neighborhoods that are predominantly Black or Hispanic are less likely to have access to broadband internet compared to other ethnic groups (Li et al., 2023), and usage of high-tech aids (e.g., computer-based systems) is lower among underrepresented groups compared to non-Hispanic Whites (Chan & Marsack-Topolewski, 2022; Reed et al., 2005). Currently, IndiAide© is a web-based app; thus, the need for internet access as well as a device from which to access the aid may inherently limit access. Examining the feasibility of a downloadable version of the app that can run without internet connection may partially reduce the impact of the digital divide relative to IndiAide© use.

Clinical Implications

Current findings have several implications for clinical practice. As always, it is important to use an individualized approach when developing rehabilitative plans, particularly given the heterogeneity of PD in terms of symptom presentation (Greenland et al., 2019), cognitive presentation (Kehagia et al., 2013), disparate challenges related to learning (Marinelli et al., 2017), and potentially reduced technology familiarity among adults with cognitive decline (McLaren et al., 2023). To determine whether a client is a good candidate for IndiAide©, guidelines from the Technology Assistance in Dementia framework may be helpful (Kaser et al., 2024). This framework broadly calls for the holistic assessment of needs and development of evidence-based problem-solving approaches to guide technology selection and implementation. The Compensatory Techniques Inventory may be particularly informative as it identifies key barriers in everyday functioning as well as preferences for possible solutions (Sohlberg & Turkstra, 2011). It is also important to critically choose assessment targets, especially when measuring awareness. With self-monitoring, for instance, it is crucial to consider whether test items inherently provide some level of feedback, as this may improve performance and potentially mask impairments (Cassimatis et al., 2016; Clare et al., 2011).

If possible, it is helpful to identify candidates for IndiAide© early in the disease course. Here, the goal would be to increase autonomous use of IndiAide© early on to reduce later frustrations and learned helplessness. Additionally, if a client presents with low technology comfort, training may need to begin with preliminary goals related to the mechanics of the app/device prior to initiating the rehabilitation-focused training. This is also a time for clinicians and clients to experiment with different motor support tools to determine how best to limit the impact of motor symptoms on aid use. As overall functioning declines, more structured training may be necessary. For instance, clients who display evidence of diminished awareness during assessment may benefit from salient feedback and errorless learning during therapy. Feedback is thought to support performance monitoring (Clare et al., 2011), as well as a variety of other motor and cognitive skills (Brown & Marsden, 1988; Gräber et al., 2014; Hsieh et al., 1995). Thus, external cues could support both awareness of performance with the aid as well as motor learning. Errorless learning may be particularly beneficial, as this form of feedback has been found to be effective in individuals with MCI (Roberts et al., 2018) and dementia (de Werd et al., 2013).

Lastly, it is important that treatment intentionally includes care partners, such as training them how to access the aid as well as when and how to best provide cues. If care partners do not ‘buy-in’ to the app, or if they experience undue frustration related to the aid, they may be less likely to endorse aid use to the client. This may lead to low adoption and subsequent use of the aid by the client (Turner & Berridge, 2023). Additionally, as the care partner spends more time with the client at home compared to the clinician, they can provide more opportunities for practice and everyday use. Here, consistency between the training approach employed in the clinic and the home is helpful to avoid potential confusion, particularly in users with dementia who may be more at risk for disorientation (Berry, 2014; Rodriguez et al., 2021). Of note, care partner inclusion should be approached judiciously so as to not overwhelm care partners, as increased caregiver burden is linked to worse health outcomes (Lwi et al., 2017). The assessment phase of rehabilitation may be an ideal time to interview care partners to determine their overall comfort with technology, preferences regarding cognitive aids, and bandwidth for providing additional care at home.

Limitations

As discussed, the present investigation included a relatively small number of individuals with PDD, and the sample was mostly comprised of white males. Thus, outcomes are limited in their transferability to other populations. Additionally, the choice to use one cognitive screener limited the ability to capture a more nuanced view of cognitive functioning. Typically, more detailed neuropsychological testing can take several hours. As the current study aimed to limit cognitive fatigue among participants, more comprehensive testing was not feasible. In combination with the use of an abridged version of the MDS-UPDRS, these decisions limited the ability to capture the breadth and depth of motor and cognitive challenges among participants. This was particularly limiting given that this study did not include a control group. There was a trend for worsening of motor symptom severity among participants with PDD compared to MCI or SCD, making it difficult to parse out the impact of motor versus cognitive symptoms on some aspects of aid use. To allow for a clearer examination of motor versus cognitive impact on aid use, a control group of individuals with PD and normal cognition could be employed. Lastly, in Phase II, analyses were underpowered. To have sufficient power ($1-\beta = .80$) to capture effect sizes seen in similar literature (e.g., Chudoba & Schmitter-Edgecombe, 2020), this study would have needed to recruit 70 dyads. Achieving this size of a sample when recruiting members of a clinical population is challenging; thus, findings should be interpreted with this caveat in mind.

