Using Smartphone Applications to Support Cognition in Individuals with Parkinson's Disease: A Pilot Treatment Study

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A thesis

submitted in partial fulfillment of the

requirements for the degree of

Master of Science

University of Washington

2018

Committee:

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Program Authorized to Offer Degree:

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Abstract

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Cognitive impairment from Parkinson's disease can limit performance in daily activities, reduce participation in social/leisure activities, and increase caregiver burden. A 5-week treatment program was developed to train the use of smartphone applications to support cognitive functioning in personally-relevant activities. Voice commands were selected as an efficient access method to address progressive motor impairment in PD, and the principles of systematic instruction were incorporated throughout treatment. Two participants with cognitive impairment secondary to Parkinson's disease completed training in reminder and calendar application skills using voice commands. Both participants demonstrated improvements across measures of skill acquisition (accuracy, success) and treatment impact (Goal Attainment Scaling, questionnaires) immediately following treatment and maintained most gains at two-month follow-up.

Introduction

Parkinson's Disease Overview

Parkinson's Disease (PD) is a neurodegenerative disorder resulting primarily from a progressive loss of dopaminergic cells in the substantia nigra. The cell loss leads to a deficiency in the neurotransmitter dopamine, altering basal ganglia circuit function. These neuronal changes manifest as the cardinal motor symptoms of resting tremor, akinesia or bradykinesia, rigidity, and postural instability and also contribute to nonmotor symptoms of the disease, including cognitive impairment (Galvan & Wichmann, 2008; Wichmann, DeLong, Guridi, & Obeso, 2011). The average age of onset of PD is about 60 years (Ishihara, Cheesbrough, Brayne, & Schrag, 2007) and average life expectancy following diagnosis is about 15 years (Duffy, 2013). However, the rate of disease progression is heterogeneous across individuals (Berg et al., 2014; Fereshtehnejad et al., 2015), and this variability has been associated with age of onset and different patterns of symptom presentation (Fereshtehnejad et al., 2015; Ishihara et al., 2007; Suchowersky et al., 2006). PD has been estimated to cost the United States at least $14.4 billion per year, a figure that could double by the year 2040 if per person costs remain unchanged (Kowal, Dall, Chakrabarti, Storm, & Jain, 2013).

Cognitive impairment is a nonmotor symptom impacting a significant proportion of individuals with PD, even at the time of diagnosis, and is considered a risk factor for Parkinson's Disease Dementia (PDD) or major neurocognitive disorder (major NCD)[1] (Aarsland, Bronnick, Larsen, Tysnes, & Alves, 2009; Broeders et al., 2013; Domellöf, Ekman, Forsgren, & Elgh,

[1] While the terms mild cognitive impairment (MCI) and dementia remain prevalent in research literature and continue to be used as medical diagnostic codes under the World Health Organization's International Classification of Diseases and Related Health Problems, Tenth Revision (ICD-10), the fifth and most recent edition of the American Psychiatric Association's Diagnostic and Statistical Manual of Mental Disorders (DSM-V) replaces the terms MCI and dementia with mild neurocognitive impairment (mild NCD) and major neurocognitive impairment (major NCD), respectively (American Psychiatric Association, 2013; World Health Organization, 2011). This document adheres to the DSM-V terminology wherever possible. However, when discussing previous studies, the terms PD-MCI and PDD are used to remain consistent with referenced publications and thereby avoid confusion.

2015; Muslimović, Post, Speelman, & Schmand, 2005; Pedersen, Larsen, Tysnes, & Alves, 2017; Santangelo et al., 2015). Cognitive impairment not only negatively affects patients' functional performance in instrumental activities of daily living (IADLs) and reduces participation in social and leisure activities, it also increases financial strain and caregiver burden (Foster & Hershey, 2011; Jones et al., 2017; Lawson et al., 2014; Pirogovsky et al., 2014; Vossius, Larsen, Janvin, & Aarsland, 2011). Therefore, it is important in clinical practice to identify cognitive impairment in individuals with PD and determine intervention strategies that maintain or improve individuals' independence and quality of life, which in turn may reduce financial strain and caregiver burden. The purpose of the proposed study is to examine the feasibility and impact of a hybrid (individual and small group) treatment program designed to address the cognitive challenges of PD using smartphones. To this end, a brief review of the characteristics of PD will first be provided, with emphasis on common cognitive challenges and their effect on individuals with PD, their family members, and society. A summary of the landscape of interventions for PD with a focus on treatments designed to support cognition will also be provided.

Incidence & Prevalence of PD

A 2016 systematic review and meta-analysis by Hirsch et al. examined worldwide studies on incidence proportions of PD published between 2001 and 2014. In individuals ages 40 and up, pooled incidence proportions for males and females were 44.21 and 37.16, respectively. Incidence proportions increased with age for both genders, peaking between ages 70 and 79. The study also found gender differences in incidence rates with males having higher incidence rates in all age groups. However, the difference was only statistically significant between ages 50 and 59. With respect to prevalence, Pringsheim, Jette, Frolkis, and Steeves (2014) used the highest

quality studies published between 1985 and 2010 to show increasing prevalence with age from less than 0.2% in individuals between ages 50 and 59 to about 1.3% in individuals between ages 70 and 79 and about 2.5% in individuals over 80. Like incidence, prevalence was higher in men than women in nearly all age groups, but the difference was only statistically significant between ages 50 and 59.

Etiology of PD

The cause of PD remains unknown, but research suggests a possible interaction between genetic and environmental factors. Mutations to at least four genes have been found to cause familial forms of PD: α-synuclein, parkin, PINK1, and DJ-1. Research suggests that the α-synuclein and parkin genes may also contribute to sporadic PD (Moore, West, Dawson, & Dawson, 2005). Age and estrogen have been identified as correlative factors, but it remains unclear how or why the ageing process or reduced estrogen levels may be risk factors for PD (Schapira & Jenner, 2011). Environmental factors that have been associated with the development of PD include: industrialization; rural environment; well water; plant-derived toxins; infections; and exposure to organic solvents, carbon monoxide, carbon di-sulfide, and pesticides (Schapira & Jenner, 2011). Cigarette smoking and caffeine intake have been shown to reduce the risk of developing PD, but evidence supporting the risk-reduction benefits of exercise, anti-inflammatories, antihypertensives, and antilipidaemics is less clear (Schapira & Jenner, 2011).

Symptoms of PD

Motor symptoms. Characterizing an individual's motor symptoms is the first step toward making a clinical diagnosis of PD under the 2015 Movement Disorders Society (MDS) diagnostic criteria (Postuma et al., 2015). PD motor symptoms are categorized as either primary

or secondary and can have a profound impact on an individual's safety, independence, and quality of life.

Primary motor symptoms. The core motor symptoms of PD include bradykinesia, rigidity, and resting tremor. The terms **bradykinesia**, akinesia, and hypokinesia are often used interchangeably to describe an overall slowness of volitional movement, including slowness to initiate or stop motor actions, lack of spontaneous, automatic movement, and reduced amplitude and speed of continuous, repetitive movements (Duffy, 2013; Magrinelli et al., 2016; Postuma et al, 2015). **Rigidity** refers to a state of constant muscular hypertonia, resulting in stiffness and reduced range of motion. **Resting tremor** is characterized by a 4- to 6-Hz rhythmic oscillation of a resting body part, most often the distal limbs but also the lips, chin, or jaw, that is inhibited by volitional movement (Duffy, 2013; Jankovic, 2008). **Postural instability** has also classically been considered one of the cardinal motor features of PD. Diminished postural reflexes can create difficulties with transitioning from sitting to standing, turning, and correcting body position in response to tilting or falling (Duffy, 2013). Because postural instability is more common in PD later in the disease course, postural instability at earlier disease stages is more likely to suggest a diagnosis of certain atypical parkinsonian disorders, such as progressive supranuclear palsy or multiple systems atrophy (Köllensperger et al., 2008). Therefore, this feature is not included in the 2015 MDS diagnostic criteria for PD (Postuma et al, 2015).

Secondary motor symptoms. In addition to PD's primary motor symptoms, there are numerous secondary motor symptoms thought to arise from an interaction between primary motor features and other nonmotor symptoms, including deficits in cognition and sensory-motor integration (Duffy, 2013; Magrinelli et al., 2016). Common secondary motor symptoms are outlined in Table 1, and include freezing or festinating gait, reduced arm swing while walking,

hypokinetic dysarthria, dysphagia, and micrographia (Duffy, 2013; Jankovic, 2008; Magrinelli et al., 2016).

Nonmotor symptoms. In addition to the motor symptoms described above, individuals with PD also experience a vast array of sensory, autonomic, psychiatric, and cognitive symptoms. Several of the most common of these symptoms are also included in Table 1. Cognitive symptoms of PD will be discussed in greater detail in the following section.

Table 1. Summary of motor and nonmotor characteristics of Parkinson's disease.

Motor Symptoms	
Primary Bradykinesia Rigidity Resting Tremor Postural Instability	**Secondary** Freezing/Festinating Gait Reduced Arm Swing Masked Face Impaired Fine and Gross Motor Control Micrographia Hypokinetic Dysarthria Dysphagia
Nonmotor Symptoms	
Sensory Sensory Processing & Integration Deficits Loss of Olfaction (Hyposmia) Pain Parasthesia	**Autonomic** Orthostatic Hypotension Sweating Dysfunction Gastrointestinal Issues Urogenital Dysfunction
Psychiatric Anxiety Depression Hallucinations/Psychosis Sleep Dysfunction (e.g., Rapid Eye Movement Behavior Disorder)	**Cognitive** Attentional Deficits Slowed Processing Speed Memory Deficits Deficits in Executive Functions Visuospatial Deficits

Sources: Boecker et al., 1999; Duffy, 2013; Jankovic, 2008; Magrinelli et al., 2016.

Cognitive Impairment in PD

Cognitive decline can be one of the earliest nonmotor symptoms in individuals with PD, with studies reporting that approximately 20% to 40% of individuals with newly diagnosed PD demonstrate some degree of cognitive impairment (Aarsland et al., 2009; Broeders et al., 2013; Domellöf et al., 2015; Muslimović et al., 2005; Pedersen et al., 2017; Santangelo et al., 2015). Furthermore, Aarsland et al. (2009) found that even individuals classified as having normal cognition at the time of diagnosis still performed significantly worse than healthy controls on neuropsychological tests of attention, speed of processing, verbal memory, and visuospatial abilities. At various stages of the disease, cognitive deficits may range in severity from mild to severe. Traditionally, individuals with mild cognitive dysfunction have been diagnosed with mild cognitive impairment (MCI or PD-MCI), whereas individuals with more severe cognitive impairment have been classified as having dementia or PDD. Regardless of severity, cognitive deficits can have a detrimental impact on quality of life and caregiver burden (Jones et al., 2017; Lawson et al., 2014).

Prevalence of cognitive impairment in PD. Determining the prevalence of cognitive impairment in PD has been challenging due to inconsistent diagnostic criteria and heterogeneity among patient cohorts, particularly in terms of time since diagnosis, disease severity, and medication status (Kalbe & Kessler, 2015; Litvan et al., 2011). Following publication of the 2012 MDS Task Force diagnostic criteria (Litvan et al., 2012), several longitudinal studies employing the new criteria have examined MCI prevalence and its conversion to PDD over time (Broeders et al., 2013; Domellöf et al., 2015; Pedersen et al., 2017; Santangelo et al., 2015). These studies found that at the time of PD diagnosis, the prevalence of PD-MCI ranged from 20.2% to 42.6%, and cumulative prevalence rates over a four- to five-year period ranged from

37.3% to 59.5%.[2] Furthermore, individuals meeting criteria for PD-MCI at baseline or during the first year of diagnosis converted to PDD within 4- to 5-years at rates 4 to 8 times higher than those observed for individuals with PD and normal cognition (Broeders et al., 2013; Domellöf et al., 2015; Pedersen et al., 2017; Santangelo et al., 2015).

Factors associated with cognitive impairment in PD. Cognitive impairment in PD has been linked to numerous factors, including *older age* (Aarsland et al., 2010; Lawson et al., 2014; Leroi, McDonald, Pantula, & Harbishettar, 2012; Litvan et al., 2011; Riedel et al., 2008; Weintraub et al., 2015), *older age at PD onset* (Aarsland et al., 2010; Leroi et al., 2012; Tang et al., 2016), *longer disease duration* (Aarsland et al., 2010; Litvan et al., 2011), *lower premorbid education level* (Dujardin et al., 2015; Lawson et al., 2014; Santangelo et al., 2015), *increased severity of motor symptoms* (Aarsland et al., 2010; Broeders et al., 2013; Domellöf et al., 2015; Goldman, Weis, Stebbins, Bernard, & Goetz, 2012; Lawson et al., 2014; Leroi et al., 2012; Litvan et al., 2011; Santangelo et al., 2015; Weintraub et al., 2015), *lower proportion of dopamine agonist use* (Aarsland et al., 2010; Leroi et al., 2012), *presence of depression or apathy* (Aarsland et al., 2010; Broeders et al., 2013; Pedersen et al., 2017; Santangelo et al., 2015; Tremblay, Achim, Macoir, & Monetta, 2013), *left-sided motor symptoms* (Goldman et al., 2012; Tomer et al., 1993) and *motor symptoms consistent with non-tremor dominant motor subtype* (Kehagia, Barker, & Robbins, 2012; Tremblay et al., 2013). It is important to note that correlates with PD-MCI are inconsistent across studies, and some studies, such as Aarsland et al. (2009), have not found any patient characteristics that differ significantly between individuals with PD-MCI and those with PD and normal cognition.

[2] Pedersen et al., 2017 is the only paper that calculated the 5-year cumulative prevalence rate. The 4- and 5-year cumulative prevalence rates were calculated using the same methodology as Pedersen et al., 2017 for the three other studies based on data presented in those studies on number of individuals converting from normal cognition to PD-MCI over the course of the study.

Profile of cognitive impairment in PD. In addition to variation in time of onset of cognitive symptoms and rate of progression of cognitive decline, there is also significant variability in the potential cognitive domains affected across individuals with PD (Litvan et al., 2011; Watson & Leverenz, 2010). Numerous studies have found that individuals with PD-MCI experience impairments to multiple cognitive domains, including executive functions, attention and working memory, processing speed, visuospatial abilities, and memory (Cholerton et al., 2014; Domellöff et al., 2015; Goldman et al., 2012; Kalbe et al., 2016; Lawson et al., 2014; Leroi et al., 2012; Muslimović et al., 2005). However, these same studies report differences in the most prevalently affected domains, with some finding a greater proportion of individuals with impairments in executive functions and/or attention (Domellöf et al., 2015; Kalbe et al., 2016; Lawson et al., 2014; Leroi et al., 2012; Muslimović et al., 2005) and others identifying a higher percentage of individuals with impaired memory and/or visuospatial abilities (Cholerton et al., 2014; Goldman et al., 2012). One hypothesis that may explain these different patterns in cognitive profile is the "dual syndrome hypothesis," which proposes two distinct cognitive syndromes in PD: one involving dysfunction in dopamine-mediated fronto-striatal circuits resulting in a cognitive profile characterized primarily by deficits in executive function and attention, and a second characterized by greater memory and visuospatial impairment due to wider-spread cortical Lewy Body pathology and marked cholinergic depletion (Kehagia et al., 2012). This hypothesis may also help explain the variability in progression observed across patient cohorts. Individuals with more prominent executive dysfunction typically exhibit a more stable cognitive profile over time, while those presenting with early deficits in visuospatial functions have been found to progress more rapidly to dementia (Kehagia et al., 2012).

Psychosocial and functional impact of cognitive impairment in PD. To date, limited studies have examined the impact cognitive impairment in individuals with PD without dementia has on patient quality of life, particularly on activity limitations and participation restrictions (International Classification of Functioning, Disability and Health [ICF], World Health Organization [WHO], 2001); patient and caregiver finances; and caregiver burden.

Quality of life. Cognitive deficits in PD have been shown to have a greater impact on quality of life than other motor and nonmotor PD symptoms (Berganzo et al., 2016; Foster & Hershey, 2011). Cognitive deficits in individuals with PD without dementia have been correlated with poorer self-assessment of quality of life, particularly in the domains of communication, stigma, and social support (Lawson et al., 2014; Reginold et al., 2013). These findings may in part be due to individuals with PD-MCI demonstrating poorer performance on instrumental activities of daily living (IADLs) than individuals with PD and normal cognition, as well as healthy controls, which has led to reduced participation in such activities and increased dependence on others (Foster & Hershey, 2011; Pirogovsky et al., 2014). In addition to reduced participation in IADLs, individuals with PD-MCI also report reduced participation in social and leisure activities, which could lead to feelings of social isolation (Foster & Hershey, 2011).

Financial strain. In 2010, individuals with PD in the United States incurred an estimated $12,800 more in direct medical expenses than similar individuals without PD, over $4,000 of which was paid for out-of-pocket (Kowal et al., 2013). Annual nonmedical expenses were estimated to be an additional $10,000 per person (Kowal et al., 2013). While the costs of PD are already significant, a 2011 study of a group of people with PD living in Norway found that cognitive impairment was associated with higher patient costs (Vossius et al., 2011). Over the period spanning 1993 to 2001, the costs of patients with dementia were 3.3 times more per year

of survival as compared to patients without dementia, which remained significant after controlling for age, disease duration, and motor symptom severity. This increase in costs was attributed to higher direct nonmedical costs, such as services for cleaning help, home care, and adult day care (Vossius et al., 2011). The study also found correlations between increasing direct nonmedical costs and early cognitive changes in patients without dementia (Vossius et al., 2011).

Caregiver burden. Levels of caregiver burden are important to understand because the well-being of caregivers influences the well-being of the individuals for whom they care (Berry, Elliott, Grant, Edwards, & Fine, 2012; Visser-Meily, Leentjens, Marinus, Stiggelbout, & van Hilten, 2006). Few studies have examined the impact cognitive impairment in PD has on caregivers' health, finances, emotional well-being, social life, and interpersonal relations. A recent study by Jones and colleagues (2017) found significant differences in caregiver burden, as measured by the Zarit Burden Interview (ZBI), between those caring for individuals with PD-MCI versus individuals with PD and normal cognition. Furthermore, differences remained significant even after controlling for disease duration, psychiatric symptoms, ability to perform everyday tasks, motor difficulties, and time spent caregiving. These findings were contrary to those reported in an earlier study, which determined that caregiver burden was only significantly higher in caregivers of individuals with PD and dementia (Leroi et al., 2012). This discrepancy may have been due to differences in the diagnostic criteria used to distinguish between individuals with PD with cognitive decline versus normal cognition.

Interventions for PD

Interventions for motor symptoms. Interventions for motor symptoms are categorized as either pharmacological or nonpharmacological. The most effective pharmacological options for managing motor symptoms include dopamine agonists and Levodopa, a drug that is

metabolized into dopamine in the body. These drugs address the primary cause of motor symptoms in PD – dopamine depletion. Nonpharmacological treatments include surgical procedures, the most common being deep brain stimulation (DBS), and therapeutic options such as physical therapy, occupational therapy, and speech and swallowing therapy (Martinez-Ramirez & Okun, 2016).

Interventions for nonmotor symptoms. While a variety of pharmacological options are available to help manage psychiatric and autonomic symptoms of PD, most pharmacological options that have been investigated for cognitive symptoms (e.g., acetylcholinesterase inhibitors) have only been studied in individuals with dementia and have had limited benefit and/or inconsistent results (Martinez-Ramirez & Okun, 2016; Seppi et al., 2011). Given the high prevalence of cognitive impairment in individuals with PD, its impact on quality of life and caregiver well-being, its increased risk of progression to major NCD, and the current lack of pharmacological treatment options, behavioral interventions for cognitive impairment in PD are of particular importance.

Cognitive Rehabilitation for PD

Smasne, Spencer, Caldwell, Sohlberg, and Yorkston (2017) detailed a thorough review of the literature on cognitive rehabilitation in PD published through 2015. This document summarizes their findings, provides further review on the training of compensatory strategies within articles covered by the review, and includes an updated literature search through October 2017.

Summary of previous review. Studies on cognitive rehabilitation in PD published through 2015 focused primarily on cognitive treatment targeting impairment-level functions using traditional and non-traditional methods (Smasne et al., 2017). Traditional methods were

defined as paper-and-pencil exercises (e.g., drawing lines to join numbers to corresponding letters, as in the Trail Making Test, to target alternating attention); cognitive-based games (e.g., category matching for memory); activities considered to be cognitively stimulating (e.g., Sudoku puzzles); and computer-based training (e.g., Attention Process Training, Second Edition). Non-traditional methods included wellness and music therapies, physical training (e.g., gait training and aerobic exercise), and therapies combining both physical and cognitive training. While most studies reported improvements in cognitive performance following treatment in the domains of attention, processing speed, executive functions, and/or memory, cognitive outcome measures were limited to impairment-level neuropsychological test scores and results were often inconsistent across multiple tools intended to measure the same domain. Although several studies attempted to determine whether treatment improved quality of life using self- and/or informant-report questionnaires, few considered reported improvements in daily activities, and none attempted to understand the impact on patient-specific activity and participation goals. Furthermore, most studies had small sample sizes and either did not explicitly state exclusion of individuals with normal cognition or did not adequately assess and report participants' baseline cognitive status. These factors limit the external validity of the results.

To elaborate on the previous review, four studies referred to the use of treatment approaches targeting compensatory strategies in addition to training techniques focused on improving impairment-level functions (e.g., Peña et al., 2014; Naismith, Mowszowski, Diamond, & Lewis, 2013; Reuter, Mehnert, Sammer, Oechsner, & Engelhardt, 2012; Petrelli et al., 2014). Naismith and colleagues (2013) included 14 hours of psychoeducation in addition to 14 hours of computer-based training targeting impairment-level functions. The psychoeducation sessions included content on internal memory strategies (e.g., mnemonics, verbal rehearsal), external

memory strategies (e.g., diaries, post-it notes), some form of metacognitive strategy instruction (e.g., structured problem solving, task analysis), environmental modifications (e.g., minimizing distractions), and pacing strategies, such as taking frequent breaks (Naismith et al., 2011). However, it is unclear from the information provided whether each strategy was taught over multiple sessions and whether opportunities for practice within functional activities were offered. The study by Reuter et al. (2012) included training of mnemonic strategies for memory, which accounted for 15% of cognitive training time. However, like the Naismith et al. (2013) study, no detail was provided on the instructional methods used to teach them. In addition, Petrelli and colleague's (2014) treatment protocol, NeuroVitalis, included two sessions with content on "memory strategies" (Supplementary Material, Petrelli et al., 2014), and the Peña et al. study (2014) employed the REHACOP program, which used "restoration, compensation, and optimization strategies." However, the references providing more detail on each protocol were not available in English (Baller, Kalbe, Kaesberg, & Kessler 2010; Ojeda et al., 2012). Therefore, while it appears that training in compensatory strategies was a treatment component in some studies covered by the previous review, it was not a primary intervention focus. Furthermore, there is insufficient detail to critically evaluate the types of strategies trained or the instructional methodologies selected to teach their use.