Future Directions

There are several directions in which this research could expand, including opportunities to examine user sentiment regarding new features (e.g., notifications) and across a range of cognitive decline and neurological conditions. Examination of task-specific awareness related to aid use could also benefit from examining other behaviors related to aid use, such as awareness of errors. Additionally, involvement of care partners in future research would bolster the ecological validity of app testing and allow for examination of the usability of the care partner access routes for the app. Continuation of testing in a more naturalistic environment is recommended. For instance, a pilot diary study could be conducted in which individuals with cognitive impairment and their care partners are given access to the IndiAide© app for several days. Each day, they would be prompted to use the app for a series of tasks and submit a journal entry detailing their experience (Bartlett, 2012). A study of this sort would illuminate the app’s effectiveness in supporting everyday functioning. These studies could culminate in a randomized controlled clinical trial comparing IndiAide© to other cognitive support tools.

Final Conclusions

In conclusion, this study adds to the growing body of literature examining the effectiveness of electronic aids to support cognitive decline. Outcomes endorse the use of

IndiAide©, as the app appeared to be a usable and feasible tool to support cognition in users with PD and a range of cognitive decline. The severity of cognitive decline and technology familiarity appeared to impact the user experience, but success with the aid was possible when given proper scaffolding. Global and task-specific awareness was altered among users with PD, typically reflecting a heightened awareness of cognitive changes and an overestimation of time to complete IndiAide© tasks. Awareness should be monitored with disease progression given the likelihood of changes to executive and metacognitive functioning (Orfei et al., 2018; Smirnov et al., 2020).

Data Availability Statement

The data sets generated and/or analyzed during either Phase of the current study are available upon request.

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Appendix A: Pre-Screening Telephone Protocol

A. Screening script for participants with PDD

***Note*: For Phase II, begin with this script if the person with PDD initiates the call**

Thank you for calling! **How did you find out about our study?**

IF THEY HAVE A FLYER: Then you may already know that we are doing research at the University of Washington to study a new computer app that can help people with their everyday life. We are particularly interested in determining whether this app will be helpful to people with Parkinson disease.

For our study, we would show you the app and then ask you to try it out for yourself. You would also be asked to complete a few brief tests and questionnaires, and we will ask you a few questions about the app.

IF NO: Then let me tell you a little bit about our study. We are researchers in the Speech & Hearing Sciences department at the University of Washington. We are studying a new computer app that can help people with their everyday life. We are particularly interested in determining whether this app will be helpful to people with Parkinson's disease.

For our study, we would show you the app and then ask you to try it out for yourself. You would also be asked to complete a few brief tests and questionnaires, and we will ask you a few questions about the app.

The study will take approximately 1.5-2 hours. We will drive to your house to complete the study in your home, and you will receive a payment of $40 for your time.

Do you have any questions so far?

Next, I need to ask you a few questions to determine whether this study is appropriate for you. The questions concern general information about yourself and your Parkinson's disease. You are free to not answer any questions you do not wish to answer. Would you like to continue with the questions?

IF YES: Okay thank you (continue with statement below).

IF NO: That's fine. If you'd rather not continue, we can stop right here! Thank you very much for calling to find out about our study.

We are particularly interested in people with Parkinson disease who have experienced changes to their thinking, such as the ability to pay attention, or remember things, or solve problems. Does that sound like you?

IF YES: * Please tell me a little bit about the changes you noticed.

* Do these changes affect your everyday life?

* (*IF SPECIFIC PROMPT NEEDED*): Compared to when you were first diagnosed… Do everyday tasks take longer to complete than they used to? Are you having more difficulty with tasks, like paying the bills or preparing a meal? Is it harder to find the words you want to say?

* How many years were you diagnosed with PD before you began noticing these changes to your thinking?

* Have you been given cognitive or thinking tests by a doctor? Have they ever used the term "dementia"?

IF NO: * I see. What types of changes have you noticed from your Parkinson's disease?

EITHER: Yes, that is the sort of issue that we are doing research on now…

OR: I'm sorry to hear of your difficulties. At this point, we're not doing research on the types of challenges you're having. We're focusing on changes to cognition/thinking. Perhaps in the future our research will cover some of the changes that you are experiencing. Are there any questions I can answer for you?

I do want to let you know that we will not keep any of the information that you provided during this phone call.

Thank you so much for calling….

IF STILL A POTENTIAL SUBJECT: **May I ask you a few more questions to see if you meet the picky criteria for this particular study?**

* (*IF NOT ALREADY STATED*): Do you have Wi-Fi in your home that we can use during our visit?

* Are you between 50-80 years old?

* Are you currently living at home?

* Do you have a lot of problems with your hearing or vision?

* We are also checking with participants to see if they have any challenges that might influence their performance during the study. Have you been formally diagnosed with a psychiatric disorder such as schizophrenia or bipolar disorder, or a developmental disorder, such as autism?

Thank you for answering all of these questions! At this point, it sounds like you are a good fit for our study. If you agree to participate, you will be asked to fill out a short questionnaire regarding your personal information, complete a vision screening, and complete the testing and tasks with the app I mentioned earlier. You can stop participating in the study at any point in time, for any reason.

Phase I *OR* Phase II if the researcher has already spoken to the care partner:

Are you interested in participating?

> *IF YES*: Great! Then let's get you scheduled… If you need to contact me before the session, here's my name and phone number (Dale Summers at 630-618-8197) which is also on the flyer.
>
> *IF NO*: That's completely fine. We won't keep any of the information that you provided to me during this phone call. Should you have any further questions about the study, please feel free to call me (Dale Summers at 630-618-8197). Thank you so much for calling to find out about our study.

Phase II if the researcher needs to speak to the care partner:

Are you interested in participating?

> *IF YES*: Great! Before we get you scheduled, I have a few questions I would like to ask your spouse or someone who spends a lot of time with you most days. Is there someone like that around? If so, can you please give the phone to them? [If not, is there a better time for me to reach them….?]
>
> *IF NO*: That's completely fine. We won't keep any of the information that you provided to me during this phone call. Should you have any further questions about the study, please feel free to call me (Dale Summers at 630-618-8197). Thank you so much for calling to find out about our study.

B. Screening script for care partners

***Note*: For Phase II, begin with this script <u>if care partners initiate the call</u>**

Thank you for calling! **How did you find out about our study?**

IF THEY HAVE A FLYER: Then you may already know that we are doing research at the University of Washington to study a new computer app that can help people with their everyday life. We are particularly interested in determining whether this app will be helpful to people with Parkinson disease.

For our study, we would show someone with Parkinson disease the app and then ask them to try it out for themselves. They would also be asked to complete a few brief tests and questionnaires, and we will ask them a few questions about the app. Since you saw our flyer and gave us a call, do you have someone in mind for our study?

* If yes → What is your relationship with them?

* If no → Thank you for calling, but we are looking for people with Parkinson disease to complete our study.

IF NO: Then let me tell you a little bit about our study. We are researchers in the Speech & Hearing Sciences department at the University of Washington. We are studying a new computer app that can help people with their everyday life. We are particularly interested in determining whether this app will be helpful to people with Parkinson’s disease.

For our study, we would show someone with Parkinson disease the app and then ask them to try it out for themselves. They would also be asked to complete a few brief tests and questionnaires, and we will ask them a few questions about the app. Since you gave us a call, do you have someone in mind for our study?

* If yes → What is your relationship with them?

* If no → Thank you for calling, but we are looking for people with Parkinson disease to complete our study.

The study will take approximately 1.5-2 hours. We will drive to their house to complete the study in their home, and they will receive a payment of $40 for their time.

Do you have any questions so far?

Next, I need to ask you a few questions to determine whether this study is a good match for your (spouse/parent/partner). The questions concern general information about their Parkinson’s disease. After we finish chatting, I will ask that you give the phone to your (spouse/parent/partner) so I can ask them similar questions to hear their perspective. You are free to not answer any questions you do not wish to answer. Would you like to proceed?

We are particularly interested in people with Parkinson disease who have experienced changes to their thinking, such as the ability to pay attention, or remember things, or solve problems. Does that sound like your (spouse/parent/partner)?

IF YES: * Please tell me a little bit about the changes you noticed.

* Do these changes affect their everyday life?

* (*IF SPECIFIC PROMPT NEEDED*): Compared to when they were first diagnosed… Do everyday tasks take longer to complete than they used to? Are they having more difficulty with tasks, like paying the bills or preparing a meal? Does it seem like they have a harder time finding the words they want to say?

* How many years were they diagnosed with PD before you began noticing these changes to their thinking?

* Have they been given cognitive or thinking tests by a doctor? Have they ever used the term "dementia"?

IF NO: * I see. What types of changes have you noticed from their Parkinson's disease?

EITHER: Yes, that is the sort of issue that we are doing research on now…

OR: I'm sorry to hear of their difficulties. I'd like to talk to your spouse to hear their thoughts about how their Parkinson disease has affected them. Can you please give the phone to them?

IF STILL A POTENTIAL SUBJECT: **May I ask you a few more questions to see if you meet the picky criteria for this particular study?**

* (*IF NOT ALREADY STATED*): Do they have Wi-Fi in their home that we can use during our visit?

* Are you involved in the care of your (spouse/parent/partner)? How much time per week do you spend together? What does your support look like?

* **During the visit for the study, would you be willing to complete a brief survey asking about your (spouse/parent/partners)'s thinking and cognition? We would also ask you to record your age, level of education, and how you know the person with PD. Do you agree to participating with that part of the study?**

IF YES: Thank you….