Updated literature search findings. Since the end of 2015, one meta-analysis and nine studies have been published on nonpharmacological interventions for cognition in individuals with PD. Using Smasne and colleague's (2017) framework, six of the nine studies investigated treatments focusing on impairment-level targets: three evaluated computer-based training (Adamski, Adler, Opwis, & Penner, 2016; Diez-Cirarda et al., 2016, 2017) and three studied physical training programs (de Natale et al., 2017; Ferrazoli et al., 2017; Picelli et al., 2016). The

remaining three studies investigated treatments focused on training compensatory strategies (Foster, McDaniel, & Rendell, 2017a; Foster, Spence, & Toglia, 2017b; Goedeken, Potempa, Prager, & Foster, 2017). A summary of these ten publications is provided below.

Studies targeting impairment-level functions. Lawrence, Gasson, Bucks, Troeung, and Loftus (2017) performed a **meta-analysis** on cognitive training studies conducted over the same time frame as the previously reviewed Leung et al. (2015) study. Their analysis included controlled trials with or without randomization and set out to compare standardized versus tailored cognitive training. However, there were an insufficient number of controlled trial studies evaluating tailored training to make such a comparison. Considering standardized and tailored training together, findings of the Lawrence et al. study were generally consistent with those reported by Leung and colleagues. Specifically, both studies found that measures on impairment-based neuropsychological tests demonstrated statistically significant improvements in the domains of executive functions, attention/working memory, and global cognition but not visuospatial function. Lawrence et al. further found statistically significant improvements in measures of memory, whereas the improvements found in the Leung et al. study were not statistically significant.

The three new studies focused on **computer-based cognitive training** provided evidence of improvements on some (but not all) impairment-level measures of visual short-term memory and delayed recall (Adamski et al., 2016), which is consistent with findings of prior studies; imageable brain changes following treatment (Diez-Cirarda et al., 2016); and maintenance of brain changes, impairment-level improvements in processing speed, theory of mind, and visual memory, and self-reported functional disability improvements at 18 months post-treatment

(Diez-Cirarda et al., 2017). Interpretation of these studies is limited by small sample sizes and treatment groups with unknown baseline cognitive status.

Cognitive outcomes across three studies evaluating **physical training** were consistent with those reported in the prior review. That is, physical training resulted in improvements in executive functions (Picelli et al., 2016) and attention and processing speed (Picelli et al., 2016; Ferrazzoli et al., 2017; de Natale et al., 2017), as measured by neuropsychological assessment tools. A common limitation across all three studies was that participants' cognitive status was either unknown (de Natale et al., 2017) or appeared within normal limits for some participants (Ferrazzoli et al., 2017; Picelli et al., 2016). Two of the three studies also had small sample sizes (de Natale et al., 2017; Picelli et al., 2016).

Studies incorporating training in compensatory strategies. While a few earlier studies supplemented cognitive training targeting impairment-level functions with compensatory strategy instruction, none focused exclusively on training compensatory strategies to improve cognitive function in individuals with PD. Since the prior review, three studies have been published on cognitive intervention with an emphasis on *internally*-generated compensatory strategies. Studies conducted by Foster et al. (2017a) and Goedeken et al. (2017) investigated the effects of an encoding strategy called implementation intentions (II) on the performance of prospective memory tasks. II utilizes verbal rehearsal of an intention statement, which combines the prospective memory task with its corresponding time-based or event-based cue, and visualization of the task's execution. An example of an intention statement with a time-based cue would be, "When it's 11:00am, I will take my antibiotic," whereas an intention statement with an event-based cue would be, "When I eat lunch, I will take my antibiotic." Foster and colleagues (2017a) found that use of the II strategy, which was supported during the experiment by general

external reminders, significantly improved performance on computer-simulated prospective memory tasks in the laboratory. However, Goedeken and colleagues (2017) did not find that II improved prospective memory performance in daily tasks, as measured by participant self-report at one-month follow-up. In fact, when participants were asked at follow-up to explain the II strategy, roughly two-thirds could not recall it with complete accuracy. Although several factors may explain this outcome, the limited instruction time and absence of transfer training activities likely partially accounts for the lack of self-reported improvement on daily prospective memory tasks – II training occurred over a single 30-minute session, and strategy practice was entirely computer-based.

The third study (Foster et al., 2017b) evaluated the feasibility of an individually-tailored intervention program targeting compensatory strategies for persons with self-reported cognitive decline and PD. The primary outcomes included participants' views on the credibility of the treatment rationale (credibility measure) and whether they expected intervention to improve their cognitive function (expectancy measure). The intervention approach employed metacognitive strategy instruction techniques to help individuals anticipate challenges in participant-selected activities, create and execute strategies to address those challenges, and evaluate their performance during and following the task, including determining whether the chosen strategies were effective. Instruction was carried out during simulated functional activities, or whenever that was impractical, through a detailed discussion of the activity. Homework was assigned to encourage participants to practice strategies generated during the session in real-life activities. Participants also practiced self-monitoring and self-evaluation by recording each time they implemented strategies at home and writing a reflection on whether strategies were effective and how they might be modified to improve effectiveness. Foster and colleagues (2017b) found that

participants rated the intervention as having high credibility and their expectations for improvement were moderate. Furthermore, both ratings of credibility and expectancy trended upward from pre-treatment to post-treatment. There was also evidence suggesting that the intervention resulted in clinically meaningful change in self-reported performance of daily activities in six out of seven participants and satisfaction with performance in four out of seven participants. The single individual that did not show a clinically meaningful improvement in performance or satisfaction with daily activities was the only participant with impaired neuropsychological test performance on multiple tests across multiple domains.

While these studies add to the cognitive rehabilitation literature for PD by shifting from treatment approaches targeting impairment-level functions to those designed to provide training in compensatory strategies, investigating whether trained strategies transfer to daily activities, and considering patients' perspectives on goals and treatment rationale, they are limited in several ways. In the case of the Foster et al. (2017a) and Goedeken et al. (2017) studies, adequate training and practice in functional activities was not provided, and participants' baseline cognitive status was not well-described. Foster et al. (2017b) sufficiently described participants' cognitive profile, but only one individual met criteria for probable cognitive impairment. That participant was the only individual that did not report clinically meaningful improvements in performance and satisfaction in daily activities following treatment, which is consistent with other literature that has suggested that internally-generated strategies may be less effective than externally-cued strategies for individuals with cognitive impairment secondary to PD (Goedeken et al., 2017; Knoke, Taylor, and Saint-Cyr, 1998; Spencer, 2007). Moreover, given mild neurocognitive disorder (mild NCD) in PD has been identified as a risk factor for major NCD and evidence supports the use of externally-aided strategies in individuals with dementia, it

might be most helpful and cost-effective to teach strategies that can continue to benefit these individuals should cognitive function further decline or eventually convert to major NCD (e.g., Clare et al., 2010; Schmitter-Edgecombe, Howard, Pavawalla, Howell, & Rueda, 2008).

Proposed Study Rationale

Focus on external cognitive aids. External cognitive aids, or assistive technology for cognition (ATC), are tools that facilitate the completion of daily activities by reducing demands on an individual's cognitive challenges and/or altering the activity or environment to capitalize on an individual's cognitive strengths (Gillespie, Best, & O'Neill, 2012; Leopold, Lourie, Petras, & Elias, 2015; Sohlberg & Turkstra, 2011; Wild, 2013). These tools are often categorized by their technological sophistication. *No technology* aids include paper-based tools such as notebooks and wall calendars, and *low technology* aids include items such as alarm clocks and kitchen timers. *High technology* aids range from relatively inexpensive, commercially-available devices and applications, such as personal digital assistants (PDAs) and smartphones, to costly, specialized, and/or custom-built devices (Leopold et al., 2015; Sohlberg & Turkstra, 2011; Wild, 2013). Literature on the use of external aids to compensate for cognitive impairment is abundant for several clinical populations, including stroke, major NCD, and traumatic brain injury (TBI) (Gillespie et al., 2012). In fact, there is sufficient high-quality evidence supporting the effectiveness of external aids to compensate for memory impairment secondary to TBI and stroke that their use with these populations has been endorsed as a practice guideline by several groups of experts, including the American Congress of Rehabilitation Medicine's Brain Injury Interdisciplinary Special Interest Group, the European Federation of Neurological Societies, and the INCOG Expert Panel (Cappa et al., 2005; Cicerone et al., 2005; Cicerone et al., 2000; Velikonja et al., 2014). There are also numerous studies demonstrating the effectiveness of

external aids in compensating for impairments in attention and executive functions, including initiation, organization, planning, and problem solving (Fish et al., 2006; Gentry, Wallace, Kvarfordt, & Lynch, 2008; Gillespie et al., 2012; Leopold et al., 2015; Wilson, Emslie, Quirk, & Evans, 2001).

While literature on the use of external cognitive aids is robust for acquired brain injury, Smasne and colleagues (2017) were the first to evaluate their use in individuals with cognitive impairment secondary to PD. Their 8-week treatment study targeted use of external aids to improve functional performance in daily activities in individuals with cognitive impairment secondary to PD. Specifically, the authors employed systematic instruction principles to teach the use of external aids, including cell phone calendars/alerts, medication organizers, and tools to locate missing items (e.g., Tile). All three study participants demonstrated improvements on personally-identified goals and self-reported measures of well-being and depression. Furthermore, improvements maintained at one-month follow-up. These results suggest that training external aids might prolong independence in functional activities for individuals with PD and cognitive impairment, which may in turn improve quality of life, decrease financial strain, and reduce caregiver burden. Therefore, additional research in training external aids in individuals with PD is warranted.

External aid selection. A relatively recent systematic review by Charters, Gillett, and Simpson (2015) highlighted the benefits of high technology portable devices, such as PDAs and smartphones, over non-portable cognitive aids. These benefits included their relative ease of use in multiple locations (e.g., home, work, community, and social outings), social acceptability, increased adoption by the general population, and accessibility options for individuals with motor and sensory challenges (Charters et al., 2015). Portable electronic aids may also be

superior to their paper-based counterparts because they can further compensate for challenges in remembering to use or internally initiate the use of paper-based aids (Dowds et al., 2011; Gentry et al., 2008). Although the extensive functionality of high technology tools may make them more complex to use, and therefore more difficult to learn, there is evidence that individuals with cognitive impairment and limited to no familiarity with the type of high technology aid to be trained can still learn to use and apply it (e.g., Ehlhardt Powell et al., 2012).

Smartphones, which are mobile phones with advanced features (e.g., Wi-Fi capabilities, navigation/global positioning system, camera, and access to hundreds of thousands of apps) may be a particularly powerful portable ATC device due to their functional versatility and increasing ubiquity, including among older adults and individuals from low-income households. According to 2016 Pew Research Center data, 77% of Americans own a smartphone[3] (Pew Research Center, 2017). Recent systematic reviews on ATC have identified evidence supporting the use of smartphones as ATC devices for individuals with heterogeneous cognitive profiles (Charters et al., 2015; Gillespie et al., 2012). Studies covered by these reviews and those published later have used smartphones to alert, remind, and prompt individuals with deficits in attention, executive functions, and memory (Gillespie et al., 2012, Svoboda & Richards, 2009; Svoboda, Richards, Polsinelli, & Guger, 2010; Svoboda, Richards, Leach, & Mertens, 2012; Svoboda, Richards, Yao, & Leach, 2015). Perhaps the most well-designed studies investigating the use of smartphones as ATC devices are a series of case studies conducted by Svoboda and colleagues (2009, 2010, 2012, & 2015). These studies demonstrated that individuals with moderate-to-severe memory impairment secondary to various etiologies of acquired brain injury learned to independently use and apply the calendar and reminder functions on their commercial

[3] Among older adults, 74% ages 50 to 64 own a smartphone, while 42% (up from just 18% in 2013) of Americans ages 65 and older own a smartphone. 64% of individuals from households earning $30,000 or less per year also now own a smartphone.

smartphones to improve performance on everyday memory tasks immediately following intervention and at 12 to 19 months follow-up. Four of the ten participants that benefited from the treatment also demonstrated baseline impairments in other cognitive domains, including attention, processing speed, and executive functions (Svoboda et al., 2012).

One theme that emerged from participant goals in the Smasne et al. (2017) study was an interest in learning to use the smartphone more effectively to compensate for challenges in organization, planning, initiation, and memory (including prospective memory). This finding is consistent with that reported in another recent study, which found that most of the goal statements developed by a group of individuals with mild to moderate PDD or dementia with Lewy Bodies involved learning or relearning to use a technological device or software (Watermeyer et al., 2016). Learning to use smartphones to improve performance in daily activities and participation in leisure and social functions may present an opportunity to leverage existing participant motivation and preexisting device familiarity. The proposed study therefore seeks to build upon the preliminary success achieved by Smasne and colleagues (2017) in training the use of commercial smartphones as ATC devices to compensate for planning and organizational challenges in individuals with PD and cognitive impairment.

Instructional approach to training external aids. The key to success in training any external aid is ensuring that the individual (1) learns to use the aid correctly and (2) remembers to use the aid in his/her daily life. Systematic instruction comprises a collection of instructional methods and training variables designed to support the initial acquisition, generalization, and maintenance of new learning in individuals with neurological compromise secondary to a variety of etiologies, including acquired brain injury and major NCD (Ehlhardt et al., 2008; Sohlberg & Turkstra, 2011). These methods and training variables are outlined in Table 2 and support three

Table 2. Systematic instruction methods and training variables.

Key Instructional Methods	
Method	**Description**
Errorless Learning	The acquisition phase of learning is supported upfront by clinician models to obviate trial-and-error learning. In the event of an error, immediate corrective feedback is provided to prevent the individual from learning the error.
Method of Vanishing Cues	As the individual demonstrates a predefined criterion for success with the training target, cues/supports are gradually faded.
Spaced Retrieval	Explicit learning is bypassed by priming the individual through repeated trials of stimulus-response pairings. If an accurate response is provided, trials are presented over increasing time intervals.
Key Training Variables	
Variable	**Description**
Task Analysis	Intervention targets are clearly delineated. Complex tasks, such as multistep procedures, are broken down into simpler components.
Strategies to Promote Effortful Processing	Strategies such as visualization, verbal elaboration, and self-generated learning techniques have been demonstrated to increase recall.
Sufficient Practice	It has been demonstrated that studies involving greater training periods (6 or more sessions) produce better learning outcomes.
Distributed Practice	Following initial massed practice, providing frequent opportunities for distributed practice promotes consolidation and maintenance of learning.
Ecological Validity	Personally-relevant tasks and stimuli support learning, generalization, and learning engagement.
Stimulus Variation	Multiple stimuli are used during training to support generalization.

Sources: Ehlhardt et al., 2008; Ehlhardt Powell et al., 2013; Sohlberg & Turkstra, 2011.

key objectives: (1) minimizing errors during the acquisition of new information or skills by providing explicit models, (2) enhancing the learner's engagement by focusing on personally-relevant activities, and (3) guiding application practice to promote generalization and maintenance. Systematic instruction is well-supported by research and has been demonstrated to be more effective than conventional instructional methods (e.g., trial-and-error learning) in supporting new learning, including training high technology ATC devices, in individuals with heterogenous cognitive profiles (Ehlhardt et al., 2008; Ehlhardt Powell et al., 2012; Svoboda et al., 2009; Svoboda et al., 2010; Svoboda et al., 2012; Svoboda et al., 2015).

Training format. While systematic assessment and instruction of ATC are evidence-based practices, their implementation in clinical settings may be difficult due to limited patient financial resources; constraints on therapists' time due to productivity standards, large caseloads, and long waitlists; and restrictions on the number of covered treatment sessions imposed by insurance companies[4]. One proposed solution for providing more efficient, and potentially more cost-effective, treatment may be to develop group or hybrid treatment programs (Ehlhardt Powell, Glang, & Ettel, 2013; Huckans et al., 2010; Ownsworth, Fleming, Shum, Kuipers, & Strong, 2007; Sohlberg & Turkstra, 2011). While forming and implementing group treatment programs may not be feasible in all clinical settings, if it is possible, group and/or hybrid treatment may offer benefits to both clinicians and patients. Within INCOG's practice guidelines for the management of memory deficits following TBI, group treatment is endorsed as an

[4] Many insurance companies participating in state and federal marketplaces have adopted annual session caps on outpatient rehabilitation services. In the state of Washington, this cap is typically 25 outpatient visits for physical therapy (PT), occupational therapy (OT), and speech-language therapy (ST) combined (e.g., 2017 Regence BlueShield individual plans, 2017 Premera Blue Cross PersonalCare plans). The symptoms of PD often necessitate all three types of rehabilitation services. Furthermore, within speech-language therapy services, many individuals with PD may also require speech, voice, and/or swallowing therapy. This significantly reduces the number of covered visits for cognitive treatment. Within the Medicare framework, outpatient visits are covered by Medicare Part B. Based on 2017 Therapy Caps and reimbursement rates, if an individual allotted 50% of their $1,980 therapy cap for PT and ST services combined to ST services and only received one-on-one cognitive treatment, they could receive a maximum of 9 1-hour visits before a manual review would be required to determine medical necessity of services (American Speech-Language-Hearing Association [ASHA], 2016).

effective format for the training of internal memory strategies. Several studies have also demonstrated positive outcomes from group treatments that train the use of external aids for individuals with cognitive impairment secondary to acquired brain injury. These outcomes have included an increase in the perceived usefulness and usage frequency of cognitive aids, reduced self- and informant-reported everyday memory failures, and improved performance in structured functional activities, such as simulated medication management and bill paying tasks (Huckans et al., 2010; Radford, Lah, Thayer, Say, & Miller, 2012; Schmitter-Edgecombe & Dyck, 2014; Schmitter-Edgecome, Fahy, & Long, 1995; Thickpenny-Davis & Barker-Collo, 2007).

Several unique benefits to training the use of external cognitive aids in a group format rather than in an individualized format have also been cited. These benefits encapsulate two general themes: social support and practice. Studies have noted that participants report benefits from receiving encouragement from and working with others who are experiencing similar challenges, gaining comfort from knowing they are not alone, and having access to additional opportunities for general comradery and social participation (Huckans et al., 2010; Schmitter-Edgecombe & Dyck, 2014; Schmitter-Edgecome et al., 1995). Additionally, Huckans and colleagues (2010) note that the group format allowed participants to share multiple different applications of trained strategies with one another, which may enhance learning and generalization.

Although relatively limited research exists comparing the effectiveness of group and individualized treatment formats for cognitive rehabilitation, at least two studies found that combined or hybrid approaches, which include both group and individual treatment components, appear to have a benefit over individual and/or group formats alone (Ownsworth et al., 2007; Vestri et al., 2014). Thus, even with group treatment demonstrating several potential advantages

over individual treatment, there may still be a benefit to supplementing group treatment with individual treatment sessions to allow for training of individualized, patient-centered goals and address practical issues in the provision of group instruction, such as variability in cognitive profiles, learning rates, and learning styles.

Measuring training effects for personally-relevant goals. Goal Attainment Scaling (GAS) is a method for systematically and objectively quantifying treatment progress in both research and clinical practice. It may be used when standardized measures do not exist or are not appropriate to measure treatment outcomes. This is often the case in rehabilitation when treatment goals are personally-relevant and target activity limitations and participation restrictions (Krasny-Pacini, Evans, Sohlberg, & Chevignard, 2016). GAS is therefore compatible with a person-centered treatment approach. An additional benefit to GAS is that it uses a 5-point scale, typically -2 to +2, to measure varying levels of goal attainment. Because this scale is consistent across goals, scores can be compared between goals within and across participants, as well as aggregated into a single T-score to demonstrate overall group response to a common treatment (Krasny-Pacini et al., 2016). Because GAS is particularly susceptible to bias, it is important that appropriate controls are implemented to ensure the reliability and validity of results. Krasny-Pacini and colleagues (2016) recently summarized proposed criteria outlined in the GAS literature for writing GAS to improve reliability and validity. The authors also summarize additional recommended criteria for the application of GAS in research. These criteria are explained in Table 3.

Table 3. Proposed criteria for Goal Attainment Scaling (GAS) implementation.

Core Criteria	
	Description
Validity	1. GAS goals must be functional, important, and reflect meaningful change to the client. Therefore, GAS goals should be collaboratively set and scaled with the client and the ICF domain addressed by each goal should be noted to ensure that most address activity or participation domains. 2. Trained GAS goals used to measure treatment progress should be specific to the intervention targets and untrained GAS goals used to measure treatment generalization should be related enough to the treatment targets that they could reasonably be expected to change as a result of the intervention.
Reliability: GAS Writing	3. The time allotted to goal attainment should be defined in advance. 4. All GAS levels must be realistic in terms of attainability (i.e. no levels reflect miraculous change) and difficulty (i.e. not so easy that the effects of treatment are overstated and not so difficult that a potentially effective treatment appears ineffective). 5. The degree of difficulty required to progress from one level to the next should be the same between all levels. GAS levels should not overlap, nor should any gaps exist between levels. 6. GAS levels should be tailored to each client's baseline performance, where baseline represents a score of -1 or -2. Baseline scores should be consistent across goals within and across clients (i.e. if one scale sets baseline performance at the level of -1, all scales should set baseline performance at the level of -1).
Reliability: GAS Writing & Scoring	7. GAS levels should be sufficiently described, and the scale should not have any blank levels requiring the reader/scorer to infer content from adjacent levels. An individual who is independent from the GAS writer should be able to easily and reliably use the scale. 8. Each GAS should measure only one variable for change. 9. GAS levels should be measurable and thus defined based on observable behaviors.
Additional Recommended Criteria for the Application of GAS in Research	
1. Individuals writing and scoring GAS goals should be trained. 2. GAS goals should be set prior to randomization or GAS writers should be blind to group assignment. 3. GAS scoring should be tested for interrater reliability. 4. GAS goals should be scored by a blind individual who is independent from the GAS writer and treating clinician. 5. Control goals that would not be expected to respond to treatment should be used. 6. Two distinct GAS scales should be developed by independent clinicians to evaluate participants. 7. GAS goals should be set by a group or verified by an external judge. 8. Examples of GAS scales should be provided in the report.	

Sources: Krasny-Pacini et al., 2016.