IF NO: For this particular study, we need to find people with PD who have a care partner who can participate with the survey. Can you think of anyone else who might serve that role for your (spouse/parent/partner)? If not, this study doesn't appear to be a good fit at this time…

If the researcher needs to speak to the person with PDD:

Thank you for answering all of these questions! I appreciate you sharing your perspective about how Parkinson disease has affected your (spouse/parent/partner). At this point, I'd like to talk to them to get their perspective about how Parkinson disease has affected their life. If they are eligible, and if they want to participate in our study, we will schedule a session where I will come to their house and ask them to fill out a short questionnaire regarding their personal information, complete a vision screening, and do the tasks with the app I mentioned earlier. While they do this, you will be asked to fill out a short questionnaire asking about their thinking/cognition.

If the researcher has already spoken to the person with PDD:

Thank you for answering all of these questions! After talking with you and your (spouse/parent/partner), it sounds like they are a good fit for our study. During our session together, they will be asked to fill out a short questionnaire regarding their personal information, complete a vision screening, and do the tasks with the app I mentioned earlier. While they do this, you will be asked to fill out a short questionnaire asking about your (spouse/parent/partner)'s thinking/cognition. If your (spouse/parent/partner) decides they no longer want to participate, we can stop the study at any point in time, for any reason.

Your (spouse/parent/partner) has indicated they would like to participate in this study, so let's get you all scheduled… If you need to contact me before the session, here's my name and phone number (Dale Summers at 630-618-8197) which is also on the flyer.

Appendix B: Demographic Questionnaire

Please answer the following questions.

1. What is your age? ________
2. What is your gender?
    - Female
    - Male
    - Non-binary
    - Prefer not to say
3. What is your race/ethnicity?
    - White
    - Hispanic
    - Black
    - Latino
    - Asian
    - Native Hawaiian
    - American Indian
    - Other or mixed race
    - Prefer not to say
4. Years of education: ________
5. What is your employment status?
    - Full-time
    - Part-time
    - Retired
    - Disabled/other
    - Prefer not to say
6. How old were you when you were diagnosed with Parkinson's disease? ________
7. How old were you when you first started noticing symptoms? ________
8. What are your primary challenges related to PD?

    ____

    ____

9. What medications, if any, are you taking for PD?

____

____

Appendix C: Abridged Version of the MDS-UPDRS Part III

3.14 GLOBAL SPONTANEITY OF MOVEMENT (BODY BRADYKINESIA)

Instructions to examiner: This global rating combines all observations on slowness, hesitancy, and small amplitude and poverty of movement in general, including a reduction of gesturing and of crossing the legs. This assessment is based on the examiner's global impression after observing for spontaneous gestures while sitting, and the nature of arising and walking.

0: Normal: No problems.

1: Slight: Slight global slowness and poverty of spontaneous movements.

2: Mild: Mild global slowness and poverty of spontaneous movements.

3: Moderate: Moderate global slowness and poverty of spontaneous movements.

4: Severe: Severe global slowness and poverty of spontaneous movements.

3.15 POSTURAL TREMOR OF THE HANDS

Instructions to examiner: All tremor, including re-emergent rest tremor, that is present in this posture is to be included in this rating. Rate each hand separately. Rate the highest amplitude seen. Instruct the patient to stretch the arms out in front of the body with palms down. The wrist should be straight and the fingers comfortably separated so that they do not touch each other. Observe this posture for 10 seconds.

0: Normal: No tremor.

1: Slight: Tremor is present but less than 1 cm in amplitude.

2: Mild: Tremor is at least 1 but less than 3 cm in amplitude.

3: Moderate: Tremor is at least 3 but less than 10 cm in amplitude.

4: Severe: Tremor is at least 10 cm in amplitude.

R

L

3.18 CONSTANCY OF REST TREMOR

Instructions to examiner: This item receives one rating for all rest tremor and focuses on the constancy of rest tremor during the examination period when different body parts are variously at rest. It is rated purposefully at the end of the examination so that several minutes of information can be coalesced into the rating.

0: Normal: No tremor.

1: Slight: Tremor at rest is present ≤ 25% of the entire examination period.

2: Mild: Tremor at rest is present 26-50% of the entire examination period.

3: Moderate: Tremor at rest is present 51-75% of the entire examination period.

4: Severe: Tremor at rest is present > 75% of the entire examination period.

3.17 REST TREMOR AMPLITUDE

Instructions to examiner: This and the next item have been placed purposefully at the end of the examination to allow the rater to gather observations on rest tremor that may appear at any time during the exam, including when quietly sitting, during walking, and during activities when some body parts are moving but others are at rest. Score the maximum amplitude that is seen at any time as the final score. Rate only the amplitude and not the persistence or the intermittency of the tremor.
As part of this rating, the patient should sit quietly in a chair with the hands placed on the arms of the chair (not in the lap) and the feet comfortably supported on the floor for 10 seconds with no other directives. Rest tremor is assessed separately for all four limbs and also for the lip/jaw. Rate only the maximum amplitude that is seen at any time as the final rating.

Extremity ratings

0: Normal:	No tremor.
1: Slight:	< 1 cm in maximal amplitude.
2: Mild:	≥ 1 cm but < 3 cm in maximal amplitude.
3: Moderate:	≥ 3 cm but < 10 cm in maximal amplitude.
4: Severe:	≥ 10 cm in maximal amplitude.

☐ RUE

☐ LUE

☐ RLE

☐ LLE

HOEHN AND YAHR STAGE

0: Asymptomatic.

1: Unilateral involvement only.

2: Bilateral involvement without impairment of balance.

3: Mild to moderate involvement; some postural instability but physically independent; needs assistance to recover from pull test.

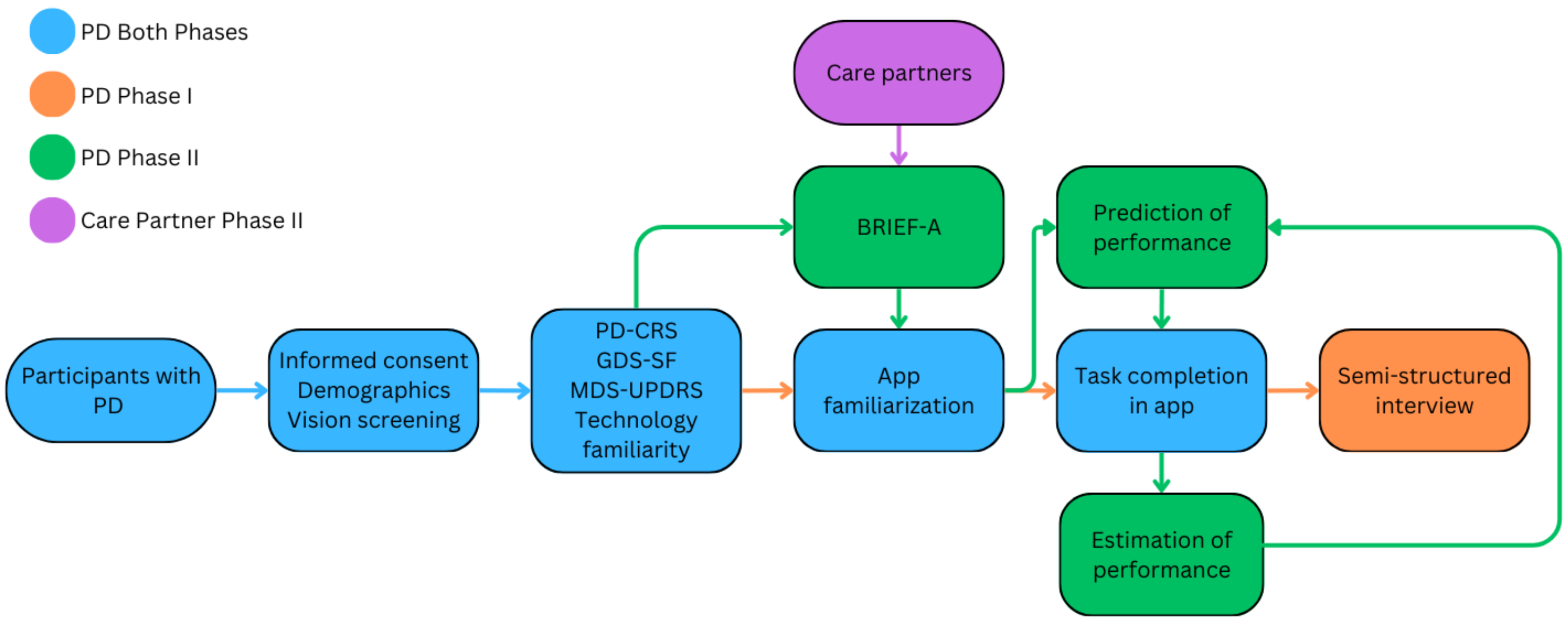
4: Severe disability; still able to walk or stand unassisted.

5: Wheelchair bound or bedridden unless aided.

☐

Total score: ________

Appendix D: Procedural Flowchart



Note. PD-CRS = Parkinson Disease-Cognitive Rating Scale; GDS-SF = Geriatric Depression Scale-Short Form; MDS-UPDRS = Movement Disorder Society-Unified Parkinson Disease Rating Scale; BRIEF-A = Behavior Rating Inventory of Executive Function-Adult Version

Appendix E: IndiAide© Introduction Script

This is the app we will be working with today. It was made to help people remember important information and manage everyday tasks, and we are looking to understand how we can make it the most helpful for people with Parkinson disease.

Today, I'll be asking you to complete some tasks using the app, then I will ask you a few questions about your experience. Before we get started, I want to show you how to use the app.

Here is the homepage. Each of these boxes (point to boxes) can be clicked on to take you to different pages. Let's practice.

(Hand tablet to participant)

We're going to practice how to find personal information about Bethany and navigate the app.

- Access the "About Me" page
- Tell me Bethany's phone number
- Open the "Care Team" page
- Tell me Laura Rivers email address
- Return to the home page

Appendix F: Likert Scales

How **difficult or easy** were these tasks?

Extremely difficult	**Difficult**	**Neutral**	**Easy**	**Extremely Easy**

How **unhelpful or helpful** is this feature in supporting everyday life?