Research Questions & Hypotheses

This study evaluated a 5-week hybrid (small group plus individual) systematic instruction program for individuals with cognitive impairment secondary to PD. The program focused on training voice commands (i.e. "Hey Siri" or "OK Google") to use two primary smartphone functions: (i) reminders and (ii) the calendar. Specifically, participants were trained to use voice commands to enter, view, clear (or mark as completed), and delete reminders and enter, view, delete, and modify calendar events (i.e., "Targeted Smartphone Skills"). Voice commands were selected as an efficient access method to address progressive motor impairments in PD. The reminder and calendar functions were chosen because they can be used to address common cognitive complaints in individuals with PD (e.g., difficulty with scheduling and organization; Smasne, 2017). This study tested the following research questions:

1) What is the effect of a 5-week hybrid individual and small group treatment program on the acquisition of Targeted Smartphone Skills as assessed by pre-treatment, mid-treatment, and post-treatment **measures of accuracy** (number of errors) **and rate** (total time to complete all steps) for each Targeted Smartphone Skill (primary outcome measures)?
2) What is the impact of applying Targeted Smartphone Skills to personally relevant goals as assessed by changes in pre-treatment to post-treatment **Goal Attainment Scaling levels** (primary outcome measure) and **self- and informant-reported measures** of progress and participant and caregiver well-being (secondary outcome measures), specifically:
    a. *Compensation Techniques Inventory*
    b. *Behavioral Rating Inventory of Executive Functions-Adult: Self-Report*

c. *Behavioral Rating Inventory of Executive Functions-Adult: Informant-Report*

d. *PROMIS Item Bank v2.0: Cognitive Function-Short Form 6a*

e. *PROMIS Item Bank v2.0: Satisfaction with Social Roles and Activities-Short Form 6a*

f. *Parkinson's Disease Questionnaire-8*

g. *Beck Depression Inventory II*

h. *Zarit Burden Interview-22* (measure of caregiver burden)

3) Will the primary and secondary outcome measures change at the two-month maintenance phase compared to pre-treatment and immediately post-treatment levels?

4) What is the effect of the hybrid training program on a control problem solving task (i.e. Sudoku puzzle)?

It was hypothesized that participants would learn to complete all steps for each Targeted Smartphone Skill accurately, independently, and at a faster rate than they could prior to treatment. It was further hypothesized that participants would successfully apply Targeted Smartphone Skills to trained personally-relevant goals, as measured by GAS. The application of these skills to personally-relevant goals was further expected to improve self- and informant-reported measures of progress and participant and caregiver well-being. Positive treatment effects were expected to maintain at the two-month follow-up. It was not expected that participants' performance on the control problem-solving task would improve at post-treatment or follow-up.

Methods

Design

This study utilized a case series design with pre-treatment, mid-treatment, post-treatment, and two-month follow-up measures. It was approved by the Human Subjects Internal Review Board of the University of Washington.

Participants

Recruitment. Participants were actively recruited from support groups and community speech language pathologists (SLPs) located within the greater Seattle area.

Eligibility. Participants were selected based on meeting the following inclusion criteria: (1) diagnosis of idiopathic PD by a neurologist (per self-report), (2) stable antiparkinson medication regimen, (3) age 50 to 80, (4) self-reported cognitive challenges that are impacting performance of daily activities, (5) possession and at least monthly use of a smartphone, (6) stated motivation to learn smartphone skills that may be utilized to improve current level of functioning in daily activities, and (7) stated commitment and ability to attend treatment and maintenance sessions at the University of Washington. Exclusion criteria included: (1) diagnosis of atypical parkinsonian disorders or secondary parkinsonism, (2) severe cognitive impairment rendering the individual incapable of providing informed consent or fully participating in the study, (3) severe speech impairment prohibiting use of the smartphone voice command feature, (4) history of deep brain stimulation, (5) severe or uncontrolled psychiatric disorder, (6) severe depression per *Beck Depression Inventory II* (BDI-II) score ≥ 29, (7) history of neurologic compromise beyond PD (e.g., stroke, TBI), (8) premorbid learning disability, (9) alcohol or drug dependent, (10) currently taking sedatives or tranquilizers, (11) vision or hearing not adequate to permit participation in this study, (12) English language skills not adequate to permit

participation in this study, (13) currently participating in behavioral therapy related to cognitive functioning, and (14) currently successfully using the Targeted Smartphone Skills independently.

Description. Three participants completed an initial assessment, but one participant dropped out for medical reasons prior to the first treatment session. Characteristics of all three participants are provided in Table 4. Details regarding smartphone use are provided in Table 5 for the two participants that completed the study.

Procedures

An overview of study procedures is provided in Figure 1. All study components took place at the University of Washington and were conducted by the lead investigator, a graduate student in the medical speech-language pathology master's program. Informed, written consent was obtained from each participant and his spouse prior to the commencement of the initial assessment.

Initial assessment. Once informed consent had been provided, each participant underwent an initial assessment, including (1) a semi-structured interview and needs assessment, (2) neuropsychological screening, (3) self- and informant-report questionnaires evaluating the participant's cognitive function and social participation, as well as the participant's and spouse's well-being, and (4) baseline assessment of Targeted Smartphone Skills (i.e. *Targeted Smartphone Skills Acquisition Probe*).

Interview and needs assessment. A semi-structured interview of the participant and his/her spouse was conducted to determine study eligibility (inclusion and exclusion criteria) and evaluate whether the training provided as part of this study would be important to the participant and address his/her needs. A standardized list of questions (Appendix A) and the *Compensation*

Figure 1. Overview of study procedures and measurement timing.

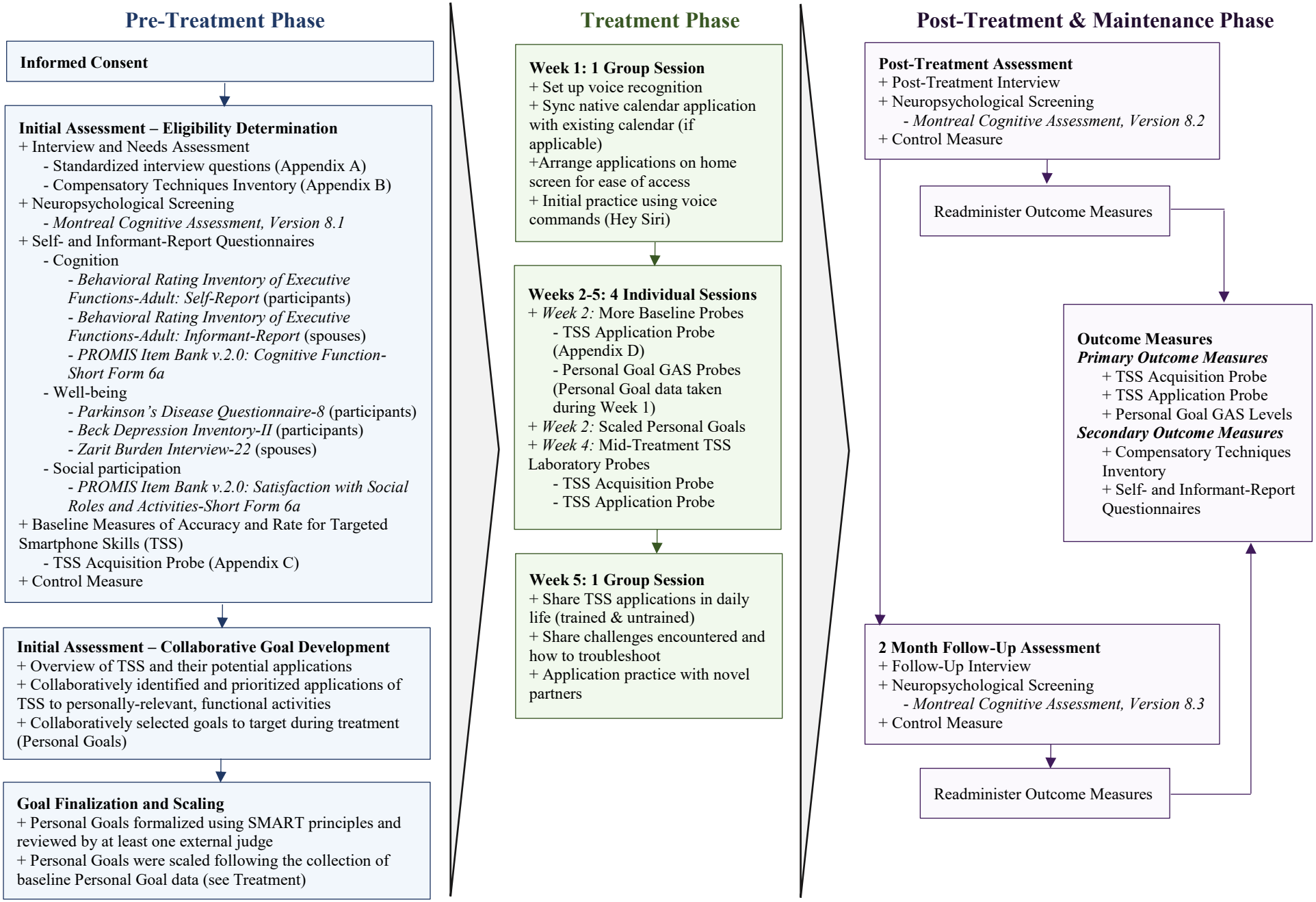


Table 4. Participant characteristics.

	Participant 1 (P1)	Participant 2 (P2)	Participant 3 (P3) Dropped Out
Demographics			
Age	68	59	68
Sex	Male	Male	Female
Race	Caucasian	Caucasian	Caucasian
Native language	English	English	English
Education	M.A., Education	B.S., Computer Science	J.D.
Vocational status	Retired math teacher	On long-term disability from job as a senior manager at a telecommunications company	Self-employed risk management consultant
Relevant Medical History (Based on Self-Report)			
Time since diagnosis	3 years, 9 months	6 years, 3 months	3 years
Side of motor symptom onset	Left	Left	Right
Primary motor symptoms	Tremor, bradykinesia, rigidity	Bradykinesia, rigidity	Tremor
Primary non-motor symptoms	Visual hallucinations, sleep disturbance	Anxiety, sleep disturbance	Anxiety, sleep disturbance
Primary cognitive symptoms	Difficulties with short-term memory, attention, planning, and organization	Difficulties with attention, multitasking, planning, and organization	Difficulties with attention and memory
Cognitive treatment history	None	Some cognitive treatment with SLP	None
Medication status	Stable	Stable	Stable
Daily medications	Valsartan, Ondansetron, Rivastigmine, Carbidopa-Levodopa, Memantine	Azilect, Carbidopa-Levodopa, Entacapone, Trazadone, Melatonin	Unknown
Neuropsychological Screening			
MoCA score[1]	21	29 (29)	25
Self-reported impact on iADLs	No longer completing iADLs independently (relies on spouse)	Still completing iADLs independently, but they are more challenging and take longer	Still completing iADLs independently, but they are more challenging and take longer

[1.] MoCA = Montreal Cognitive Assessment. Form 8.1 was administered for all participants. Because P2 stated that he had recently completed Form 8.1 and reported knowing the list of words used to assess memory before they were given, he also completed Form 7.3 before his first treatment session. This second score is noted in parentheses. Using a cutoff score of 26, the MoCA has 90% sensitivity and 53% to 75% specificity in detecting cognitive impairment (Dalrymple-Alford et al., 2010; Hendershott, Zhu, Llanes, & Poston, 2017; Hoops et al., 2009).

Table 5. Participant smartphone use.

	P1	P2
Smartphone Use		
Make *(model, operating system)*	iPhone 6s *(MKT12LL/A, 11.2.6)*	iPhone 6s Plus *(MKUJ2LL/A, 11.2.6)*
Duration of smartphone experience	1 year with iPhone (no prior experience with any other type of smartphone)	1.5 years with iPhone (previously owned an Android smartphone for several years)
Frequency of use	Daily	Daily
Smartphone functions used	Calls, texts, internet, weather, stocks	To-do lists, alarms, calls, texts, internet, email, banking, weather, news
Self-rated smartphone skill level	Beginner	Intermediate
Voice commands experience	None	Using microphone for speech to text within apps; however, limited experience with Siri
Reminder/calendar function experience	Has a shared calendar with his wife that he can check, but he reported that this is challenging for him	Creates lists in reminder application but not setting time-based reminders; limited experience with calendar application

Techniques Inventory (CTI; Appendix B; Sohlberg & Turkstra, 2011) were used to obtain information necessary to (1) characterize cognitive challenges and their impact on daily activities, (2) identify strategies the participant uses to address cognitive challenges, including use of daily reminder and/or calendar smartphone functions, (3) determine degree of success in implementing existing strategies, and (4) establish whether the individual uses voice commands on his/her smartphone, and if not, whether he/she would be interested in learning how to use voice commands to improve smartphone accessibility. The individual's smartphone model, operating system, and existing native or acquired applications for reminder and calendar functions were noted. The ideal candidate was considered an individual who was (1) self-aware of his/her cognitive challenges, (2) not managing his/her schedule well, presumably due to his/her cognitive challenges (e.g., demonstrating difficulty with organizing, planning, and

initiating daily activities), (3) generally familiar with his/her smartphone but not currently maximizing its functionality to compensate for cognitive challenges, and (4) motivated to address cognitive challenges by learning to use and apply the Targeted Smartphone Skills. If a candidate was a good match, a brief introduction to the study, including its rationale and required time commitment/number of sessions, was provided, and spouses were invited and encouraged to participate in all study components.

Neuropsychological screening. Participants meeting all inclusion/exclusion criteria and identified as good candidates for the study based on the initial interview and needs assessment underwent a neuropsychological screening for descriptive purposes. The *Montreal Cognitive Assessment* (MoCA) is a brief (10-minute) global cognitive screening tool that may be administered in a variety of clinical settings and has three alternate/equivalent versions allowing repeated administration. Compared to other similar tools, several studies support the reliability and validity of the MoCA for screening cognitive status in individuals with PD (Benge et al., 2017; Gill, Freshman, Blender, & Ravina, 2008; Hoops et al., 2009; Zadikoff et al., 2008). The MoCA has demonstrated superior sensitivity relative to the *Mini Mental State Exam* (MMSE) in detecting cognitive impairment in individuals with PD and discriminating mild NCD secondary to PD from major NCD and normal cognition (Dalrymple-Alford et al., 2010; Hoops et al., 2009). Using a cutoff score of 26, the MoCA has 90% sensitivity and 53% to 75% specificity in detecting cognitive impairment (Dalrymple-Alford et al., 2010; Hendershott, Zhu, Llanes, & Poston, 2017; Hoops et al., 2009). Another recent study has recommended using a cutoff score of 25 to optimize sensitivity and specificity (77% and 79%, respectively) for detecting mild NCD (Lucza et al., 2015).

Self- and informant-report questionnaires. Information obtained during the interview and neuropsychological assessment was supplemented by self- and informant-report questionnaires evaluating cognition, well-being, and social participation. Questionnaires were either completed during the session or at home. To further describe **cognition**, the *Behavioral Rating Inventory of Executive Functions-Adult* (BRIEF-A; Roth et al., 2005) and *PROMIS Item Bank v2.0: Cognitive Function-Short Form 6a* (PROMIS-2: CF6a; PROMIS Health Organization and PROMIS Cooperative Group, 2016) were administered. The BRIEF-A comprises 75 items designed to measure daily executive functions, including inhibition, self-monitoring, planning, shifting, initiation, task monitoring, emotional control, working memory, and organization. It includes both self- and informant-report questionnaires, which were compared to determine each individual's degree of self-awareness into his/her cognitive challenges. The PROMIS-2: CF6a includes six questions relating to breakdowns in general cognitive functioning and their frequency, as rated on a 5-point scale from 1 (several times a day) to 5 (never).

Additional information on participant and spouse **well-being** was obtained through the *Parkinson's Disease Questionnaire-8* (PDQ-8), *Beck Depression Inventory-II* (BDI-II), and *Zarit Burden Interview-22* (ZBI-22). The PDQ-8 is an 8-item self-report questionnaire assessing an individual's overall health and well-being across eight functional domains: mobility, activities of daily living, emotional well-being, stigma, social support, cognition, communication, and bodily discomfort (Jenkinson, Fitzpatrick, Peto, Greenhall, & Hyman, 1997). The BDI-II is a self-report questionnaire assessing the intensity of 21 symptoms of depression that has been found to be sensitive to depression in PD (Visser-Meily et al., 2006). The BDI-II was used to exclude participants with severe depression using a cutoff score of ≥ 29 and to determine the presence

and severity of depression at baseline in participants. The ZBI is a 22-item self-report measure designed to assess the degree of strain on overall well-being experienced by informal (unpaid) caregivers, such as family members (Zarit, S. & Zarit, J., 1990). Participants' satisfaction with **social participation** was evaluated using the *PROMIS Item Bank v2.0: Satisfaction with Social Roles and Activities-Short Form 6a* (PROMIS-2: SSRA6a).

Targeted Smartphone Skills (TSS) Laboratory Probes. Participants' performance on each Targeted Smartphone Skill (setting a reminder, viewing a reminder, clearing a reminder, deleting a reminder, entering a calendar event, viewing the calendar, modifying a calendar event, and deleting a calendar event) was assessed in terms of accuracy (number of errors) and rate (total time to complete all steps) using two Targeted Smartphone Skills (TSS) Laboratory Probes (Acquisition Probe and Application Probe). The TSS Acquisition Probe was designed to establish baseline measures of acquisition in a highly structured task (Appendix C). Each skill was elicited individually with a verbal instruction that clearly set the expectation for which TSS was being targeted by including the key words each participant would need to formulate his/her instruction to Siri. The TSS Application Probe was developed to assess participants' ability to use the TSS in a more functional task (see Appendix D for a sample probe for P1 and P2). The TSS Application Probe included two tasks: (i) keeping track of details throughout the day and (ii) creating a schedule for the upcoming week. Each task required the participant to complete five skills. The first task required adding five reminders, while the second task required adding five calendar events. Personally-relevant stimuli were developed for each participant, and the level of complexity was tailored for each participant's baseline cognitive functioning.

Control Measure. To address the internal validity limitations imposed by a case series design, a control measure that was not expected to change due to treatment was administered for

each participant. Participants were allowed 5 minutes to complete as much of an Easy level Sudoku puzzle (each puzzle was sourced from a New York Times Monday paper) as possible. Sudoku requires sustained and alternating attention, working memory, and deductive reasoning. The number of filled boxes (out of 43 total empty boxes), the number of correctly filled boxes, and percentage accuracy (calculated as the number of correctly filled boxes divided by the 43 empty boxes needing to be filled to complete the puzzle) were tracked for each participant (Control Measure).

Collaborative goal development. At the end of the initial assessment, the clinician provided examples of how reminder and calendar functions may be used in everyday life and employed motivational interviewing techniques to collaboratively identify and prioritize personally-relevant goals related to the application of Targeted Smartphone Skills at home or in the community for each participant (Personal Goals). At least one goal was set for each function (reminder and calendar). Personal Goals were scored based on participant- and caregiver-report of performance.

Goal finalization and scaling. Following the initial assessment, all goals were formalized using "SMART" principles (specific, measurable, achievable, realistic/relevant, and time-based; Bovend'Eerdt, Botell, & Wade, 2009). These principles ensured adherence to many of the GAS criteria proposed to improve the psychometric properties of GAS (see Table 3; Krasny-Picini et al., 2016). At least one external judge with GAS experience reviewed the goals to confirm that they were unidimensional and SMART. Once goals were finalized, any changes made to ensure their adherence to SMART principles were discussed with the participants. Participants and spouses in attendance received training on how to collect baseline data for Trained Goals during the first group treatment session. Baseline performance on Trained Goals

was established at the beginning of the first individual treatment session using the data collected during the week between the first group treatment session and first individual treatment session. Trained Goals were then collaboratively scaled (i.e. the five levels of goal attainment were established) with participants and their spouses (if in attendance) based on the core criteria outlined in Table 3. The -1 GAS level was fixed to reflect performance at baseline. Having consistent baseline GAS scores across goals makes comparison of outcome scores within and across participants possible. Setting baseline performance to equate to the -1 instead of -2 level allows for the detection of a decline in performance during subsequent measurements. An outcome score of -1 (i.e. maintenance of baseline performance) represented less than expected performance, while a score of -2 reflected an outcome that was much less than expected. 0, +1, and +2 GAS levels were established to reflect increasing levels of attainment. 0 reflected the expected or target level of performance, while +1 and +2 represented attainment that is greater than expected and much greater than expected, respectively. All levels were reasonably difficult but attainable as determined by consensus across at least two investigators. All GAS scales were reviewed by at least one external judge with GAS experience to verify that each scale has equidistant levels that are sufficiently described (Krasny-Pacini et al., 2016).

Treatment delivery. Treatment included two 1-hour group treatment sessions and four 90-minute individual treatment sessions completed within 5 weeks. Approximately 30 minutes from two of the four individual treatment sessions were dedicated to baseline and mid-treatment probes. The number of treatment sessions was established based on (1) research demonstrating that treatment programs employing systematic instruction achieved better outcomes when training occurred over six or more sessions and (2) the proposed study's goal to develop a training protocol that addresses the challenges of implementing systematic instruction in clinical

practice (i.e. limited time/financial resources and reimbursement constraints imposed by insurance companies).

Session content. Group treatment sessions focused on setting up smartphones for optimal access to reminder and calendar applications, setting up voice recognition for the Hey Siri feature, providing initial introduction and instruction on voice commands, sharing different ways of applying the Targeted Smartphone Skills, providing additional practice opportunities in a new setting with new people to facilitate generalization, and discussing troubleshooting solutions for commonly encountered problems/challenges. Individual treatment sessions focused on training acquisition of Targeted Smartphone Skills and their application to personally-relevant, functional goals. The timing and content of each session is provided in Table 6.