Extremely unhelpful	**Unhelpful**	**Neutral**	**Helpful**	**Extremely Helpful**

Appendix G: Data Tracking Form

Feature	Order	Task	No cues	Verbal	Verbal+gestural	Model
Appointments		Access “Appointments”				
		Tell me the appointment Bethany has on [insert date]				
		Tell me the name of the care team member for the doctor’s appointment*				
Medications		Access “Medications”				
		Temm me the time of day to take Lisinopril				
		Tell me the side effects of Pramipexole				
Care team		Access “Care Team”				
		Tell me the phone number for Amy Washington				
		Tell me when Bethany has her next appointment with Dr. Rivers				
Contacts		Access “Contacts”				
		Tell me the phone number for Bethany’s spouse				
		Tell me the email of Bethany’s daughter				
Photos		Access “Photos”				
		Select the last photo and read the text				
To-Do List		Access “To-Do List”				
		Tell me the first item on the To-Do List for this Friday				
		Tell me Bethany’s grocery list when she goes shopping this Friday				
Therapies		Access “Therapies”				
		Tell me what type of physical therapy exercises Bethany is working on				
		Tell me how many reps of bird dog Bethany has to do every day				
Notes		Access “Notes”				
		Read the note for Dr. Rivers				

Note. For Phase II, this task was updated to become, “Tell me the name of the care team member for the neurology appointment.”

Appendix H: Coding Schematic

Below are the questions that were used to guide the semi-structured interviews in Phase I. From these questions, four overarching concepts were decided *a priori* – overall experience, content, persuasiveness, and alliance. The primary investigator reviewed transcripts, iteratively applying codes and later summarizing codes into themes. Themes were grouped under a relevant concept to organize participant feedback. Codes were given a classifier of neutral, positive, or negative, when appropriate, per the definitions provided in the table. If a participant answered a question with content relevant to another question topic, the response was coded for the most relevant question. For example, if a person answered the general evaluation question with, "I would use this app because of how simple it is," the response would be coded positive and grouped under persuasiveness.

Question	**Code**	**Definition**
General evaluation: What was your experience using this app?	Neutral	The app provides the user with a non-specific experience, does not relate to the feeling users experience when using the system
	Positive	The app provides the user with a positive experience
	Negative	The app provides the user with a negative experience
Content: What would you like to see added to or changed on the app?	Neutral	User expresses opinions about adding or changing things to the app in a nonspecific manner
	Positive	User expresses opinions about adding or changing things to the app in a positive manner
	Negative	User expresses opinions about adding or changing things to the app in a negative manner
Therapeutic Persuasiveness: How motivated would you be to use this app?	Neutral	User expresses nonspecific statements about motivations for using the app
	Positive	User expresses positive statements about motivations for using the app
	Negative	Users express negative statements about motivations for using the app
Therapeutic Alliance: How would you use this app to support your everyday needs?	Neutral	Users expresses nonspecific comments about using the app
	Positive	Users expresses positive comments about using the app for support
	Negative	Users expresses negative comments about using the app for support

Appendix I: Technology Familiarity Scale

Do you use a mobile phone or tablet that has a touchscreen, internet access, and can run applications?

☐ Yes
☐ No

If yes, how long have you owned a smartphone or tablet?

☐ Less than 1 year
☐ 1-5 years
☐ 6-10 years
☐ 10 or more years

If no, do you have a mobile phone that can be used for simple tasks like making phone calls?

☐ Yes
☐ No

How often do you perform the following actions with your phone or tablet?

Action	**Never**	**Very Rarely**	**Rarely**	**Occasionally**	**Very Frequently**	**All the time**
Make phone calls						
Browse the web / search for info						
Use apps (for any purpose)						
Listen to music/podcasts/audiobooks/radio						
Watch videos						
Play games						
Check the news						
Take pictures						
Record video						
Check email						
Text						
Check social media						

Total score: _______

Appendix J: High-Level Report

This is a high-level summary of the usability test and semi-structured interviews and is not intended as a final analyzed report. This report is meant to share some key observations with the core team while the final report is being prepared.

Participants

ID	Suspected Cognitive Status
1	Mild cognitive impairment
2	Parkinson disease dementia
3	Mild cognitive impairment
4	Mild cognitive impairment
5	Parkinson disease dementia
6	Subjective cognitive decline
7	Subjective cognitive decline

Overall User Experience

- *The app is intuitive, easy to use, and visually pleasing* – The majority of participants reported having a positive experience interacting with the app. They labeled the app as user-friendly, readable, attractive, and intuitive, and the simple design was listed as a strength of the app.