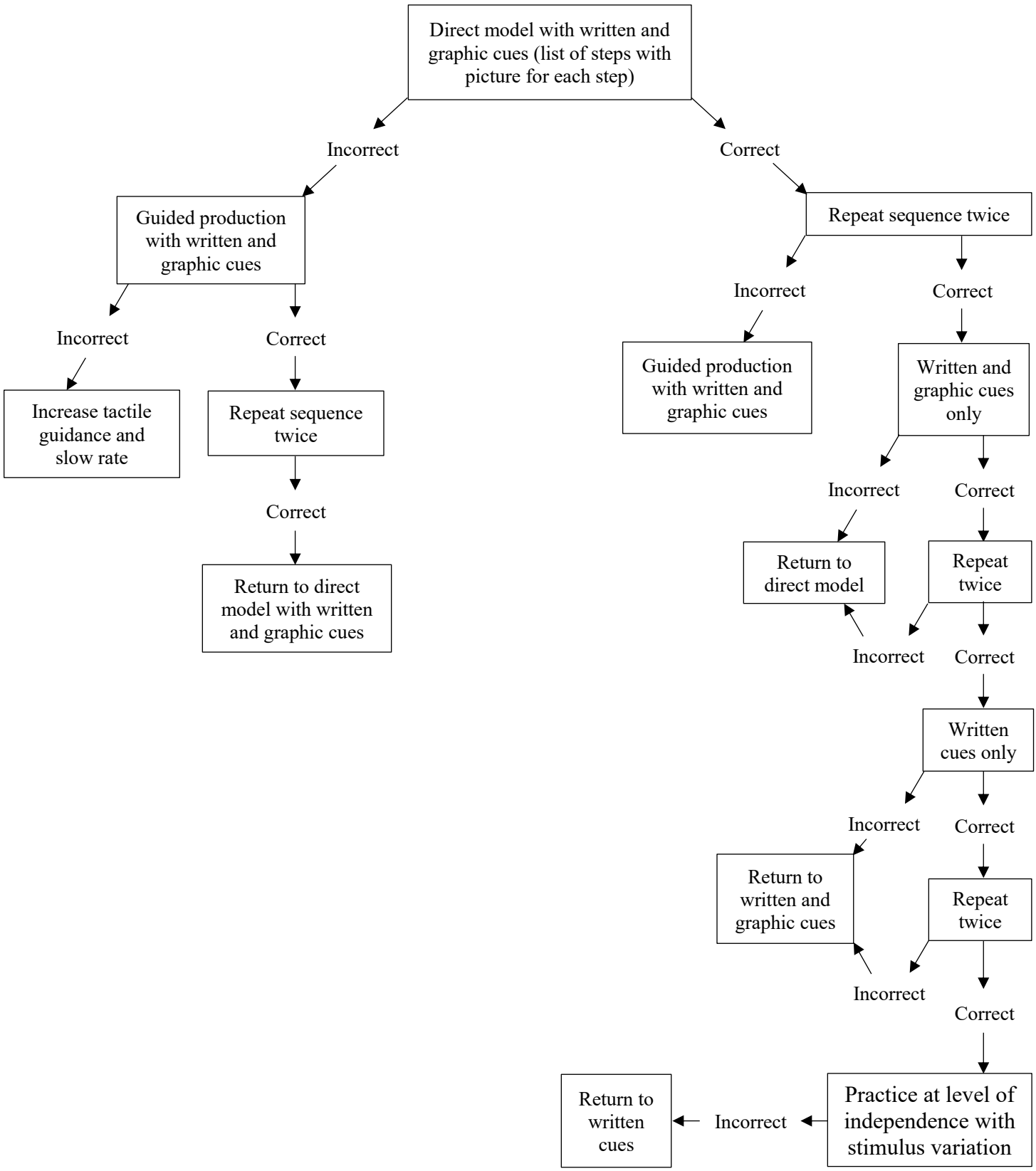
Instructional approach. In keeping with the tenets of systematic instruction, the task analysis for each Targeted Smartphone Skill (Appendix C) clearly defines the treatment targets, and only one Targeted Smartphone Skill was trained at a time. Systematic instruction principles indicate that treatment targets should be taught in order of complexity. Because the Targeted Smartphone Skills related to the reminder function require fewer steps, they were deemed to be the least complex and were thus taught first. Depending on each participant's needs, the full sequence of steps was either targeted all at once, or the steps were chunked into smaller increments and later chained together. As participants learned each new Targeted Smartphone Skill, the lead investigator controlled for errors (method of errorless learning) by supporting each skill in accordance with a most-to-least cueing hierarchy (see Figure 2). Support was faded as the participants met the criterion for success specified in Figure 2 (method of vanishing cues). Once participants could independently perform an individually trained Targeted Smartphone Skill with

Table 6. Summary of treatment session timing and content

	Description of Session Content
Week 1: 1 Group Session	▪ Provided an overview of external aids and their importance ▪ Assisted each participant in cleaning up the home screen on his/her phone ▪ Arranged the reminder and calendar applications to be easily accessible ▪ Instructed participants on how to initiate voice commands (speak clearly and at an adequate pace; "Okay Google" or "Hey Siri"), providing a direct model and high number of trials ▪ Trained participants and/or spouses to collect data for Personal Goal GAS levels ▪ Provided a binder for handouts on session content and homework assignments
Weeks 2-5 4 Individual Sessions	*Week 2:* ▪ Conducted baseline TSS Application probe ▪ Scaled Personal Goals using baseline data collected at home / in the community ▪ Trained use of voice commands for skills related to the reminder function *Week 3:* ▪ Reviewed use of voice commands for skills related to the reminder function ▪ Trained use of voice commands for skills related to the calendar function if criterion for success met for reminder function skills *Week 4:* ▪ Administered mid-treatment TSS Laboratory Probes ▪ Reviewed skills trained during Week 3 and continued training skills that had not yet met criterion for success ▪ Incorporated practice scenarios applying TSS in personally-relevant contexts if criterion for success met for calendar function skills *Week 5:* ▪ Reviewed skills trained during Week 3 and continued training skills that had not yet met criterion for success ▪ Incorporated practice scenarios applying TSS in personally-relevant contexts if criterion for success met for calendar function skills
Week 5: 1 Group Session	▪ Shared applications of TSS (trained or untrained) that they had been using at home ▪ Shared take-aways from treatment ▪ Discussed any commonly encountered problems and how to circumvent ▪ Provided group practice opportunities using simulated activities (e.g., find a partner and schedule a dinner using the TSS) ▪ Requested participants and/or spouses collect data for Personal Goal GAS levels

Note. GAS = Goal Attainment Scaling; TSS = Targeted Smartphone Skills

Figure 2. Illustration of cueing hierarchy.



80% accuracy over 5 trials (Criterion for Acquisition), a new Targeted Smartphone Skill was trained.

During initial skill acquisition, participants completed at least 15 trials per skill trained in any given individual session (sufficient practice) using simulated stimuli (e.g., practice appointments) tailored to each client based on his or her Trained Goals (ecological validity). Practice scenarios, partners, and environments varied throughout treatment to promote generalization (stimulus variation). Once a participant reached the Criterion for Acquisition for a given skill, training shifted to using real-life scenarios provided by the participant (ecological validity; stimulus variation). Additionally, frequent opportunities for distributed practice were provided by increasing the amount of time between practice trials during the session and homework exercises were assigned to promote consolidation and maintenance of learning. To help guide distribution of home practice, the clinician explained the concept of distributed practice to participants and spouses and provided a recommended homework schedule. The final group session served to further support Targeted Smartphone Skill application by providing opportunities to engage in additional practice scenarios with individuals other than the clinician and spouse (distributed practice; ecological validity; stimulus variation). Throughout individual and group treatment sessions, strategies to promote effortful processing were incorporated (e.g., the clinician asked participants to predict their performance before a trial, reflect on what went well / what was challenging during a trial or homework activity, think of the key phrase for the Siri command to complete each skill).

Treatment fidelity. To ensure treatment integrity across sessions and participants, an independent investigator randomly observed approximately 30 to 50% of each participant's treatment program, with observations occurring across both individual and group sessions.

During observation, the independent investigator determined whether each instructional component was conducted as described above and whether the cueing hierarchy was administered correctly using observational checklists (see Appendices E and F). The use of observational checklists to measure treatment fidelity has been described and implemented in speech-language pathology research (Kaderavek & Justice, 2010). The independent investigator and lead investigator met weekly to discuss any issues related to treatment delivery. Treatment fidelity of instructional components was calculated as the number of instructional components observed divided by the total number of instructional components described above. Treatment fidelity was also calculated for the cueing hierarchy by taking the number of trials in which the correct level of support was provided by the clinician divided by the total number of trials observed. In addition, the lead investigator documented the treatment target(s) within each session, number of trials completed for each targeted skill, stimuli used for each targeted skill, level of cueing required for the final trial of each targeted skill, homework assigned during each session, and total duration of each treatment session (see Appendix G for sample treatment log). Participants also documented their homework completion each week (see Appendix H for sample homework log).

Post-treatment and follow-up assessment. Immediately following treatment, participants and their spouses participated in a post-treatment assessment, which included a post-treatment interview (including the CTI), neuropsychological screening, self- and informant-report questionnaires, and assessment of post-treatment performance on the TSS Acquisition Probe, Application Probe, Trained Goal Probes, and Control Measure. Participants and/or spouses provided data on Trained Goals for the week between the final group treatment session and the post-treatment assessment session. The post-treatment interview was designed to obtain

qualitative input from participants and spouses on the treatment program, including overall satisfaction, progress on goals, whether they demonstrated any generalization of Targeted Smartphone Skills to other smartphone functions (e.g., using voice commands to send a text message), what they liked most, what they would change, and perceived advantages/disadvantages of a hybrid treatment format. Two months following treatment, participants returned for a follow-up assessment that included the same components as the post-treatment assessment.

Data Collection and Analysis

The primary outcome measures included indicators of accuracy and rate for the TSS Laboratory Probes and GAS levels for Personal Goals. Accuracy and rate for each Targeted Smartphone Skill was measured through the TSS Laboratory Probes (TSS Acquisition Probe and TSS Application Probe) at pre-treatment (baseline), mid-treatment, immediately post-treatment, and at two-month follow-up. All TSS Laboratory Probes were video-recorded, transcribed, and coded for errors (see Appendix I for error coding instructions). To ensure scoring consistency on TSS Laboratory Probes, an independent external judge transcribed and scored 33.3% of all TSS Laboratory Probes and interrater reliability was calculated using Cohen's Kappa. GAS levels for Personal Goals were measured at pre-treatment (baseline), immediately post-treatment, and at two-month follow-up based on participant- and/or informant-reported performance at home and in the community.

Secondary outcome measures, including self-reported measures of well-being and progress (PDQ-8, BDI-II, BRIEF-A, PROMIS-2: CF6a, PROMIS-2: SSRA 6a, CTI, ZBI-22), and the Control Measure were administered at pre-treatment, immediately post-treatment, and at two-month follow-up. A neuropsychological screening (MoCA) was also administered at pre-

treatment, immediately post-treatment, and two-month follow-up. Although the MoCA was only used for descriptive purposes and the proposed treatment should not have any influence on performance on this measure, the MoCA was re-administered using alternate forms at post-treatment and follow-up to account for the possibility of day-to-day variability in cognitive performance and cognitive decline due to the neurodegenerative nature of PD.

Results

Participant One

Initial assessment. P1, a 68-year-old retired math teacher, was diagnosed with PD in July of 2014. He reported that his cognitive symptoms were greater than his physical symptoms and that his attention, memory, and organization were most affected. P1 scored a 21 on the MoCA Version 8.1, which falls below the suggested cut-off score of 26, indicating cognitive impairment (Dalrymple-Alford et al., 2010; Hendershott et al., 2017; Hoops et al., 2009). Item analysis revealed difficulties in the areas of visuospatial skills, short-term memory, working memory, and abstraction. On the BRIEF-A, P1 endorsed clinically significant challenges in all executive domains except self-monitoring, with greatest difficulty noted in the areas of initiation, working memory, planning and organization, and task monitoring. On the BRIEF-A Informant Report, P1's spouse also endorsed observing clinically significant challenges in initiation, working memory, and task-monitoring, but her ratings were lower than P1's across all domains, reflecting slightly less concern.

P1 explained that his cognitive challenges have had a significant impact on his independence. Specifically, P1 indicated that he no longer drives and relies on his spouse to manage his schedule, medications, and finances. He also reported that he has difficulties with reading, particularly at paragraph and discourse levels. On the CTI functional cognition screen,

P1 reported that he frequently does not know the date and constantly does not know his upcoming appointments. He marked both of these areas as important goal areas. Furthermore, while P1 noted that he rarely misses appointments, this was because P1's spouse provided transportation and verbal reminders to get ready and leave.

P1 had obtained his first smartphone, the iPhone 6, a little over one year ago. He expressed frustration in his attempts to learn to use the phone, indicating that he "fought with it" for a few months before giving up. He continues to use the phone daily for basic tasks, such as checking the weather, texting, and calling. For scheduling, P1 and his spouse use a shared Google calendar that is managed by P1's spouse. P1 stated that he rarely checks the calendar on his phone because he can't remember the steps to do so. Although P1 did not have any prior experience using Siri to navigate his phone, he had some experience using voice commands with the Amazon Alexa. At baseline, P1 rated his skill level as beginner (27 out of 100 on a visual analog scale with 0 being absolute beginner and 100 being expert). He rated his confidence in using the smartphone as 22 on a 100-point scale (with 0 being not at all confident and 100 being very confident) and his satisfaction with his smartphone skills as 21 on a 100-point scale (with 0 being not at all satisfied and 100 being very satisfied).

Goal development, finalization, and scaling. P1 desired to improve his smartphone skills enough to lessen his frustration with the device and increase his independence with scheduling and remembering to complete daily tasks, such as taking his medications. The GAS Goals in Tables 7 and 8 were co-constructed to target these areas. They were scaled collaboratively with P1 and P1's spouse following an assessment of baseline performance. Baseline performance was set to level -1 for all goals.

Treatment. P1 attended 9 sessions, including three 90-minute assessment sessions

Table 7. P1's Personal GAS Goals for the reminder application.

Reminder Application				
Goal 1: Level of support required to remember to enter time-based reminders for daily reminders				
-2	**-1**	**0**	**1**	**2**
P1 does not enter time-based reminders, even when his spouse reminds him to do so	P1 only enters time-based reminders when his spouse reminds him to do so (100% of the time)	P1 independently enters some time-based reminders, but continues to require a reminder from his spouse ≥ 50% of the time	P1 independently enters many time-based reminders, but continues to require occasional (< 50% of the time) reminders from his spouse	P1 consistently (100% of the time) enters time-based reminders without his spouse needing to remind him to do so
Goal 2: Level of support required to successfully enter time-based reminders for daily reminders				
-2	**-1**	**0**	**1**	**2**
P1 can enter time-based reminders into his iPhone using Siri only when provided **maximum support** (i.e. demonstration or step-by-step guided instruction)	P1 can enter time-based reminders into his iPhone using Siri only when provided **minimum** (i.e. written stimulus / assistance formulating the correct instruction for Siri) **to moderate support** (i.e. written step-by-step directions)	P1 can enter time-based reminders into his iPhone using Siri **without support some of the time**, but requires support ≥ 50% of the time	P1 can enter time-based reminders into his iPhone using Siri **without support most of the time**, but continues to require occasional support (<50% of the time)	P1 can enter time-based reminders into his iPhone using Siri **consistently (100% of the time) without support**
Goal 3: Level of support required to respond to time-based phone reminders				
-2	**-1**	**0**	**1**	**2**
P1 does not respond to iPhone reminders, even when his spouse reminds him to do so	P1 only responds to iPhone reminders when his spouse reminds him to do so (100% of the time)	P1 independently responds to some iPhone reminders but requires a reminder from his spouse ≥ 50% of the time	P1 independently responds to most iPhone reminders, but continues to require occasional (< 50% of the time) reminders from his spouse	P1 consistently responds to time-based reminders without his spouse reminding him to do so
Goal 4: Perceived effort with using the iPhone reminder application in daily life				
-2	**-1**	**0**	**1**	**2**
Using the iPhone reminder application in daily life is **impossible**	Using the iPhone reminder application in daily life is **possible but very effortful**	Using the iPhone reminder application in daily life is **moderately effortful**	Using the iPhone reminder application in daily life is **minimally effortful**	Using the iPhone reminder application in daily life is **not at all effortful**

Table 8. P1's Personal GAS Goals for the calendar application.

Calendar Application				
Goal 1: Level of support required to remember to enter calendar events for real activities				
-2	**-1**	**0**	**1**	**2**
P1 does not enter calendar events, even when his spouse reminds him to do so	P1 only enters calendar events when his spouse reminds him to do so (100% of the time)	P1 independently enters some calendar events, but continues to require a reminder from his spouse ≥ 50% of the time	P1 independently enters many calendar events, but continues to require occasional (< 50% of the time) reminders from his spouse	P1 consistently (100% of the time) enters calendar events without his spouse needing to remind him to do so
Goal 2: Level of support required to successfully enter calendar events for real tasks				
-2	**-1**	**0**	**1**	**2**
P1 **cannot enter** calendar events into his iPhone using Siri, even when provided maximum support (i.e. demonstration or step-by-step guided instruction)	P1 can enter calendar events into his iPhone using Siri only when provided **maximum support** (i.e. demonstration or step-by-step guided instruction)	P1 can enter calendar events into his iPhone using Siri when provided **minimum** (i.e. written stimulus / assistance formulating the correct instruction for Siri) **to moderate support** (i.e. written step-by-step directions) most of the time, but may still require occasional maximum support (<50% of the time)	P1 can enter calendar events into his iPhone using Siri **without support some of the time**, but requires support ≥ 50% of the time	P1 can enter calendar events into his iPhone using Siri **without support most of the time**, but continues to require occasional support (<50% of the time)
Goal 3: Perceived effort with using the iPhone calendar application in daily life				
-2	**-1**	**0**	**1**	**2**
Using the iPhone calendar application in daily life is **impossible**	Using the iPhone calendar application in daily life is **possible but very effortful**	Using the iPhone calendar application in daily life is **moderately effortful**	Using the iPhone calendar application in daily life is **minimally effortful**	Using the iPhone calendar application in daily life is **not at all effortful**

(initial / baseline, post-treatment, and follow-up), two 60-minute group sessions, and four 90-minute individual sessions. Approximately 30 minutes of each of two individual sessions were dedicated to probes (baseline and mid-treatment), as well as establishing GAS goals and levels. Therefore, total training time was about seven hours. Although training was designed to target eight smartphone skills within the reminder and calendar applications, only four were taught to P1: adding a reminder using Siri, viewing reminders using Siri, adding a calendar event using Siri, and viewing the calendar using Siri. The remaining four skills were not targeted because P1 did not meet the criterion for success on initial skills soon enough to advance to more complex skills within the allotted treatment period of 5 weeks. The first two individual sessions were dedicated to training Skills 1 and 2 (adding and viewing reminders using Siri), and the third session was dedicated to training Skills 5 and 6 (adding and viewing calendar events using Siri). The final individual session used real reminders and appointments to practice applying Skills 1, 2, 5, and 6. P1's spouse accompanied P1 to all sessions and was an integral part of training. She assisted P1 in completing his daily homework tasks and took all home data to support GAS level ratings for Personal Goals.

Primary outcome measures.

TSS Laboratory Probes. P1's performance on the TSS Laboratory Probes at baseline, mid-treatment, post-treatment, and follow-up are displayed in Table 9 (Acquisition Probe) and Table 10 (Application Probe). Initially, performance on the probes was to be assessed based on measures of accuracy (number of errors) and rate (time to complete all steps within a skill). Rate was chosen as an outcome measure to capture improvements in efficiency that may have resulted from acquisition training. However, while calculating and analyzing rate, it became clear that this measure was influenced by several confounding factors, including the participant's speed of

Table 9. P1's Targeted Smartphone Skills Acquisition Probe performance across skills and time.

TSS Acquisition Probe		Baseline	Mid-Treatment	Post-Treatment	Follow-Up
Reminder Function					
Skill 1 (Add): TRAINED	Attempts	1	1	1	1
	Errors	2	0	0	1
	Success	No	Yes	Yes	Yes
Skill 2 (View): TRAINED	Attempts	1	1	2	1
	Errors	2	0	2	1
	Success	No	Yes	Yes	Yes
Skill 3 (Clear): NOT TRAINED	Attempts	1	1	0[1]	2
	Errors	3	1	N/A[1]	4
	Success	No	No	No	No
Skill 4 (Delete): NOT TRAINED	Attempts	1	1	0[1]	1
	Errors	2	1	N/A[1]	1
	Success[2]	No	No	No	Yes
Calendar Function					
Skill 5 (Add): TRAINED	Attempts	1	1	1	1
	Errors	3	1	0	1
	Success	No	Yes	Yes	Yes
Skill 6 (View): TRAINED	Attempts	1	1	1	1
	Errors	2	0	0	0
	Success	No	Yes	Yes	Yes
Skill 7 (Modify): NOT TRAINED	Attempts	1	1	0[2]	1
	Errors	4	3	N/A[2]	2
	Success	No	No	No	Yes
Skill 8 (Delete): NOT TRAINED	Attempts	1	1	0[3]	1
	Errors	2	1	N/A[3]	1
	Success	No	No	No	No
Totals					
# of Attempts *(Trained / Not Trained)*		**4 / 4**	**4 / 4**	**5 / 0**	**4 / 5**
# of Errors *(Trained / Not Trained)*		**9 / 11**	**1 / 6**	**2 / N/A**	**3 / 8**
# Successfully Completed *(Trained / Not Trained)*		**0 / 0**	**4 / 0**	**4 / 0**	**4 / 2**

[1.] At Post-Treatment, P1 completed Skill 2 (View) for Skills 3 (Clear) and 4 (Delete). Therefore, errors cannot be calculated reliably for Skills 3 and 4.
[2.] At Post-Treatment, P1 stated he did not think he could complete Skill 7 (Modify).
[3.] At Post-Treatment, P1 completed Skill 6 (View) for Skill 8 (Delete). Therefore, errors cannot be calculated reliably for Skills 7 and 8.

Table 10. P1's Targeted Smartphone Skills Application Probe performance across tasks and time.

Application Probe	Baseline	Mid-Treatment	Post-Treatment	Follow-Up
Reminder Task				
Total Attempts (For 5 Skills)	5	5	5	5
Total Errors	11	3	4	5
Percentage of Reminders Successfully Added (Out of 5)	40%	60%	100%	80%
Perceived Effort (100 mm VAS)	9 mm	63 mm	72 mm	28 mm
Calendar Task				
Total Attempts (For 5 Skills)[1]	0	2	2	5
Total Errors[1]	N/A	1	2	2
Percentage of Calendar Events Successfully Added (Out of 5)	0%	40%	40%	100%
Perceived Effort (100 mm VAS)	47 mm	12 mm	50 mm	46 mm

[1.] At Baseline, P1 completed steps to add reminders instead of calendar events for all 5 items. Therefore, total errors cannot be calculated reliably. At mid-treatment and post-treatment, P1 completed steps to add reminders instead of calendar events for 3 out of 5 items. Total errors only includes errors made when P1 attempted to schedule a calendar event.

processing and initiation, differences in stimuli length (e.g., "schedule a meeting with Alexandra" takes more time to say than "schedule brunch with Sam"), phone speed, and Siri's inconsistent responses of variable duration and number of steps. An attempt was made to control for as many of these factors as possible by calculating time for each individual step within each skill and removing any time associated with the phone's processing time or Siri's responses. This process was prohibitively tedious, and the result still did not appear to approximate the intended construct (see Appendix J for a sample of the modified instructions for calculating rate and resulting data). Therefore, rate was not included in the final analysis. Two additional measures

reflected in Tables 9 and 10 are "attempts" and "success." An attempt was defined as the completion of one or more steps toward the achievement of the outcome of an elicited TSS. Success was defined as whether the outcome of the elicited TSS was achieved, regardless of errors (i.e. were the steps correct enough for Siri to respond in the intended way, and/or was the participant able to self-correct errors to achieve the desired outcome). Table 10 also presents data on the participant's perceived effort for completing each task.

TSS Acquisition Probe. P1 demonstrated improvements following treatment in measures of accuracy and success. His total errors across all trained skills (Skills 1, 2, 5, and 6) decreased from 9 at baseline to 2 post-treatment, and his number of successfully completed skills increased from 0/4 trained skills at baseline to 4/4 trained skills post-treatment. These improvements were maintained at two-month follow-up. P1 did not demonstrate improvements in the number of successfully completed untrained skills (Skills 3, 4, 7, and 8) from baseline to post-treatment, which remained steady at 0. However, P1 completed 2/4 untrained skills successfully at two-month follow-up. The improvement in success was not due to changes in P1's behaviors but rather an update to Siri that now permitted the verbal instructions P1 gave for deleting reminders/events[5].

TSS Application Probe. P1 also showed improvements on the Application Probe. On the reminder task, P1's total errors decreased from 11 at baseline to 1 at post-treatment, and he increased the percentage of reminders successfully added (out of 5 total reminders) from 40% at baseline to 100% post-treatment. At two-month follow-up, P1 maintained improvements in total

[5] P1 rescheduled events at baseline by deleting the old event and adding a new event. He continued to do this at follow-up. However, he could now successfully delete reminders/events using the instructions he used at baseline due to a Siri update. Although total errors decreased for all untrained skills from baseline to mid-treatment and from baseline to two-month follow-up, analysis of the errors revealed that this was due to a reduction in errors for a common step across all skills. At baseline, P1 consistently attempted to activate Siri by saying "Siri" instead of "Hey Siri" across all skills. However, at mid-treatment and 2 months follow-up, P1 was consistently saying "Hey Siri" to activate Siri, and this alone accounted for the reduction in errors from baseline to mid-treatment and two-month follow-up on untrained skills.

errors but his success decreased to 80% due to an error in which P1 did not speak clearly enough for Siri to understand his instruction. On the calendar task, it is not possible to comment quantitatively on improvements in total errors from baseline to post-treatment because P1 attempted to add reminders instead of calendar events for all 5 items at baseline. However, P1 showed some improvement in that he increased the percentage of successfully added calendar events (out of 5 total events) from 0% at baseline to 40% post-treatment. At two-month follow-up, P1 demonstrated additional improvements in success from post-treatment, completing 100% of skills successfully. Despite completing additional skills at follow-up relative to post-treatment, P1's total errors remained unchanged, meaning the average number of errors per skill decreased between post-treatment and follow-up. P1's perceived effort on this task did not improve, and in fact, P1 reported significantly more effort at post-treatment relative to baseline. At follow-up, P1's perceived effort was lower than at mid- and post-treatment but still remained above baseline.

Personal Goal GAS levels. Table 11 displays P1's GAS levels on Personal Goals related to using the reminder and calendar functions at home and in the community at baseline, post-treatment, and follow-up.

Reminder Function. Only one of four Personal Goals was directly targeted in treatment (*successfully entering* time-based reminders). The goals of *remembering to enter* time-based reminders and *responding* to time-based reminders were not addressed due to P1 needing additional time for acquisition training. The goal related to *perceived effort* with using the reminder application was expected to change based on learning skills related to the reminder function. P1's GAS levels improved from -1 at baseline to +1 (greater than expected outcome) at post-treatment on his one trained Personal Goal, as well as on one other Personal Goal

Table 11. P1's Personal Goal GAS levels across time.

GAS Levels	Baseline	Post-Treatment	Follow-Up
Reminder Function Goals[1]			
Goal 1 (Remembering to Enter)	-1	0	0
Goal 2 (Successfully Entering)	-1	1	1
Goal 3 (Responding)	-1	1	1
Goal 4 (Perceived Effort to Use)	-1	0	0
Calendar Function Goals[1]			
Goal 1 (Remembering to Enter)	-1	0	-1
Goal 2 (Successfully Entering)	-1	1	0
Goal 3 (Perceived Effort to Use)	-1	0	0 / -1[2]

[1.] The *process of entering* reminders / calendar events accurately was the primary focus of treatment for P1. Thus, Reminder Function Goal 2 and Calendar Function Goal 2 were the only Personal GAS goals directly targeted in treatment.
[2.] During the follow-up session, P1 rated perceived effort as Level 0, but the visual analogue scale included in P1's home data during the week leading up to the follow-up session suggested that P1's perceived effort may have more closely aligned with Level -1.

(*responding* to time-based reminders). On the remaining two Personal Goals, P1 saw modest improvements from -1 at baseline to +0 (expected outcome) at post-treatment. Improvements in GAS levels observed for all goals between baseline and post-treatment were also maintained at two-month follow-up.

Calendar Function. As with the reminder function, only one of P1's Personal Goals for the calendar function was directly targeted in treatment (*successfully entering* calendar events). The other two goals (*remembering to enter* calendar events and *perceived effort* with using the calendar application) were not actively addressed. P1's GAS levels improved from -1 at baseline to +1 (greater than expected outcome) at post-treatment on his one trained Personal Goal. P1 saw

Table 12. Relevant items from Compensatory Techniques Inventory for P1 across time.

	Baseline		Post-Treatment		Follow-Up	
Independence Screen						
Making Appointments	3		2		2	
Social Arrangements	3		3		2	
Avg. Rating Across Above Tasks	**3.0**		**2.5**		**2.0**	
Avg. Rating Across All Tasks	**2.5**		**2.6**		**2.1**	
1 = unable, 2 = lots of help, 3 = occasional help, 4 = reminders only, 5 = independent						
Functional Cognition Screen						
Don't Know the Date	2		3		2	
Miss Appointments[1]	N/A		N/A		N/A	
Double Schedule[1]	N/A		N/A		N/A	
Don't Know Upcoming Appointments	1		2		1	
Have Trouble Organizing Days / Tasks That Need to be Completed	2		2		2	
Forget to Complete Tasks	3		3		3	
Avg. Rating Across Above Issues	**2.0**		**2.5**		**2.0**	
Avg. Rating Across All Issues	**2.8**		**2.9**		**2.7**	
1 = constantly, 2 = frequently, 3 = occasionally, 4 = rarely, 5 = not an issue						
Compensation Use						
Electronic Scheduling Aids	***None***		***iPhone (Siri)***		***iPhone (Siri)***	
	Frequency	**Usefulness**	**Frequency**	**Usefulness**	**Frequency**	**Usefulness**
Enter Scheduled Events	0	0	2	2	1	2
Enter Things to Do	0	0	2	2	2	2
Refer to Entries	0	0	2	2	2	2
Set Alarm	0	0	0	0	0	0
Check Off Entries	0	0	0	0	0	0
Reschedule as Needed	0	0	1	2	0	0
Avg Rating Across All Uses	**0**	**0**	**1.2**	**1.3**	**0.8**	**1.0**
Other Scheduling Aids	***None***		***Wall Calendar[2]***		***Wall Calendar[2]***	
Avg Rating Across All Uses	**0**	**0**	**0.4**	**0.4**	**0.4**	**0.4**
Frequency: 0 = never, 1 = 1x/week, 2 = a few times/week, 3 = most days *Usefulness: 0 = N/A or not useful, 1 = rarely helps, 2 = pretty helpful, 3 = very helpful*						

1. P1 depended on his spouse for both transportation and scheduling throughout the study. Therefore, these items were scored as N/A.
2. Average rating across all uses is lower than the iPhone because P1's spouse manages the wall calendar. P1 only uses it to refer to entries.

modest improvements from -1 at baseline to +0 (expected outcome) at post-treatment on his other two Personal Goals. P1's GAS levels on all calendar goals declined between post-treatment and two-month follow-up, although the GAS level for his trained Personal Goal remained above baseline.

Secondary outcome measures.

Compensatory Techniques Inventory. P1's responses to items related to scheduling and remembering daily tasks on the CTI's Independence, Functional Cognitive, and Compensation Use Screens are provided in Table 12 (see Appendix K for responses to all items). At baseline, P1 required frequent or occasional help for most life tasks, and P1's level of independence with life tasks declined over the course of the study. Before treatment, P1 experienced frequent difficulty with organization and prioritization of tasks, remembering to complete daily tasks, and having awareness of his schedule. After treatment, P1 noted some improvement in his awareness of the date and upcoming events, but these improvements were not maintained at follow-up.

The most significant changes seen on the CTI were in P1's compensation use. At baseline, P1was not using any scheduling aids. However, immediately following treatment and at two-month follow-up, P1 was using Siri to enter events, enter reminders, and refer to these entries one to three times per week, and he considered these iPhone functions helpful. In addition, P1's spouse began entering events on a wall calendar during treatment for P1 to reference. Also not shown in Table 12 (but may be seen in Appendix K), is that P1 was relying on reminders from his spouse to take medications because he disliked using audible alarms. At post-treatment and follow-up, however, P1 was using a recurring iPhone reminder with a vibrating alerter tone to remind him to take his medications.

Self- and informant-report questionnaires. Table 13 presents P1's self- and informant-report questionnaire scores at baseline, post-treatment, and two-month follow-up.

Cognition. At baseline, P1 endorsed clinically significant challenges with executive functions per the BRIEF-A Global Executive Composite (GEC) score, and P1's self-reported GEC score did not significantly change at post-treatment or follow-up. At baseline, P1's spouse endorsed challenges that approached clinical significance based on the GEC score. At post-treatment and follow-up, informant-reported GEC scores increased slightly to clinically significant levels. Although self- and informant-report GEC scores did not improve, Appendix L shows that both self- and informant-report T-scores in the areas of initiation, planning/organization, task monitoring, and organization of materials improved from baseline to post-treatment. Furthermore, most of these improvements were maintained at follow-up. T-scores on the PROMIS Item Bank v2.0: Cognitive Function-Short Form 6a remained at least 1.5 standard deviations below the normative mean throughout the study.

Well-being. P1 consistently reported a moderate impact of PD on his functioning and well-being according to the Parkinson's Disease Questionnaire-8 Single Index of Functioning and Well-Being. P1 endorsed mild depression on the Beck Depression Inventory-II (BDI-II) at post-treatment and follow-up, whereas he indicated minimal to no depression at baseline. Scores on the Zarit Burden Interview-22 revealed limited to no changes in caregiver well-being from baseline to post-treatment and follow-up.

Social participation. T-scores on the PROMIS Item Bank v2.0: Satisfaction with Social Roles and Activities-Short Form 6a indicate that P1 experienced satisfaction with social roles and activities within the average range at baseline, post-treatment, and two-month follow-up.

Table 13. Self- and informant-report questionnaire responses across time for P1.

Questionnaire	Baseline	Post-Treatment	Follow-Up
Cognition			
BRIEF-A: Self-Report Global Executive Composite Score *(T-Scores ≥ 65 are clinically significant)*	T-Score: 86 Percentile: 99th	T-Score: 79 Percentile: 99th	T-Score: 78 Percentile: 99th
BRIEF-A: Informant-Report Global Executive Composite Score *(T-Scores ≥ 65 are clinically significant)*	T-Score: 64 Percentile: 86th	T-Score: 67 Percentile: 90th	T-Score: 67 Percentile: 90th
PROMIS Item Bank v2.0: Cognitive Function-Short Form 6a *(Higher scores reflect fewer concerns. Maximum raw score = 30.)*	Raw Score: 13 T-Score: 35.2	Raw Score: 7 T-Score: 26.6	Raw Score: 12 T-Score: 34.0
Participant Well-Being			
Parkinson's Disease Questionnaire-8 Single Index of Functioning and Well-Being *(Scale from 0 = no impact of PD to 100 = severe impact of PD)*	40.6	34.4	56.3
Beck Depression Inventory-II *(0 to 13 = minimal to no depression, 14 to 19 = mild depression, 20 to 28 = moderate depression, and ≥ to 29 = severe depression)*	12.5	19	18
Caregiver Well-Being			
Zarit Burden Interview-22 *(Higher scores reflect greater caregiver distress/burden. Maximum raw score = 88.)*	29	29	27
Social Participation			
PROMIS Item Bank v2.0: Satisfaction with Social Roles and Activities-Short Form 6a *(Higher scores reflect greater satisfaction. Maximum raw score = 30.)*	Raw Score: 21 T-Score: 48.2	Raw Score: 15 T-Score: 41.2	Raw Score: 15 T-Score: 41.2

Other measures.

Control Measure. P1's percentage accuracy on a Sudoku puzzle at baseline, post-treatment, and follow-up was 16.3%, 20.9%, and 30.2%, respectively. Although percentage accuracy improved, the number of boxes P1 filled in 5 minutes did not change.

Neuropsychological screening. P1's scores on alternate versions of the Montreal Cognitive Assessment at baseline, post-treatment, and follow-up were 21, 25, and 22, respectively. Scores remained below the suggested cutoff of 26 for cognitive impairment throughout the study.

Self-rated smartphone skills. P1's self-rated smartphone skill level, confidence, and satisfaction at baseline, post-treatment, and follow-up are displayed in Table 14. P1's perceived skill level and confidence using his smartphone declined from baseline to post-treatment, and no changes in these rating were seen between post-treatment and two-month follow-up. P1's satisfaction with his smartphone skills did not change from baseline to post-treatment or follow-up.

Table 14. P1's self-rated smartphone skills across time.

Self-Rated Smartphone Skills	Baseline	Post-Treatment	Follow-Up
Self-Rated Smartphone Skill Level *(100 mm Visual Analogue Scale – higher numbers represent more advanced skill levels)*	27	11	12
Self-Rated Confidence Using Smartphone *(100 mm Visual Analogue Scale – higher numbers represent greater confidence)*	22	5	6
Self-Rated Satisfaction with Smartphone Skills *(100 mm Visual Analogue Scale – higher numbers represent greater satisfaction)*	21	23	21

Qualitative statements from field notes. Table 15 presents statements from P1 and his spouse about the study and its impact.

Table 15. Summary of statements from P1 and his spouse.

Topic	Statements
Siri / Phone Use	**P1:** At follow-up, P1 said, "My level of knowledge is higher than coming into the study and I've learned to a somewhat reliable degree how to use the features on the phone." P1 noted that the phone is "becoming easier to use" and that his frustration has lessened, but he still gets frustrated. At both post-treatment and follow-up, P1 reported using Siri daily to stay up-to-date on sports, conduct internet searches, check the weather, and make phone calls. He was particularly pleased with Siri's ability to make calling people easier. At follow up, P1 said he has "looked like a wizard showing other people how they can talk to their phone." **P1's Spouse:** At follow-up, P1's spouse said, "[P1] is good about making plans with his phone [reminder application] about what needs to be done the next day or week." At post-treatment and follow-up, she stated P1 "begrudgingly" uses the calendar application, more for reference "to see his plan for the day" than for entering events. At post-treatment, P1's spouse also commented that P1 can make phone calls using Siri more easily because Siri involves fewer steps.
Siri / Phone Limitations	**P1:** At post-treatment and follow-up, P1 reported frustration with Siri being "pretty picky" with the instructions she accepted, and that the format wasn't intuitive. He also noted challenges using names in reminders/events that were not in his contacts list because Siri would change the name. At follow-up, P1 also stated that he still chooses to use his spouse's calendar because he "doesn't like how the calendar looks on the phone." **P1's Spouse:** At post-treatment, P1's spouse commented that P1 often makes long pauses when speaking his instructions to Siri, which results in Siri interrupting or not taking the instruction. She therefore "wished Siri gave more time to spit out the whole phrase."
Treatment Format	**P1:** "Learning occurred in the individual sessions." P1 also said that his spouse learned during individual sessions. He indicated that he "wished we had more of a chance to get to know people in the group," and he wondered if there was a way to incorporate more group learning. **P1's Spouse:** P1's spouse said she would have liked to have more time because we "didn't get to some things."
Other Concerns	**P1:** At post-treatment, P1 reported that he's "using [his] phone more," but he's "still a minimal user." He wondered whether his needs were met by the skills taught in this study because he hadn't noticed any benefits with respect to his experience with daily cognitive challenges. At follow-up, P1 said he "hasn't figured out how to make reminders work yet." **P1's Spouse:** At post-treatment, P1's spouse stated that P1 still has questions about when to use each key phrase (i.e. "Schedule…" versus "Remind"). At

	post-treatment and follow-up, P1's spouse reported noticing ongoing changes in P1's cognition, stating that it fluctuates – "Some days he is clear and well, others he is confused." At follow-up, she noted that P1 has been "more confused in the last two months." "He's asking more questions. He asks something, then 10 minutes later asks again."

Participant Two

Initial assessment. P2 is a 59-year-old male who was diagnosed with PD in January of 2012. P2 reported that his cognitive symptoms began about one year ago and recently prompted him to go on long-term disability from his job as a senior manager at a telecommunications company in December of 2017. He expressed having difficulties with his attention, organization and prioritization of tasks, time management, and communication (maintaining his train of thought and finding the right word). P2 also noted experiencing significant anxiety, which compounded these issues and caused him to frequently lose sleep. P2 scored a 29 on the MoCA Version 8.1, which does not indicate cognitive impairment according to the suggested cut-off score of 26 (Dalrymple-Alford et al., 2010; Hendershott et al., 2017; Hoops et al., 2009). Because P2 stated that he had recently been given this version of the MoCA and still remembered the list of words for the memory section, P2 was reassessed a week later using the MoCA Version 7.3. However, his score did not change. Although P2's MoCA score suggested "normal" cognitive functioning, his responses on the BRIEF-A endorsed clinically significant challenges in several executive functions, including shifting, initiation, working memory, and planning and organization. Additionally, his T-score for task monitoring approached clinical significance (T-score = 63). On the BRIEF-A Informant Report, P2's spouse endorsed challenges in working memory and task-monitoring that approached clinical significance, but like P1's spouse's ratings, her ratings were lower than P2's across all domains, reflecting less concern.

P2 explained that his cognitive challenges have a significant impact on his ability to organize his day. He was project managing a cabin renovation and had several upcoming deadlines related to his annual tax filing. He noted that he often does not feel that he accomplishes as much as he used to because he feels that he has trouble prioritizing tasks and gets too caught up in the details of his day. On the CTI Functional Cognition Screen, P2 reported that he constantly starts but does not finish tasks, occasionally loses track of time, and occasionally has difficulty organizing days and tasks to be completed. However, he noted that he rarely forgets to complete tasks or has any difficulty knowing what appointments are on his schedule. He also noted that missing appointments, not knowing the date, and double scheduling were not issues for him.

P2 had several years of experience using an Android smartphone but obtained his first iPhone, the iPhone 6, about year and a half prior to beginning the study. He uses his phone daily for making/referencing to-do lists, setting alarms, calling, texting, searching the internet, emailing, banking, reading the news, and checking the weather. P2 reported that he created to-do lists within the reminder application, but he was not setting time-based reminders. Therefore, he had to remember to access and review his to-do list on his own. For scheduling, P2 was using a desktop-based Outlook calendar on his laptop. Because his Outlook calendar was not web-based, it was not possible to sync with his smartphone. P2 therefore either had to bring his laptop with him or remember to check his calendar on his laptop before leaving the house. On days when he had multiple scheduled appointments or activities, P2's spouse would help him organize these activities by writing them down in chronological order on a piece of paper.

At baseline, P2 had experience using the microphone button for text-to-speech within apps on his iPhone. However, he did not have any prior experience using Siri to *navigate* his

phone and expressed an interest in learning this feature because he felt that manually navigating the phone with his finger was often slow. At baseline, P2 rated his skill level as intermediate (53 out of 100 on a visual analog scale with 0 being absolute beginner and 100 being expert). He rated his confidence in using the smartphone as 63 on a 100-point scale (with 0 being not at all confident and 100 being very confident) and his satisfaction with his smartphone skills as 27 on a 100-point scale (with 0 being not at all satisfied and 100 being very satisfied).

Goal development, finalization, and scaling. P2 acknowledged that his phone travels with him more than his laptop and he therefore desired to increase the frequency with which he used his phone to remember things "on the fly" and keep track of his schedule. P2 also stated that he had been using a "Today" to-do list within the reminder app on his phone to help him prioritize tasks to complete throughout his day. However, he noted that it was not that helpful because he only remembered to look at the list one to two times per week. The GAS Goals in Table 16 were co-constructed to address P2's desire to increase the frequency with which he used his phone to schedule appointments / activities and remember to complete tasks. They were scaled collaboratively with P2 following an assessment of baseline performance. Baseline performance was set to Level -1 for all goals.

Treatment. P2 attended 9 sessions, including three 90-minute assessment sessions (initial / baseline, post-treatment, and follow-up), two 60-minute group sessions, and four individual treatment sessions (three lasting 90 minutes and 1 lasting 60 minutes). Approximately 45 minutes of each of two individual sessions were dedicated to probes (baseline and mid-treatment), as well as establishing GAS goals and levels. Therefore, total training time was about six hours.

Table 16. P2's Personal GAS Goals for the reminder and calendar applications.

Reminder Application				
Goal 1: Frequency of entering time-based reminders on P2's iPhone				
-2	**-1**	**0**	**1**	**2**
P2 enters time-based reminders into his iPhone <20% of the time	P2 enters time-based reminders into his iPhone 20% to 39% of the time	P2 enters time-based reminders into his iPhone 40% to 59% of the time	P2 enters time-based reminders into his iPhone 60% to 79% of the time	P2 enters time-based reminders into his iPhone ≥ 80% of the time
Goal 2: Frequency of viewing P2's "Today" reminder list				
-2	**-1**	**0**	**1**	**2**
P2 views his "today" reminder list at the beginning of the day <1 time per week	P2 views his "today" reminder list at the beginning of the day 1-2 times per week	P2 views his "today" reminder list at the beginning of the day 3-4 times per week	P2 views his "today" reminder list at the beginning of the day 4-5 times per week	P2 views his "today" reminder list at the beginning of the day > 5 times per week
Calendar Application				
Goal 1: Frequency of entering calendar events on the iPhone				
-2	**-1**	**0**	**1**	**2**
P2 enters calendar events into his iPhone <5% of the time	P2 enters calendar events into his iPhone 5% to 19% of the time	P2 enters calendar events into his iPhone 20% to 34% of the time	P2 enters calendar events into his iPhone 35% to 49% of the time	P2 enters calendar events into his iPhone ≥ 50% of the time
Goal 2: Frequency of missing activities / deadlines				
-2	**-1**	**0**	**1**	**2**
P2 will miss > 3 activities / deadlines per week	P2 will miss 3 activities / deadlines per week	P2 will miss 2 activities / deadlines per week	P2 will miss 1 activity / deadline per week	P2 will miss 0 activities / deadlines per week

Although training was designed to target eight smartphone skills within the reminder and calendar applications, only four were systematically taught to P2: adding a reminder using Siri, viewing reminders using Siri, adding a calendar event using Siri, and viewing the calendar using Siri. The remaining four skills (marking reminders as completed, deleting reminders, deleting calendar events, and modifying calendar events) were introduced, but due to time constraints, P2 received only one session of training and fewer than 15 total training trials for each of these skills (8 for marking reminders as completed, 6 for deleting a reminder, 12 for deleting a calendar event, and 3 for modifying a calendar event). P2 did not meet the criterion for mastery in any of these skills except deleting an event. The first individual session was dedicated to training Skills 1 and 2 (adding and viewing reminders using Siri) and introduced Skills 3 and 4 (marking reminders as completed and deleting reminders). Based on P2's stated preference to move on to the calendar application skills rather than revisit Skills 3 and 4, the second session systematically trained Skills 5 and 6 (adding and viewing calendar events using Siri) and introduced Skills 7 and 8 (deleting and modifying calendar events). The third and final individual sessions used real reminders and appointments, as well as personally-relevant role playing scenarios, to practice applying Skills 1, 2, 5, and 6. Role playing scenarios provided an opportunity for P2 to decide on the relevant skill(s) to use. For example, one scenario involved making a follow-up appointment while checking out at the doctor's office. This required P2 to view his calendar for any conflicting appointments on available dates, add an event to his calendar once a time for the follow-up appointment had been chosen, and add a time-based reminder to get ready to leave on time. Although P2's spouse was invited and encouraged to attend assessment and treatment sessions, P2 attended all sessions independently. He completed his daily homework tasks on his own and took his own home data to support GAS ratings on

Personal Goals. P2's spouse completed the BRIEF-A informant-report questionnaire and Zarit Burden Interview-22 at baseline, post-treatment, and follow-up.