User Requests (see below for feature specific requests)

- *Care partner access is a high priority* – Many users reported that their spouse helps them manage their everyday needs, and granting their spouse access to this app would make the app more useful to both parties.
- *Integration with healthcare apps affects app adoption* – Most users requested that this app be integrated with their existing healthcare apps (e.g., MyChart). One user said having to manually transfer their information from their existing apps to this app is a disincentive to adopting this app.
- *Notifications may support memory* – Several users suggested adding notifications or alerts to the medications, notes, appointments, and to-do list features to support them in remembering to complete tasks.
- *Sorting could support navigation* – Several users suggested adding a grouping or sorting feature to the contacts and to-do list features. Two users asked to be able to sort contacts by the labels (e.g., daughter, friends). One asked to be able to sort the to-do list by category (e.g., personal, medical).
- *Simplicity is good, but some customizability is better* – Most users acknowledged the importance of keeping the app interface simple. However, some asked for the ability to

customize the font size, turn features on and off depending on their needs, re-label features to personally meaningful titles, and re-organize features on the home page.

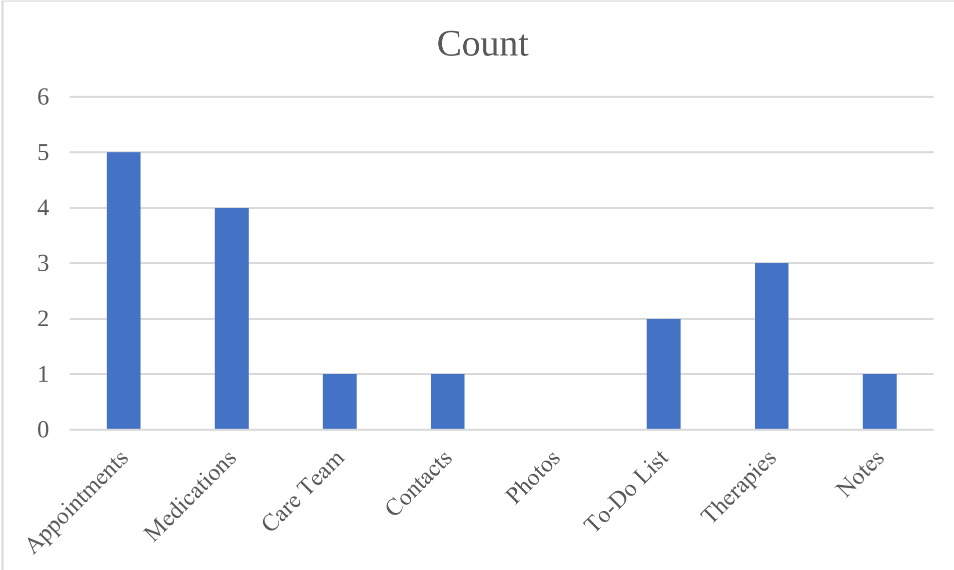
- *Check boxes are helpful for more than just medications* – Some users requested that check boxes be added to the notes and to-do list features so that they can mark when they've finished a particular task.
- *Financial support was requested by one* – One user asked if it would be possible to add a finances feature to the app where users could track whether they've paid co-pays and/or monitor their running balance for medical bills.
- *Archiving information may help maintain simplicity* – One user recognized that the app could quickly lose its simple appearance after being in use and accumulating a lot of information. They suggested adding an archive ability.
- *Integration with Zoom could support telehealth* – One user suggested integrating the app with Zoom so that users with mobility limitations could use the app to contact their healthcare providers for telehealth purposes.

Therapeutic Persuasiveness

- *Motivation to adopt dependent on current support system* – Several users reported they would not be motivated to use this app because they already have developed a cognitive support system, but they could see how this app would be helpful for someone who doesn't yet have a cognitive support system.
- *Integration with other tools improves motivation* – Several users said they would be much more motivated to use this app if it could be connected to their existing healthcare apps such that their data would automatically transfer.
- *Being a 'one-stop-shop' is motivating* – Several users stated that a strength of this app is its integration of multiple features that support cognition. One noted that the benefit of this will only increase as cognition worsens and it becomes more difficult to manage multiple tools.
- *Portability may increase motivation* – Some users said that a strength of the app is the ability to access it easily on your phone or other portable electronic devices to be able to bring it to appointments.

Therapeutic Alliance

The frequency with which participants said they would use a feature in the app to support their everyday functioning is depicted below:



Likert Ratings

Ease of Use

- *App use is relatively intuitive* – Most users reported the app was easy to use, on average. Two users reported the app was neither easy nor difficult to use, on average.
- *More complex features were more difficult to use* – The appointments feature was rated as the most difficult feature to use across users, with an average rating of 'neutral.' The medications and notes features were rated as the easiest to use.

ID	Appts.	Meds.	CareT.	Conts.	Photos	ToDo	Tx.	Notes	Avg.
1	4	4	4	4	4	4	4	4	**4.0**
2	2	5	4	4	4	4	4	5	**4.0**
3	3	5	2	4	4	5	3	4	**3.5**
4	4	5	5	4	5	5	5	5	**4.75**
5	2	4	4	5	4	2	2	5	**3.5**
6	4	5	5	5	5	5	5	5	**4.88**
7	4	5	5	4	4	5	5	5	**4.63**
Avg.	**3.29**	**4.71**	**4.14**	**4.29**	**4.29**	**4.29**	**4.0**	**4.71**	

Note. Ratings given on a 5-point Likert scale where 1 = extremely difficult and 5 = extremely easy. Avg. = Average; Appts. = Appointments; Meds. = Medications; CareT. = Care Team; Conts. = Contacts; ToDo = To-Do List; Tx. = Therapies.