Primary outcome measures.

Targeted Smartphone Skills Laboratory Probes. P2's performance on the TSS Laboratory Probes at baseline, mid-treatment, post-treatment, and follow-up are displayed in Table 17 (Acquisition Probe) and Table 18 (Application Probe).

TSS Acquisition Probe. Like P1, P2 demonstrated improvements following treatment in measures of accuracy and success. Total errors across all trained skills (Skills 1, 2, 5, and 6) decreased from 9 at baseline to 4 post-treatment, and the number of successfully completed skills increased from 3/4 trained skills at baseline to 4/4 trained skills post-treatment. P2 also saw a reduction in total errors and increase in success across skills that were introduced but not systematically trained (Skills 3, 4, 7, and 8). Total errors across these skills decreased from 20 at baseline to 7 post-treatment, and the number of skills completed successfully increased from 3/4 at baseline to 4/4 post-treatment. At two-month follow-up, P2 showed further reduction in number of errors on trained skills from 4 post-treatment to 0 at follow-up, and he continued to successfully complete 4/4 trained skills. For untrained skills, no additional improvements were seen in number of errors, and the number of successfully completed skills returned to baseline (3/4 skills).

It should be noted that at baseline, P2 consistently activated Siri by pressing the home button[6], and that although rate was found to be an unreliable metric overall and was not included in the final analysis, it was noted that activating Siri manually consistently took 2 to 3 times as long as activating Siri by voice. Additionally, all 9 errors P2 made on trained skills at baseline

[6] P2's manual activation of Siri was not counted as an error unless he also then said "Siri" or "Hey Siri" because this added an unnecessary second step.

Table 17. Targeted Smartphone Skills Acquisition Probe performance across skills and time for P2.

TSS Acquisition Probe		Baseline	Mid-Treatment	Post-Treatment	Follow-Up
Reminder Function					
Skill 1 (Add): TRAINED	Attempts	0	1	1	1
	Errors	N/A[1]	0	0	0
	Success	No	Yes	Yes	Yes
Skill 2 (View): TRAINED	Attempts	1	1	1	1
	Errors	1	0	0	0
	Success	Yes	Yes	Yes	Yes
Skill 3 (Clear): INTRODUCED	Attempts	1	2	1	1
	Errors	3	3	0	0
	Success	No	Yes	Yes	Yes
Skill 4 (Delete): INTRODUCED	Attempts	1	1	1	1
	Errors	1	0	0	0
	Success[2]	Yes	Yes	Yes	Yes
Calendar Function					
Skill 5 (Add): TRAINED	Attempts	2	1	3	1
	Errors	5	0	4	0
	Success	Yes	Yes	Yes	Yes
Skill 6 (View): TRAINED	Attempts	2	2	1	1
	Errors	3	1	0	0
	Success	Yes	Yes	Yes	Yes
Skill 7 (Modify): INTRODUCED	Attempts	4	7	4	3
	Errors	14	7	6	5
	Success	Yes	No	Yes	No
Skill 8 (Delete): INTRODUCED	Attempts	1	2	1	2
	Errors	2	2	1	2
	Success	Yes	Yes	Yes	Yes
Totals					
# of Attempts *(Trained / Introduced)*		**6 / 7**	**5 / 11**	**6 / 7**	**4 / 7**
# of Errors *(Trained / Introduced)*		**9 / 20**	**1 / 10**	**4 / 7**	**0 / 7**
# Successfully Completed *(Trained / Introduced)*		**3 / 3**	**4 / 3**	**4 / 4**	**4 / 3**

[1]. At Baseline, P2 completed Skill 5 (Add Event) for Skill 1 (Add Reminder). Therefore, errors cannot be calculated reliably for Skill 1.

Table 18. Targeted Smartphone Skills Application Probe performance across tasks and time for P2

Application Probe	Baseline	Mid-Treatment	Post-Treatment	Follow-Up
Reminder Task				
Total Attempts (For 5 Skills)	8	6	7	6
Total Errors	9	2	2	1
Percentage of Reminders Successfully Added (Out of 5)	100%	100%	100%	100%
Perceived Effort (100 mm VAS)	23 mm	5 mm	19 mm	5 mm
Calendar Task				
Total Attempts (For 5 Skills)[1]	8	7	7	6
Total Errors[1]	21	7	3	3
Percentage of Calendar Events Successfully Added (Out of 5)	100%	100%	100%	100%
Perceived Effort (100 mm VAS)	93 mm	31 mm	36 mm	63 mm

[1.] P2 made frequent attempts to view, modify, or delete appointments with errors. Total attempts only includes attempts to add a calendar event. Similarly, total errors only includes errors made during attempts to add calendar events.

were process errors (e.g., redundant steps, omitting necessary information, verbal commands that did not follow the necessary format for Siri, etc.), whereas only 1 of the 4 errors made on trained skills at post-treatment was a process error (the remaining 3 were caused by P2 not speaking loudly/clearly enough for Siri to understand him).

TSS Application Probe. On the Application Probe, P2 was already completing 100% of skills at baseline, but he showed significant reduction in the number of errors made while completing each task. On the reminder task, P2's total errors decreased from 9 at baseline to 2 at post-treatment, but his perceived effort remained about the same. At two-month follow-up, P2 maintained improvements in total errors seen post-treatment, and his perceived effort reduced by

over 70%. On the calendar task, P2's total errors decreased from 21 at baseline to 3 post-treatment, and his perceived effort to complete the calendar task decreased by about 60%. At two-month follow-up, P2 maintained post-treatment improvements in total errors, but his perceived effort doubled. However, perceived effort at follow-up remained about 30% below the level of effort reported at baseline.

Personal Goal GAS levels. Table 19 displays P1's GAS levels on Personal Goals related to using the reminder and calendar functions at home and in the community at baseline, post-treatment, and follow-up.

Table 19. Goal Attainment Scale levels for P2's Personal Goals across time.

GAS Levels	Baseline	Post-Treatment	Follow-Up
Reminder Function Goals[1]			
Goal 1 (Frequency of Entering)	-1	2	2
Goal 2 (Frequency of Viewing)	-1	1	0[2]
Calendar Function Goals[1]			
Goal 1 (Frequency of Entering)	-1	2	2
Goal 2 (Frequency of Missing)	-1	2	1

[1.] The *frequency of entering* reminders / calendar events accurately was the primary focus of treatment for P2. Thus, Reminder Function Goal 1 and Calendar Function Goal 1 were the only Personal GAS goals directly targeted in treatment.
[2.] During the follow-up session, P2 stated that he is viewing his "Today" list every day now (whereas before, he only looked at it 1 to 2 times per week), but he sometimes looks at it mid- to late-day rather than at the beginning of the day.

Reminder Function. Only one of two Personal Goals for the reminder function was directly targeted in treatment (*frequency of entering* time-based reminders). The other goal (*frequency of viewing* P2's today list) was not *systematically* trained, although it was introduced through practice stimuli for Skill 2 (viewing reminders) during treatment sessions and in

homework assignments. P2's GAS levels improved from -1 at baseline to +2 (much greater than expected outcome) at post-treatment on his one trained Personal Goal and from -1 at baseline to +1 (greater than expected outcome) at post-treatment for the non-systematically trained Personal Goal. P2's GAS level on his trained goal maintained at the +2 level at two-month follow-up. However, his GAS level on the other goal declined from +1 to 0 at two-month follow-up, although this level is still above the baseline level of -1. Although a Personal GAS Goal was not developed for perceived effort related to using the reminder function in daily life, P2's home data collected to establish baseline GAS levels and support GAS Goal ratings at post-treatment and follow-up revealed that his perceived effort for managing daily tasks and reminders declined from moderate effort at baseline to minimal to no effort at post-treatment and follow-up (see Table 20).

Calendar Function. Both of P2's Personal Goals for the calendar function were systematically trained (*frequency of entering* calendar events and *frequency of missing* scheduled appointments/activities). P2's GAS levels improved from -1 at baseline to +2 (much greater than expected outcome) at post-treatment on both Personal Goals. P2's GAS level for frequency of entering calendar events maintained at the +2 level at follow-up, but his GAS level for frequency of missing scheduled appointments/activities declined to the +1 level. However, this is still a greater than expected outcome. As with the reminder function, P2's home data revealed that P2's perceived effort related to using the calendar function in daily life declined from borderline moderate effort at baseline to minimal to no effort at post-treatment and follow-up (see Table 20).

Table 20. Home data on P2's perceived effort with using the reminder and calendar functions.

Home Data on Perceived Effort	Baseline	Post-Treatment	Follow-Up
Reminder Function			
Perceived effort for managing daily tasks and reminders without help *(100 mm visual analogue scale; 0 = not at all effortful, 100 = extremely effortful)*	38 mm	9 mm	8 mm
Calendar Function			
Perceived effort for managing activities/deadlines without help *(100 mm visual analogue scale; 0 = not at all effortful, 100 = extremely effortful)*	27 mm	6 mm	6 mm

Secondary outcome measures.

Compensatory Techniques Inventory. P2's responses to items related to scheduling and remembering daily tasks on the CTI's Independence, Functional Cognitive, and Compensation Use Screens are provided in Table 21 (see Appendix K for responses to all items). At baseline, P2 required frequent help for social arrangements but was independent for all other life tasks that he noted he completed prior to his PD diagnosis. P2's level of independence with most life tasks remained relatively stable over the course of the study, although he endorsed needing occasional help for personal care and reminders for making appointments at follow-up. At baseline, P2 experienced occasional difficulty with organization and prioritization of tasks and rare occurrences of forgetting to complete tasks or not knowing his upcoming appointments. At post-treatment, P2's average rating on scheduling and reminder issues remained relatively stable. However, at follow-up, P2 noted more frequent occurrences across 3/6 issues.

As with P1, the most significant changes noted on the CTI were in P2's compensation use. At baseline, P2 was using Outlook on his laptop as his sole electronic scheduling aid. He reported using this aid one to three times per week and that he considered this aid to be helpful.

Table 21. Relevant items from Compensatory Techniques Inventory for P2 across time.

	Baseline		Post-Treatment		Follow-Up	
Independence Screen						
Making Appointments	5		5		4	
Social Arrangements	2		4		3	
Avg. Rating Across Above Tasks	**3.5**		**4.5**		**3.5**	
Avg. Rating Across All Tasks	**4.4**		**4.6**		**4.0**	
1 = unable, 2 = lots of help, 3 = occasional help, 4 = reminders only, 5 = independent						
Functional Cognition Screen						
Don't Know the Date	5		4		4	
Miss Appointments	5		5		4	
Double Schedule	5		5		5	
Don't Know Upcoming Appointments	4		5		4	
Have Trouble Organizing Days / Tasks That Need to be Completed	3		4		3	
Forget to Complete Tasks	4		4		3	
Avg. Rating Across Above Issues	**4.3**		**4.5**		**3.8**	
Avg. Rating Across All Issues	**3.9**		**4.2**		**3.7**	
1 = constantly, 2 = frequently, 3 = occasionally, 4 = rarely, 5 = not an issue						
Compensation Use						
Electronic Scheduling Aids	***Outlook Calendar***		***Outlook Calendar***		***Outlook Calendar & iPhone Calendar***	
	Frequency	**Usefulness**	**Frequency**	**Usefulness**	**Frequency**	**Usefulness**
Enter Scheduled Events	2	3	1	2	3	3
Enter Things to Do	0	0	0	0	0	0
Refer to Entries	2	2	1	2	3	3
Set Alarm	2	2	0	0	3	3
Check Off Entries	2	2	0	0	3	3
Reschedule as Needed	2	2	1	2	3	3
Avg Rating Across All Uses	**1.7**	**1.8**	**0.5**	**1.0**	**2.5**	**2.5**
Other Scheduling Aids	***None***		***Wall Calendar***		***Wall Calendar***	
Avg Rating Across All Uses	**0**	**0**	**0.4**	**0.4**	**0.6**	**1.8**
Other Aids	***iPhone To-Do Lists***		***iPhone Lists, Reminders, Calendar***		***iPhone Lists, Reminders***	
Avg Rating Across All Uses	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**
Frequency: 0 = never, 1 = 1x/week, 2 = a few times/week, 3 = most days *Usefulness: 0 = N/A or not useful, 1 = rarely helps, 2 = pretty helpful, 3 = very helpful*						

Following treatment, P2 was reported that he continued to use his Outlook calendar, although less frequently (only one time per week). He also noted using the iPhone most days for to-do lists (used at baseline as well), reminders (new), and the calendar (new) and that he found this aid more helpful than the Outlook calendar alone. At the two-month follow-up, P2 continued to use his iPhone most days for to-do lists/reminders and the calendar, and he continued to find these functions very helpful.

Self- and informant-report questionnaires. Table 22 presents P2's self- and informant-report questionnaire scores at baseline, post-treatment, and two-month follow-up.

Cognition. At baseline, P2 endorsed clinically significant challenges with executive functions per the BRIEF-A Global Executive Composite (GEC) score. P2's self-reported GEC score fell below the threshold of clinical significance at post-treatment and remained below the threshold at follow-up. Appendix L shows that the lower GEC score was driven by lower scores in the areas of shifting, initiation, and planning/organization relative to baseline (reflecting fewer concerns) at both post-treatment and follow-up. P2's spouse did not endorse clinically significant challenges in executive functions based on the GEC score at any time point. As seen in Appendix L, her ratings across all domains remained relatively stable over time with the exception of planning/organization, which actually increased at both post-treatment and follow-up, reflecting greater concerns. At baseline, P2's T-score on the PROMIS Item Bank v2.0: Cognitive Function-Short Form 6a was nearly 1.5 standard deviations below the normative mean. P2's score increased to fall within 1.0 standard deviations below the normative mean at post-treatment, reflecting fewer cognitive concerns. However, this improvement did not maintain at follow-up.

Well-being. P2's PDQ-8 scores were somewhat variable but reflected a minimal

Table 22. Self- and informant-report questionnaire responses across time for P2.

Questionnaire	Baseline	Post-Treatment	Follow-Up
Cognition			
BRIEF-A: Self-Report Global Executive Composite Score *(T-Scores ≥ 65 are clinically significant)*	T-Score: 69 Percentile: 95th	T-Score: 60 Percentile: 85th	T-Score: 62 Percentile: 90th
BRIEF-A: Informant-Report Global Executive Composite Score *(T-Scores ≥ 65 are clinically significant)*	T-Score: 53 Percentile: 77th	T-Score: 53 Percentile: 77th	T-Score: 55 Percentile: 80th
PROMIS Item Bank v2.0: Cognitive Function-Short Form 6a *(Higher scores reflect fewer concerns. Maximum raw score = 30.)*	Raw Score: 13 T-Score: 35.2	Raw Score: 19 T-Score: 41.74	Raw Score: 15 T-Score: 37.37
Participant Well-Being			
Parkinson's Disease Questionnaire-8 Single Index of Functioning and Well-Being *(Scale from 0 = no impact of PD to 100 = severe impact of PD)*	15.6	50	37.5
Beck Depression Inventory-II *(0 to 13 = minimal to no depression, 14 to 19 = mild depression, 20 to 28 = moderate depression, and ≥ to 29 = severe depression)*	13	6	7
Caregiver Well-Being			
Zarit Burden Interview-22 *(Higher scores reflect greater caregiver distress/burden. Maximum raw score = 88.)*	18	12	15
Social Participation			
PROMIS Item Bank v2.0: Satisfaction with Social Roles and Activities-Short Form 6a *(Higher scores reflect greater satisfaction. Maximum raw score = 30.)*	Raw Score: 16 T-Score: 42.3	Raw Score: 19 T-Score: 45.8	Raw Score: 17 T-Score: 43.4

to moderate impact of PD on his functioning and well-being throughout the study. P2's BDI-II score prior to treatment was near the borderline for mild depression. However, at post-treatment and follow-up, this score fell to well within the range of minimal to no depression. Scores on the Zarit Burden Interview-22 show negligible reductions in caregiver well-being from baseline to post-treatment and follow-up.

Social participation. P2's T-scores on the PROMIS Item Bank v2.0: Satisfaction with Social Roles and Activities-Short Form 6a remained within the average range across all time points.

Other measures.

Control Measure. P2's percentage accuracy on a Sudoku puzzle at baseline, post-treatment, and follow-up was 4.7%, 34.9%, and 4.7%, respectively. Although P2's accuracy improved substantially from baseline to post-treatment, his performance returned to baseline levels at follow-up.

Neuropsychological screening. P2's scores on alternate versions of the Montreal Cognitive Assessment at baseline, post-treatment, and follow-up were 29, 29, and 27, respectively. Scores remained above the suggested cutoff of 26 for cognitive impairment throughout the study.

Self-rated smartphone skills. P2's self-rated smartphone skill level, confidence, and satisfaction at baseline, post-treatment, and follow-up are displayed in Table 23. All three metrics demonstrated improvement from baseline to post-treatment, with self-rated skill level increasing 15%, confidence increasing 35%, and self-rated satisfaction increasing 89%. Self-rated skill level and self-rated satisfaction continued to improve between post-treatment and

follow-up with self-rated skill level increasing an additional 36% and self-rated satisfaction increasing another 47%.

Table 23. Self-rated smartphone skills across time for P2.

Self-rated smartphone skills	Baseline	Post-Treatment	Follow-Up
Self-Rated Smartphone Skill Level *(100 mm Visual Analogue Scale – higher numbers represent more advanced skill levels)*	53	61	83
Self-Rated Confidence Using Smartphone *(100 mm Visual Analogue Scale – higher numbers represent greater confidence)*	63	85	82
Self-Rated Satisfaction with Smartphone Skills *(100 mm Visual Analogue Scale – higher numbers represent greater satisfaction)*	27	51	75

Qualitative statements from field notes. Table 24 presents statements from P1 and his spouse about the study and its impact.

Table 24. Summary of statements from P2.

Topic	Statements
Siri / Phone Use	At post-treatment, P2 said, "I'm using Siri exponentially more than I was before [treatment]." At follow-up, P2 stated "I actively use [reminder skills] every day," and "I'm transitioning from using the Outlook calendar on my laptop to using the iPhone. Using the calendar was definitely a new skill I learned, and I use it for appointments and so forth." P2 stated that because of the study, he is "definitely more organized" and "make[s] better use of a great tool." P2 noted at post-treatment and follow-up that he uses Siri for other functions as well, including, "googling things, like when stores are open or closed" and to open applications. He said that using Siri can make some things easier/more streamlined. P2 also commented on an unexpected benefit of using Siri. He said she has helped remind him to speak more loudly and clearly because "she doesn't understand me when I mumble."
Siri / Phone Limitations	At post-treatment and follow-up P2 indicated that using someone's name if there were multiple contacts in your phone with the same name was a challenge. He also noted difficulties using names that weren't in the contacts list because Siri would change what you said to match a programmed contact's name. At follow-up, P2 said that Siri still has trouble recognizing his voice when he speaks too fast, so he has to remember to slow down. He also explained that

	deleting and marking reminders as completed is more difficult using Siri versus just swiping/tapping because she doesn't always find the right reminder.
Treatment Format	At post-treatment and follow-up, P2 found the individual sessions helpful for learning new skills but he found that sometimes things were too simple. He stated, "I could have gone faster, but repetition is good, so I shouldn't complain." He also said, "I think I could have done some homework without instruction, like with the deleting and marking reminders as complete." He appreciated that the homework was like "forced practice" because now he is using the skills more naturally. P2 said the group sessions "were not particularly meaningful for me," and said they "might have been more helpful to set up the group with people at the same learning level."
Other Concerns	At follow-up, P2 reported that he's still using the voice recorder instead of Siri sometimes for entering reminders, but he uses Siri for the calendar application.

Reliability and validity.

Treatment fidelity. Fidelity of implementing systematic instruction components was 96.7% based on dividing the total number of instructional components observed by the total number of opportunities to implement systematic instructional components. Fidelity of adherence to the cueing hierarchy was 94% based on the number of correct cues provided divided by the total number of trials observed.

TSS Laboratory Probe scoring reliability. Cohen's Kappa was calculated to determine interrater agreement on coding errors, success, and attempts. Interpretation of Cohen's Kappa (κ) was in accordance with benchmarks proposed by McHugh (2012). For error detection, κ was 0.731 (SD=0.065), indicating moderate to strong agreement[7]. For determination of success, κ was 0.908 (almost perfect agreement), and for identification of attempts, κ was 0.986 (almost perfect agreement)[8].

[7] For agreement on determination of whether a given step was completed correctly or not, regardless of the number of errors per step, κ was 0.86 (SD=0.051), indicating strong interrater agreement.
[8] These figures do not yet incorporate interrater agreement on coding for two-month follow-up probes

Discussion

This study expanded upon the findings of a prior study conducted by Smasne et al. (2017) evaluating the impact of an external aids treatment program for individuals with cognitive impairment secondary to PD. Like the prior study, this study used systematic instruction principles to train external aids to support cognitive functioning in daily life and included many of the same outcome measures to explore the impact of training on Goal Attainment Scaling levels for personally-relevant goals and self- and informant-reported measures of participant cognition, well-being, and social participation. Unlike the prior study, this study (i) employed only one external aid to facilitate a comparison of results across participants, (ii) used a hybrid individual and small group treatment format, (iii) included outcome measures to assess skill acquisition in addition to impact, (iv) included a measure of caregiver well-being, (v) shortened treatment duration from 8 weeks to 5 weeks, and (vi) extended the maintenance period from one month to two months.

Primary Outcome Measures

Acquisition Measures for TSS Laboratory Probes. P1 and P2 both demonstrated improvements on measures of accuracy for each trained Targeted Smartphone Skill from baseline to post-treatment (Research Question 1).

TSS Acquisition Probe. Acquisition probes were designed to measure acquisition of smartphone use in a highly structured task; each skill was elicited with a verbal instruction that clearly set the expectation for which skill was being targeted by including the key words needed to formulate the instruction to Siri. Following treatment, P1 and P2 demonstrated improvements in measures of accuracy and success on TSS Acquisition Probes for four systematically trained skills (Skill 1: entering reminders, Skill 2: viewing reminders, Skill 5: entering events, and Skill

6: viewing events). For the skills that were not systematically trained (Skill 3: marking reminders as complete, Skill 4: deleting reminders, Skill 7: modifying calendar events, and Skill 8: deleting calendar events), P2 generalized his skills and showed improvements on measures of accuracy and success after only a brief introduction to the skills, although P2's improvement in success seen at post-treatment was not maintained at two-month follow-up. P1, however, only showed improvements on trained skills and did not generalize to any untrained skills across all time points.

TSS Application Probe. The TSS Application Probe was implemented to assess participants' ability to use the trained smartphone skills in a more functional task. Both participants demonstrated improvements in entering reminders and entering events. For the reminder task, both participants indicated that level of effort remained the same from baseline to post-treatment assessment. However, P2 reported significantly less perceived effort at mid-treatment and two-month follow-up. Immediately post-treatment, P1 was having a difficult time assigning the correct key phrase ("remind me" versus "schedule") to the reminder function skill, which may have accounted for his reported increase in perceived effort. Additionally, it is possible that he reported increased effort due to increased awareness of his errors. For P2, the limited improvement in perceived effort at post-treatment appears related to difficulties with one of five skills in which Siri was not understanding his speech after multiple attempts. This did not occur at mid-treatment or follow-up, and P2's perceived effort at those time points was substantially less than prior to treatment.

For the calendar task, both participants demonstrated improvements, but on different metrics. At baseline, P1 was overgeneralizing skills trained during the reminder task by trying to use them for the calendar task. Therefore, total errors could not be reliably calculated at baseline,

making it impossible to comment on changes in this metric from pre-treatment to post-treatment. However, at post-treatment, P1 used the correct phrase to add a calendar event instead of a reminder in 40% of opportunities and successfully added both events. P1 demonstrated additional improvements on the calendar task between post-treatment and follow-up, increasing his percentage of skills successfully completed from 40% to 100% and maintaining total errors at 2 despite completing more skills. It is possible that P1 realized these additional improvements by continuing to practice these skills at home with the support of his spouse. Despite improvements in accuracy and success, P1's perceived effort for this task remained unchanged throughout the study. Similar to the reminder function, P2 was already achieving 100% success on this task at baseline through trial-and-error with multiple attempts made for skills that were unsuccessful. However, his total errors decreased significantly following treatment, as did his perceived effort for this task. P2 maintained improvements in accuracy, although his perceived effort increased relative to post-treatment. This increase in perceived effort was likely influenced more by the complexity of the scheduling task itself than by the process of entering events on his phone.

***Interpretation and notable observations*.** These findings support the hypothesis that systematic instruction would result in participants learning to complete trained Targeted Smartphone Skills accurately and independently and are consistent with prior studies demonstrating that individuals with acquired deficits in attention, executive functions, and memory learned to use and apply the calendar and reminder functions on their commercial smartphones (Svoboda et al., 2012). However, differences were observed across the two participants in terms of their rate of skill acquisition. P1 required more than twice the amount of training time as P2 to meet the criterion for success for Skills 1 and 2 (entering and viewing reminders, respectively). P2 also made improvements on skills that were only introduced in

treatment with a limited number of practice trials. P1 and P2 differed at baseline in terms of the degree of their cognitive deficits (P1's deficits appeared more severe than P2's) and relative experience with the iPhone (P1 had less experience than P2). It is likely that these factors contributed to the difference in rate of skill acquisition.

Because P1 acquired skills more slowly than P2, P1 spent approximately half the amount of time as P2 engaged in application practice using real stimuli, and this appears to have influenced patterns of improvement on the TSS Application Probe. While both participants demonstrated greatest improvements in trained skills on the TSS *Acquisition* Probe from baseline to mid-treatment, and no additional improvements from mid-treatment to post-treatment, the trend in improvement across time for the TSS *Application* Probe differed between P1 and P2. Whereas P2 maintained the pattern of showing the most improvement from baseline to mid-treatment, P1 continued to make gradual improvements on the TSS Application Probe reminder task between mid-treatment and post-treatment. It is likely that although P1 had plateaued at mid-treatment in the more structured TSS Acquisition Probe based on the acquisition training provided during his first three individual sessions, the additional application provided during the last individual and group sessions (following mid-treatment probes) contributed to additional improvement within a more functional task. This pattern can also be observed for P2 on the TSS Application Probe calendar function. P2 had received some application training prior to mid-treatment probes, which may account for the fact that his performance on the TSS Application Probe reminder task had already plateaued by mid-treatment. However, most of the application practice for the calendar function occurred following mid-treatment probes, and P2 saw a gradual improvement in accuracy on the calendar task between mid-treatment and post-treatment. These additional improvements following application training experienced by P1 and P2 highlight the

importance of continuing to practice acquired skills in a variety of environments with multiple partners and realistic stimuli to improve the likelihood for carryover of these skills into functional tasks.

P1, on the other hand, did not see any improvement between mid-treatment and post-treatment on the calendar task. This was likely due to P1 receiving limited training in calendar function skills. Because two sessions were dedicated to training reminder skills, only one session could be dedicated to training Skills 5 and 6 (adding and view calendar events, respectively) because the fourth individual treatment session was designed to provide application practice for all trained skills. During application practice, P1 demonstrated difficulty differentiating between key phrases for each function and when use of each function was most appropriate (e.g., calendar event for scheduled activities versus reminders for day-to-day details). This along with P1's preference for adding reminders over calendar events at baseline may account for why P1 did not see improvement in success on the calendar task between mid-treatment and post-treatment. However, it is important to note that although P1 was slower to acquire skills, he was able to learn to use and apply new smartphone skills following systematic instruction despite limited prior experience with the iPhone, which is consistent with other studies demonstrating that individuals with cognitive impairment and limited to no familiarity with the type of high technology aid to be trained can still learn to use it (e.g., Ehlhardt Powell et al., 2012).

GAS Levels for Personal Goals. Both participants improved on all Personal Goals related to both the reminder and calendar functions and demonstrated greater improvements in GAS levels for those Personal Goals that were most closely related to training targets (Research Question 2). P1 and P2 maintained post-treatment improvements at the two-month follow-up for most Personal Goals that were closely related to training targets (Research Question 3). P1's

GAS levels for goals that were not a primary focus for treatment declined from post-treatment to follow-up, although all remained above baseline levels. P1 actually maintained post-treatment improvements at follow-up on one of his reminder goals that was not directly addressed in treatment (responding to reminders). However, all of P1's calendar function goals declined from post-treatment to follow-up, and only the goal most closely associated with training targets (successfully entering events) remained above its baseline GAS level. Additionally, although GAS goals related to perceived effort using the reminder and calendar functions at home were not developed for P2 as they were for P1, P2's home data revealed substantial reductions in perceived effort from pre-treatment to post-treatment, and the lower level of perceived effort for both functions was maintained at follow-up.

***Interpretation and notable observations*.** These findings support the hypothesis that following treatment, participants would successfully apply Targeted Smartphone Skills to trained personally-relevant goals as measured by GAS. The fact that participants improved the most on Personal Goals that were most closely associated to training targets and that post-treatment improvements on those same goals were more likely to be maintained at follow-up is consistent with literature demonstrating that systematic instruction facilitates acquisition *and* maintenance for individuals with cognitive impairment (Ehlhardt et al., 2008; Sohlberg & Turkstra, 2011). Similarly, the fact that P1 did not maintain improvements in GAS levels for Personal Goals related to the calendar function, including for the calendar goal that was directly targeted in treatment (successfully entering events), is likely explained by the fact that P1 did not receive sufficient practice in calendar skills relative to reminder skills, one of the key tenets of systematic instruction that has been demonstrated to impact treatment outcomes (Ehlhardt et al., 2008; Sohlberg & Turkstra, 2011).

Interestingly, both P1 and P2 improved on Personal Goals that were not actively targeted in treatment. It seems reasonable to expect that perceived effort of using the reminder and calendar functions in daily life would lessen in response to participants becoming more skilled in these functions. It is possible that greater exposure to using the reminder and calendar functions through treatment and homework helped P1 develop a habit for entering reminders and events, leading to improvements on those Personal Goals. It is also possible that home practice with entering reminders created opportunities for P1 to practice responding to reminders. Similarly for P2, although frequency of viewing his "Today" to-do list was not systematically trained in treatment, it was incorporated into treatment stimuli and homework assignments. Thus this exposure may have been enough for P2 to see an improvement in this goal.

Secondary Outcome Measures

Compensatory Techniques Inventory. For both P1 and P2, the most significant changes from pre- to post-treatment were observed for compensation use (Research Question 2). P1 went from not using any scheduling aids at baseline to using Siri on his iPhone for entering events, entering reminders, referring to entries, and rescheduling events one to a few times per week immediately following treatment. P1 also began referencing a wall calendar that his spouse maintained. P2 was using an Outlook calendar on his laptop and creating to-do lists on his iPhone prior to treatment. Immediately following treatment, P2 decreased the frequency with which he used his Outlook calendar in favor of using his iPhone calendar more frequently, which he rated as being more helpful than the Outlook calendar. As was the case for P1, P2 reported referring to a wall calendar that his spouse maintained following treatment and using his iPhone for time-based reminders in addition to to-do lists.

P1 and P2 showed different patterns in maintenance of compensation use at follow-up (Research Question 3). P1 was scheduling events on his iPhone less frequently and was no longer rescheduling events. However, he continued to enter reminders and refer to entries. These findings are consistent with the declines from post-treatment to follow-up observed for P1's Personal Goals related to the calendar function. P2, on the other hand, continued to use his iPhone for entering events, entering reminders, referring to entries, deleting or marking entries as completed, rescheduling events, and creating to-do lists on his iPhone most days. He continued to find using the iPhone functions more helpful than using his Outlook calendar alone.

Self- and informant-report questionnaires. Both P1 and P2 reported variable changes on secondary measures immediately following treatment, with some measures showing improvements across both participants. Neither P1's spouse nor P2's spouse endorsed significant reductions in caregiver burden following treatment (Research Question 2). Most measures that demonstrated improvements immediately following treatment maintained those improvements at follow-up (Research Question 3).

Cognition. P1's score on the BRIEF-A, a self-report measure of executive function, did not change following treatment. Interestingly, P2's level declined below the level of clinical significance immediately post-treatment and maintained below the level of clinical significance at two-month follow-up (Research Question 2, Research Question 3). Both P1 and P2 had fewer concerns in specific executive function domains that might be expected to change following treatment, including initiation and planning/organization. P1 also reported fewer concerns for task monitoring and organization of materials, while P2 reported fewer concerns related to shifting. P1's spouse endorsed fewer concerns in the same areas as P1 per the BRIEF-A informant report whereas P2's spouse's concerns remained unchanged for all areas except for

planning/organization, an area in which she endorsed *greater* concerns at post-treatment and follow-up. The divergence between P2's self-evaluation of planning/organization skills with his spouse's perceptions might be due to P2's spouse's awareness of P2's challenges in this area due to the nature of the treatment. Alternatively, P2 may have overestimated his improvements in this area following treatment. The PROMIS Item Bank Cognitive Function measure showed variable changes for both participants, with P1 reporting more concerns immediately post-treatment, P2 reporting fewer concerns immediately post-treatment, and both P1 and P2 reporting roughly the same level concern at follow-up as they had prior to treatment.

Well-Being. P1 reported relatively stable impact of PD on functioning and well-being throughout the study, although at follow-up, his concerns were approaching a moderate to severe level versus a moderate level at baseline. Additionally, P1 endorsed borderline mild to moderate depression at post-treatment versus borderline mild depression at baseline. P2 also reported a more significant impact of PD on functioning and well-being, increasing from mild impact to moderate impact at post-treatment and follow-up. However, unlike P1, P2 reported reduced symptoms of depression following treatment, with no change in BDI-II scores observed from post-treatment to follow-up.

Social Participation. Per the PROMIS Item Bank Satisfaction with Social Roles and Activities Form, both P1 and P2 experienced satisfaction with social roles and activities within the average range across all time periods.

Interpretation and notable observations.

***Measures of progress*.** As hypothesized, the training of personally-relevant goals led to some notable improvements on self-reported measures of functioning, such as increases in frequency of compensation use and fewer concerns in daily executive functions related to

reminder and scheduling aids (initiation and planning/organization). Interestingly, both P1 and P2 reported that following treatment, they began referencing a wall calendar maintained by their spouses. It is also noteworthy that P1 rated the usefulness of his iPhone calendar to be greater than that of his spouse's wall calendar and his own Outlook calendar given the fact that his iPhone is more likely to travel with him outside his home. This fact supports the findings of other studies which have demonstrated several benefits of portable external aids over non-portable aids (Charters et al., 2015; Dowds et al., 2011; Gentry et al., 2008).

Informant-report scores on the BREIF-A for both participants were lower than self-report scores (reflecting fewer concerns) across all time points, suggesting that either caregivers underestimate the frequency of everyday challenges in executive functioning, or participants overestimate the frequency of these challenges. P1's informant-report scores showed the same pattern of change from pre- to post-treatment as P1's self-report scores (domains likely to be affected by treatment showed decreases following treatment, reflective fewer concerns). However, P2's informant-report scores did not follow the same pattern of change as P2's self-report scores. P2's informant-report scores generally remained unchanged across time points except in the domain of planning/organization, where informant-report scores increased while self-report scores decreased. This might be the result of treatment / homework assignments highlighting P2's difficulties in planning/organization, raising P2's awareness of her spouse's challenges. Alternatively, P2 might be overestimating improvements in this area following treatment.

The fact that scores for the PROMIS Item Bank Cognitive Function measure and Functional Cognition Screen from the Compensation Techniques Inventory remained relatively unchanged for both participants might be due to (i) the tools not adequately measuring aspects of

daily cognitive function that would be expected to change due to training or (ii) the scales used by the tools not being sensitive enough to capturing change. The PROMIS Item Bank Cognitive Function Short Form involves rating just six statements about general cognitive functioning, few of which relate to reminders and scheduling. Additionally, items on the Functional Cognition Screen relate to more aspects of daily cognitive functioning than were targeted in treatment. Even isolating those related to reminders and scheduling reveals that there are twice as many issues related to scheduling than there are daily reminders. Given P1 did not make as many improvements with the calendar function as he did the reminder function, it is possible that he would have shown better progress on this screen had more issues related to daily reminders been included. Furthermore, while both instruments use a 5-point Likert scale for frequency, the CTI does not clearly define the differences in ratings, which may lead to issues with reliability in ratings across time (e.g., how a participant interprets rarely versus occasionally at baseline may not be the same as how he interprets rarely versus occasionally at post-treatment or follow-up).

Measures of participant well-being. Inconsistent changes, or a lack of change in some cases, on measures of participant well-being do not support the hypothesis that these measures would improve due to the application of TSS to personally-relevant goals. The measures of participant well-being used in this study (PDQ-8 and BDI-II) are broad in nature and thus potentially influenced by many factors besides the treatment provided by this study alone. The PDQ-8 only includes 2 questions (out of 8) that relate to cognitive-communication, and they are isolated to the domains of speech/language and attention/concentration, neither of which was a focus of treatment in the present study. For the BDI-II, while it is likely that numerous life factors could influence participants' emotional well-being, it is possible that P2 reported lessening symptoms of depression because he experienced a greater impact of the study than P1

who stated he had not noticed any real improvement in his daily life following treatment. Conversely, if other life factors caused P1 to experience increased symptoms of depression (including a worsening of cognitive symptoms as reported by his spouse and revealed in the CTI Independence Screen) over the course of the study, this may have contributed to P1's perception that his daily life had not seen meaningful improvements due to treatment.

Finally, while the PROMIS Item Bank Satisfaction with Social Roles and Activities-Form did not show improvements, scores suggested that social participation was not a concern for either participant at any point during treatment. This is at odds with other research which has found that individuals with cognitive impairment secondary to PD report reduced participation in social and leisure activities (Foster & Hersehy, 2011). It is possible that the two participants in this study had strong social support systems and therefore did not experience as significant of an impact on satisfaction with social participation as others.

Measures of caregiver well-being. The Zarit Burden Interview did not reveal a reduction in caregiver well-being. It is possible that the training provided in this study was too brief and/or too targeted to make a meaningful impact on informal caregivers' perceived well-being. Of note is that P1 had more severe cognitive impairment than P2, and P1's spouse endorsed experiencing a greater degree of burden than P2's spouse. This is consistent with emerging evidence that the burden experienced by informal caregivers of individuals with PD and cognitive impairment may be influenced by cognitive impairment severity (Leroi et al., 2012; Jones et al., 2017).

Other Measures

Control Measure. P1's percentage accuracy on a Sudoku Puzzle slightly improved between baseline and post-treatment and between post-treatment and follow-up. Although P2 showed some improvement in percentage accuracy at post-treatment, his accuracy returned to

baseline levels at follow-up (Research Question 4). It was hypothesized that treatment would not have any impact on the Control Measure. Improvements were most likely due to learning effects or chance (based on P1's performance, he was likely guessing without attending to all the information to reason correctly).

Neuropsychological screening. MoCA scores for P1 and P2 remained relatively stable over the course of the study. Treatment was not expected to have any impact on MoCA scores.

Self-rated smartphone skills. P1's self-rated smartphone skill level and confidence declined from baseline to post-treatment and remained steady between post-treatment and follow-up. His self-rated satisfaction with smartphone skills remained unchanged across all time points. P2, on the other hand, saw marked improvements across self-rated skill level, confidence, and satisfaction. At baseline, P1 had reported that he had given up on trying to learn new tasks on his smartphone and had therefore resigned to using it for basic functions, such as texting and calling. It is possible that participating in treatment to train new, more complex tasks resulted in increased awareness of what he did not know, resulting in the decline in perceived skill level and confidence.

Qualitative interview statements. Most of the statements captured by post-treatment and follow-up interviews support the objective data reported in this study. They also capture generalization of the foundational skill trained (saying "Hey Siri" to activate Siri) to other simple, untrained skills (e.g., placing phone calls, sending text messages, checking the weather, etc.). The one instance in which interview statements diverged from other data was in P1's post-treatment comment that he was unsure whether the skills trained in this study addressed his needs because he had not seen any changes in his daily cognitive performance despite showing improvements on his Personal Goals. This may reflect the fact that participants were selected to

fit the training rather than selecting external aids and goal areas to meet the needs of the participant. While P1 may have met all initial criteria to be selected as a good candidate for the smartphone functions trained in this study, it is possible that remembering daily activities and scheduling were less important goal areas relative to others. Additionally, P1's spouse reported that she had noticed a worsening of cognitive symptoms in P1 over the course of the study, which may have influenced his overall perception of his daily cognitive performance to a greater degree.

External versus internal cueing. Prior to treatment, P2 was using to-do lists to prioritize and remember to complete tasks. However, these lists required that he remember to look at them (internal cueing). P2 appeared to benefit more from entering time-based reminders, which included an alerting mechanism to notify him when a task was due (external cueing). This finding is consistent with the findings of others that suggest internally-generated strategies may be less effective than externally-cued strategies for individuals with cognitive impairment secondary to PD (Goedeken et al., 2017; Knoke, Taylor, and Saint-Cyr, 1998; Spencer, 2007).

Strengths and limitations of Siri. Siri provided a voice-activated access method for individuals with motor symptoms from PD that made traditional navigation methods slow and difficult. Both participants reported that Siri helped streamline certain tasks by eliminating a significant number of steps. At the same time, Siri made certain tasks more cumbersome. For example, marking reminders as complete and deleting reminders was typically easier to do by hand because Siri had a difficult time differentiating between multiple reminders that included the same word. For example, if a participant said, "Mark as complete my reminder to bring my binder to treatment," and the participant had a second reminder to "bring my baseball glove to the game," Siri would not know which reminder to mark as complete and would add additional

steps to the task. Even with the additional steps added, Siri frequently did not respond in an expected manner, meaning this process only occasionally worked. Meanwhile, it is possible to open the reminder application using Siri and complete one simple motor gesture to complete the same task (tap to mark as complete or swipe left to delete), and this process always works. This was also found to be the case for rescheduling or deleting calendar events.

Training Format. One major challenge encountered in implementing group treatment during this study might be anticipated to be experienced in clinical practice as well. P1 and P2 acquired skills at different rates which made developing group activities that would be helpful for both participants challenging. Additionally, while P1 expressed an interest in additional group learning, P2 did not find the group component helpful. This may be due to P2's perception that he was at a different place in his training than P1 or it might reflect a difference in learning styles. It is possible that some individuals may experience greater benefits from group treatment over individual treatment while others may experience the opposite. One benefit noted in a study by Huckans and colleagues (2010) that was achieved due to group sessions despite these obstacles was that participants shared different applications of trained skills, which appeared to enhance learning and generalization. For example, P1 demonstrated how he used Siri to conduct google searches during the first group session. Following that session, P2 also began conducting google searches using Siri and reported that he continued to do so at post-treatment and follow-up. However, this study found that there was indeed a significant benefit to supplementing group treatment sessions with individual sessions, as has been suggested by previous reports that hybrid approaches may have a benefit over group-only formats (Ownsworth et al., 2007; Vestri et al., 2014).

Limitations and Future Directions

This case series demonstrated that individuals with cognitive impairment secondary to PD can acquire and maintain new smartphone skills following systematic instruction and that application of these skills can support cognitive function at home and in the community as measured by improvements in performance on personally-relevant goals. However, given this was a proof-of-concept study, it was limited by a small number of participants, which restricts generalization of findings to a broader population of individuals with PD and cognitive impairment. Specifically, this study observed that differences in degree of cognitive impairment and prior smartphone experience may influence rate of acquisition and impact of trained skills on daily life. Future studies should incorporate a broader sample of individuals with PD and cognitive impairment and incorporate control groups. Additionally, future research might investigate the impact severity of cognitive impairment and baseline experience / skill level with the trained ATC device may have on treatment outcomes. Future studies might also consider comparing the benefits of Siri to other voice-activated aids, including but not limited to OK Google and Alexa.