Level of Helpfulness

- *App content generally considered helpful* – Most users reported the app would be helpful in supporting their everyday needs, on average. Two users reported the app was neither helpful nor unhelpful, on average.

ID	Appts.	Meds.	CareT.	Conts.	Photos	ToDo	Tx.	Notes	Avg.
1	4	5	2	2	2	2	4	2	**2.88**
2	3	4	2	3	2	3	3	4	**3.0**
3	4	5	5	3	4	4	4	4	**4.13**
4	4	5	5	4	3	4	5	3	**4.13**
5	5	4	4	4	5	5	4	5	**4.5**
6	5	4	5	5	4	5	4	3	**4.38**
7	5	5	5	5	5	5	5	5	**5.0**
Avg.	**4.29**	**4.57**	**4.0**	**3.71**	**3.57**	**4.0**	**4.14**	**3.71**	

- *Medication most helpful* – The contacts, notes, and photos features were rated as neither helpful nor unhelpful across users. The medications feature was rated as the most helpful feature for everyday functioning across users.

Note. Ratings given on a 5-point Likert scale where 1 = extremely unhelpful and 5 = extremely helpful. Avg. = Average; Appts. = Appointments; Meds. = Medications; CareT. = Care Team; Conts. = Contacts; ToDo = To-Do List; Tx. = Therapies.

Feedback Per Feature

Appointments

- *Usefulness dependent on personal need* – Most users stated they saw how the appointments feature could be helpful in supporting everyday functioning; however, they already receive support for appointments through other tools (e.g., Google Calendar).
- *Care partner access is beneficial* – Some users stated this feature would be more helpful if their care partner could access their calendar.
- *Synching with Google Maps may support independence* – One user suggested linking the location of appointments with Google Maps to help users navigate to their appointments.

Medications

- *Usefulness dependent on personal need* – Most users reported they already have a method of managing their medications, but that they could see how this feature would be beneficial for someone who does not have a system in place.
- *Integration viewed positively* – Some users stated it was helpful to have information about their dosage schedule and side effects in one place.
- *Care partner access is beneficial* – Some users stated this feature would be more helpful if their care partner could access their medications.

Care Team

- *Usefulness dependent on personal need* – Most users reported they already have a tool that meets this need. One user said this feature was not very helpful because they do not have many care providers.
- *Multifunctionality viewed positively* – Several users stated they liked how they were able to view or schedule appointments, contact their care providers, and add descriptive information about an appointment all in one place.

Contacts

- *Usefulness dependent on personal need* – User opinions were mixed regarding the usefulness of the contacts feature. Three said they would not use this feature, two that they see the benefit of this feature but already have another system in place, and one that they found this feature very helpful.
- *Expanding this feature increases usefulness* – Users gave several suggestions for increasing the helpfulness of this feature, including adding a search or sort function, allowing users to sync this feature with other apps, adding an email and text button, and expanding on the ‘other’ label.

Photos

- *Usefulness dependent on personal need* – Most users said they already have another system that they use for sharing photos (e.g., Google Photos, social media); however, they reported that this feature could be a nice alternative to social media.
- *Photo captions helpful but hidden* – Some users said they liked how the photos had captions, but one user found it challenging to find the captions. Two users suggested adding an icon to images that have captions to show that there is an additional layer of information.

To-Do List

- *Usefulness dependent on personal need* – User responses were generally positive. Four users said that they could see how this feature would be helpful. Three said this feature was less useful because they aren’t busy enough to need help organizing their week.
- *Care partner access is beneficial* – Some users stated this feature would be more helpful if their care partner could access their calendar.
- *A daily to-do list view was requested by one* – One user requested the ability to have a daily view for the to-do list in addition to the weekly view.
- *Repeating tasks was requested by one* – One user requested that they be able to mark tasks as repeating to reduce the amount of work required to input their schedule into the app.

Therapies

- *Multifunctionality viewed positively* – Several users stated they liked how the therapy exercises and therapists' contact information was on one page.
- *Ease of use impacted by learning curve* – Some users reported that there is a learning curve to accessing information in this feature but that ease of use improves with practice.

Notes

- *Unclear purpose led to confusion* – User opinions were mixed on the purpose of this feature. Some said they would use this feature to write notes to take to appointments. Others felt it was redundant with the 'Description' field that already exists underneath individual appointments.
- *Expanding this feature increases usefulness* – Users suggested several ways to increase the usefulness of this feature, including adding notifications, a search bar, the ability to check off when a note is done, and the ability to archive old notes.
- *Journaling may be more helpful for some* – Two users asked for a journal feature instead of a notes feature as a place to keep track of their disease progression.