GAS goal levels for Personal Goals were determined based on self- and informant-reported performance at home and in the community. Participants and spouses were trained to collect home data to help support baseline, post-treatment, and follow-up GAS levels. However, due to timing constraints, the home data sheet was developed prior to goal finalization. Thus while the data collected supported most finalized goals, P1's goal related to responding to reminders was not adequately supported by home data. Additionally, even with the collection of home data, it is still possible that GAS ratings were biased given that ratings were not assigned by an objective third party as is recommended in the GAS literature (Krasny-Pacini et al., 2016).

A second potential area for GAS bias was uncovered in this study. The GAS guidelines summarized by Krasny-Pacini and colleagues (2016) indicate that GAS levels should be equidistant with Level 0 representing the *expected* outcome following treatment. However, there might be instances in which developing equidistant levels creates a Level 0 outcome that is less than what might be expected as reasonably attainable for a given participant. This in turn could result in inflated GAS ratings. Given this was believed to be the case for some of P2's goals, comparisons of GAS levels between goals and across participants should be interpreted with caution.

This study conducted treatment on a shorter timeline than that used in prior studies of similar nature with the hope of providing guidelines for a clinically feasible treatment protocol. Given the differences in learning rates observed between the two participants in this study, future studies might consider training to criterion rather than having an established treatment timeframe to determine optimal treatment duration. While the goal was to develop a program that could fit within the current insurance environment in which individuals often qualify for a limited number of rehabilitation therapy visits, if research can establish that the optimal treatment duration cannot fit within that framework, clinicians may be better equipped to petition insurance companies to cover additional visits.

Appendix A: Participant/Family Member Interview Questions

1. When were you officially diagnosed with PD?
2. What were your initial motor symptoms? When did they begin?
3. Please list the medications you are currently taking.
4. Do you expect those medications to change in the next few months?
5. How old are you?
6. What is the highest educational degree you received (or what is the highest grade of school you completed)?
7. Have you noticed any changes in your thinking or memory since your diagnosis?
8. Have these changes caused any daily activities to become more challenging?
9. Which activities?
10. Why do you think these activities have become more challenging?
11. How long have you been having difficulty with X activities?
12. Which of these difficult activities restrict you the most from living the life you want to live?
13. How important is it for you to improve your ability to complete these activities?
14. Do you own a smartphone?
15. What is the make and model of your smartphone?
16. What operating system does your smartphone run?
17. When did you first begin using this smartphone?
18. How often do you use your smartphone?
19. For what purposes/functions do you use your smartphone?
20. How many months/years of experience *in total* do you have using *any* smartphone?

Appendix A Continued: Participant/Family Member Interview Questions

21. How would you rate your current skill level with using your smartphone (100mm visual analogue scale with anchors for beginner, intermediate, advanced)?
22. How would you rate your confidence in using the smartphone? (100mm visual analogue scale with anchors for not at all confident and very confident)
23. How would you rate your satisfaction with your current smartphone skills? (100mm visual analogue scale with anchors for not at all satisfied and very satisfied)
24. Do you have experience using voice commands (Siri) to operate your smartphone?
25. Do you use the reminder or calendar functions on your smartphone?
26. (If yes) Do you use the applications that came loaded on your smartphone or do you use applications acquired through an app store?
27. (If yes) How do you currently use these applications in your daily life?
28. How important is it for you to learn to use voice commands to use the reminder and calendar functions on your smartphone?
29. What else would you like to let us know?
30. The design of this study requires that all participants attend all treatment sessions (1 to 2 times per week for 5 weeks) and 2 follow-up assessments. Treatment will be from X date to X date, and one assessment will be scheduled immediately following the treatment phase, from X date to X date. Another assessment will occur one to two months later (between X date to X date). If you are selected for the study, will you be available to travel to the University of Washington for all treatment and assessment sessions?

Appendix A Continued: Participant/Family Member Interview Questions

Exclusionary Questions

1. Have you undergone deep brain stimulation?
2. Have you ever had a stroke, traumatic brain injury, or any other neurologic disease or condition beyond PD?
3. Did you have a preexisting learning disability before you were diagnosed with PD?
4. Are you experiencing difficulty managing the use of alcohol or drugs?
5. Are you currently taking sedatives or tranquilizers?
6. Do you have significant difficulty seeing or reading things that are within your reach, even when using corrective lenses?
7. Are you currently receiving cognitive therapy?
8. If you are selected for this study, you can only receive the treatment offered by the study from X date to X date. Are you planning on receiving cognitive therapy from a different therapist outside of the study from X date to X date?

Appendix B: Compensation Techniques Inventory

(as found in Sohlberg & Turkstra, 2011, pp. 176-178)

Compensation Techniques Inventory

Client Name:		Date:	
I. **Independence Screen**			
Life Tasks	**How much help needed? (see rating scale)**	**Comments (check any that are important goal areas)**	✓
Making appointments			
Financial management			
Social arrangements			
Shopping			
Meal planning and preparation			
Cleaning			
Laundry			
Driving			
Personal care			
1 = unable; 2 = lots of help; 3 = occasional help; 4 = reminders only; 5 = independent			
II. **Functional Cognition Screen**			
Cognitive Issue	**Frequency of Problem (see rating scale)**	**Comments (check any that really bother you)**	✓
Don't know the date			
Miss appointments			
Lose keys			
Double schedule			
Forget to complete tasks at home or work			
Don't know what appointments are coming up next week			
Have trouble organizing days and tasks that need to be completed			
Start but don't finish tasks			
Lose track of time			
Cannot stay focused and return to task when interrupted			
Forget what I did yesterday			
1 = happens constantly; 2 = happens frequently; 3 = happens occasionally; 4 = rarely happens; 5 = not an issue			

Appendix B Continued: Compensation Techniques Inventory

Compensation Techniques Inventory *(page 2 of 3)*

Past and Current Compensation Use				
Type of Aid	**Frequency of Use PRIOR**	**How Useful PRIOR**	**Frequency of Use NOW**	**How Useful NOW**
EXTERNAL SCHEDULING AIDS				
Wall Calendar *Location* _____				
• Enter scheduled events				
• Enter "things to do"				
• Refer to entries				
• Check off entries				
• Reschedule as needed				
Planner *Type* _____				
• Enter scheduled events				
• Enter "things to do"				
• Refer to entries				
• Set alarm				
• Check off entries				
• Reschedule as needed				
Electronic Scheduler *Type* _____				
• Enter scheduled events				
• Enter "things to do"				
• Refer to entries				
• Set alarm				
• Check off entries				
• Reschedule as needed				
OTHER EXTERNAL AIDS				
Voice recorder				
Car memo pad				
Digital stopwatch				
Wristwatch				
Bulletin board with notes				
Home filing system				
Post-it notes				
Reminders on fridge				
Pill reminder system				
Voice mail				
Calculator				
Camera				
Others:				

Frequency of Use Scale: 0 = never; 1 = 1X/week; 2 = a few times/week; 3 = most days
Helpfulness Scale: 0 = N/A or not useful; 1 = rarely helps; 2 = pretty helpful; 3 = very helpful

Appendix C: Targeted Smartphone Skills Acquisition Probe

Skill 1: Enter Time-Based Reminder Using Voice Commands[1]			
Step	**Description**	**Correct?**	
		Yes	**No**
1	**iPhone:** Press and hold the Home Button (iPhone 5s and earlier models) or say, "Hey, Siri" (later models) to launch Siri.		
2	**iPhone:** Say, "Remind me to *[Action]* on *[Day/Date]* at *[Time]*." (E.g., "Remind me to *have lunch with Steve tomorrow* at *3pm*.")		
	Total		

Total Steps	**2**
Total Yes Divided by Total Steps (Accuracy)	

Total Time to Complete (Rate)	

1. A simulated reminder will be provided. Example verbal instructions for the task might be, "Using voice commands, set a reminder to have lunch with Steve tomorrow at 3pm." To control for verbal short-term memory (STM)/working memory (WM) deficits, written instructions will also be provided. The reminder time will be set such that the reminder triggers during the session for the Skill 4 probe. If the participant cannot add the reminder themselves, the clinician will manually add the reminder to avoid modeling.

Skill 2: View Reminders Using Voice Commands[1]			
Step	**Description**	**Correct?**	
		Yes	**No**
1	**iPhone:** Press and hold the Home Button (iPhone 5s and earlier models) or say, "Hey, Siri" (later models) to launch Siri.		
2	**iPhone:** Say, "View reminders."		
	Total		

Total Steps	**2**
Total Yes Divided by Total Steps (Accuracy)	

Total Time to Complete (Rate)	

1. Verbal instructions for this task might be, "Using voice commands, view your reminders."

Skill 3: Clear Reminders using Voice Commands[1]			
Step	**Description**	**Correct?**	
		Yes	**No**
1	**iPhone:** Press and hold the Home Button (iPhone 5s and earlier models) or say, "Hey, Siri" (later models) to launch Siri.		
2	**iPhone:** Say, "Mark as completed."		
3	**iPhone:** When Siri asks which reminder to mark as completed, say, "*[Action]*." (E.g., "*Have lunch with Steve*.")		
	Total		

Total Steps	**3**
Total Yes Divided by Total Steps (Accuracy)	

Total Time to Complete (Rate)	

1. Verbal instructions for this task might be, "The reminder entered earlier has triggered. Please clear it using voice commands." To control for verbal STM/WM deficits, the clinician will gesture to the written instructions provided for Skill 1. If the participant completes this skill, the clinician will change the status of the reminder from completed to uncompleted so that Skill 4 may be probed.

Skill 4: Delete Reminder Using Voice Commands[1]			
Step	**Description**	**Correct?**	
		Yes	**No**
1	**iPhone:** Press and hold the Home Button (iPhone 5s and earlier models) or say, "Hey, Siri" (later models) to launch Siri.		
2	**iPhone:** Say, "Delete reminder to *[Action]* on *[Day/Date]* at *[Time]*."		
3	**iPhone:** When Siri asks to confirm, say, "Yes"/"Remove"/"Confirm" or tap "Remove"		
	Total		

Total Steps	**3**
Total Yes Divided by Total Steps (Accuracy)	
Total Time to Complete (Rate)	

1. Verbal instructions for the task might be, "Using voice commands, delete the reminder entered earlier." To control for verbal STM/WM deficits, the clinician will gesture to the written instructions provided for Skill 1.

Skill 5: Enter Calendar Event Using Voice Commands[1]			
Step	**Description**	**Correct?**	
		Yes	**No**
1	**iPhone:** Press and hold the Home Button (iPhone 5s and earlier models) or say, "Hey, Siri" (later models) to launch Siri.		
2	**iPhone:** Say, "Schedule a *[Event Name]* (with *[Person]*) *[Day/Date]* at *[Time]*." (E.g., "Schedule a *lunch* with *Steve tomorrow* at *3pm*.")		
3	**iPhone:** When Siri asks to confirm, say, "Yes"/"Remove"/"Confirm" or tap "Confirm"		
	Total		

Total Steps	**3**
Total Yes Divided by Total Steps (Accuracy)	
Total Time to Complete (Rate)	

1. A simulated calendar event will be provided. Example verbal instructions might be, "Using voice commands, enter a calendar event to have lunch with Steve tomorrow at 3pm." To control for verbal STM/WM deficits, written instructions will also be provided.

Skill 6: View Calendar Using Voice Commands[1]			
Step	**Description**	**Correct?**	
		Yes	**No**
1	**iPhone:** Press and hold the Home Button (iPhone 5s and earlier models) or say, "Hey, Siri" (later models) to launch Siri.		
2	**iPhone:** Say, "What's on my calendar/schedule for [Day/Date] (at [Time])? " (E.g., "What's on my calendar on Saturday?"/"What's on my schedule at 1:30 on July 3rd?")		
	Total		

Total Steps	**2**
Total Yes Divided by Total Steps (Accuracy)	
Total Time to Complete (Rate)	

1. A simulated stimulus will be provided based on the Skill 4 stimulus. Verbal instructions might be, "Using voice commands, view what's on your calendar for tomorrow." To control for verbal STM/WM deficits, written instructions will also be provided.

Skill 7: Modify an Existing Calendar Event Using Voice Commands[1]			
Step	**Description**	**Correct?**	
		Yes	**No**
1	**iPhone:** Press and hold the Home Button (iPhone 5s and earlier models) or say, "Hey, Siri" (later models) to launch Siri.		
2	**iPhone:** Say, "Move my [Event Name] (with [Person]) [Day/Date] at [Time] " or "Reschedule my [Event Name] [Day/Date] at [Time]. " (E.g., "Move my lunch with Steve tomorrow at 3pm")		
3	**iPhone:** When Siri asks to tell her the new day/date and time, say, "[Day/Date] at [Time]." (E.g., "Tomorrow at 1pm" [1])		
4	**iPhone:** When Siri asks to confirm, say, "Yes"/"Remove"/"Confirm" or tap "Confirm"		
	Total		

Total Steps	**4**
Total Yes Divided by Total Steps (Accuracy)	
Total Time to Complete (Rate)	

1. A simulated stimulus will be provided based on the stimulus in Skill 4. Example verbal instructions might be, "Using voice commands, reschedule your lunch with Steve to tomorrow at 1pm." To control for verbal STM/WM deficits, written instructions will also be provided.

Skill 8: Delete an Existing Calendar Event Using Voice Commands[1,2]			
Step	**Description**	**Correct?**	
		Yes	**No**
1	**iPhone:** Press and hold the Home Button (iPhone 5s and earlier models) or say, "Hey, Siri" (later models) to launch Siri.		
2	**iPhone:** Say, "Cancel my [Event Name] (with [Person]) [Day/Date] at [Time]." (E.g., "Cancel my lunch with Steve tomorrow at 1pm.")		
3	**iPhone:** When Siri asks to confirm, say, "Yes"/"Remove"/"Confirm" or tap "Confirm"		
	Total		

Total Steps	**3**
Total Yes Divided by Total Steps (Accuracy)	
Total Time to Complete (Rate)	

1. Skill 6 will be probed following Skill 5 for efficiency (it allows the same modified calendar event to be the stimulus deleted). However, during acquisition training, Skill 6 will be trained before Skill 5 because Skill 5 is less complex (i.e. has fewer steps).
2. The final calendar event from Skill 5 will be used as the stimulus. Example verbal instructions might be, "Using voice commands, delete your lunch with Steve scheduled for tomorrow at 1pm." To control for verbal STM/WM deficits, written instructions will also be provided.

Appendix D: Sample Targeted Smartphone Skills Application Probes

P1 Reminder Task

Instructions: You are planning your to-do list for the day this morning, and there are several details to remember. Demonstrate how you would keep track of the details below so that you remember them throughout the day.

Details to Remember:

1) You have a speech therapy appointment this morning. You need to remember to bring your binder when you leave the house at 10:00am.

2) You need to remember to make sure you have your phone set to ring at 11:30am today because you are expecting a call.

3) You want to remember to bring your friend's birthday card to a party this afternoon. You plan to leave for the party at 2:00pm.

4) You have a dinner reservation tonight with Cindy. You need to remember to bring your medications with you when you leave the house at 6:00pm.

5) You need to remember to take your medications this evening at 7:00 pm.

P1 Calendar Task

Instructions: You are planning your schedule for the week, and you have several activities. Demonstrate how you would schedule the activities below.

Activities:

1) Lunch with your daughter in the University District on Monday at 11:30 am.

2) Speech therapy appointment at the UW Speech and Hearing Clinic on Wednesday at 2:30 pm.

3) Doctor appointment in Bellevue on Thursday at 10:15 am.

4) Dinner reservation with Cindy in Ballard on Friday at 6:45 pm.

5) Mariner's game on Sunday at 1:30 pm.

Appendix D Continued: Sample Targeted Smartphone Skills Application Probes

P2 Reminder Task

Instructions: You are planning your to-do list for the day this morning, and there are several details to remember. Demonstrate how you would keep track of the details below so that you remember them throughout the day.

Details to Remember:

1) You have a speech therapy appointment this morning. You need to remember to bring your binder when you leave the house at 10:00am.

2) You need to remember to make sure you have your phone set to ring at 11:30am today because you are expecting a call.

3) You want to remember to bring your friend's birthday card to a party this afternoon. You plan to leave for the party at 2:00pm.

4) You have a dinner reservation tonight with your wife. You need to remember to bring your medications with you when you leave the house at 6:00pm.

5) You need to remember to check your email this evening at 7:00 pm.

P2 Calendar Task

Instructions: You are planning your schedule for the week. Below are several time-sensitive activities you must schedule around existing appointments (see the next page for a view of your current calendar).

Demonstrate how you would schedule the activities below.

Time-Sensitive Activities to Schedule:

1) Meet with a prospective buyer for the cabin. The buyer is only available on Tuesday at 11:00 am or Thursday at 2:30 pm. You expect the meeting to last about one hour.

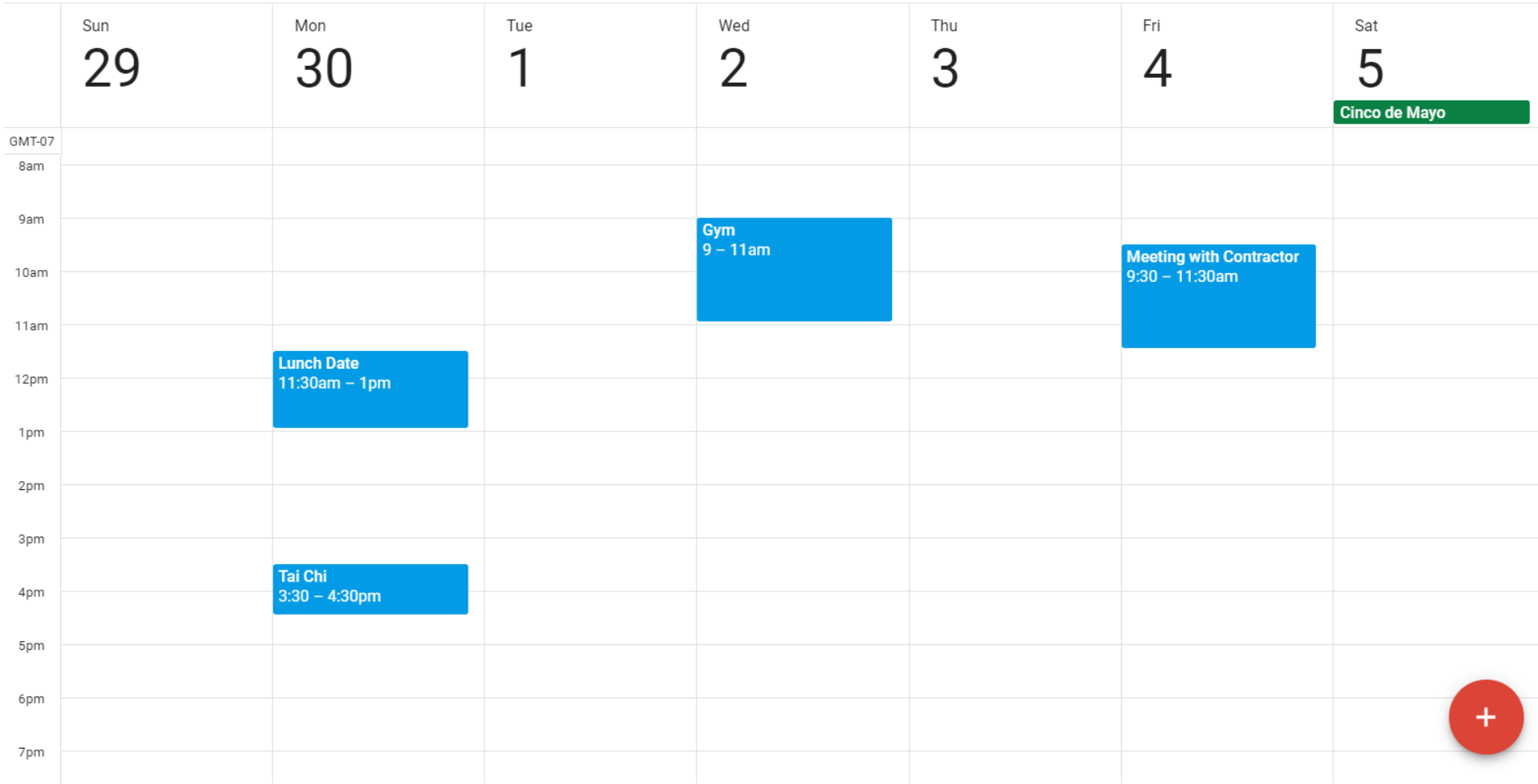
2) Set a time for a 30-minute call with your tax accountant. You need to be at home for the call to have access to documents. He is available on Tuesday between 11:00 am and 12:00 pm or Wednesday after 3:30 pm.

3) Be onsite at the cabin to receive a large delivery. The delivery can only be made on Thursday between 2:00 pm and 4:00 pm. You must be available during the entire delivery window.

4) Schedule a 90-minute appointment for the research study you are participating in. The clinician is available any time on Monday.

5) Schedule a doctor appointment. The doctor has availability Wednesday at 2:30 pm or Friday at 9:00 am. It takes 30 minutes to get from your house to the doctor's office, and the appointment will last an hour.

Appendix D Continued: Sample Targeted Smartphone Skills Application Probes



Appendix E: Treatment Fidelity Observation Checklist – Instructional Components

Component	Description	Implemented Throughout		
		Yes	No	N/A[1]
Order of Targeted Skills	Clinician trains Targeted Smartphone Skills related to the reminder function before the calendar function.			
Criterion to Advance to New Skill	Once the participant can perform a trained Targeted Smartphone Skill with 80% accuracy over 5 trials, a new Targeted Smartphone Skill will be trained.			
Errorless Learning	Clinician controls for errors by following a most-to-least cueing hierarchy.			
Method of Vanishing Cues	As the participant demonstrates the levels of mastery defined by the cueing hierarchy (Figure 2), cues are gradually faded.			
Effortful Processing Strategies	Clinician incorporates strategies to promote effortful processing during treatment (e.g., clinician asking participants to take data, visualize the next step, use self-talk, predict performance, reflect on performance).			
Task Analysis	Intervention targets are clearly delineated. Complex tasks, such as multistep procedures, are broken down into simpler components.			
Sufficient Practice	Participants will complete at least 15 practice trials per skill trained during any given individual session.			
Distributed Practice	Following initial skill acquisition (during which all practice trials will be completed in a row), practice trials will be spaced out during treatment sessions and at home.			
Ecological Validity	Simulated stimuli are tailored to each participant based on his or her Trained Goals. During application training, real-life scenarios reflecting the participant's Trained Goals are used.			
Stimulus Variation	Practice scenarios (simulated, real), partners (clinician, caregiver, group members), and environments (clinic, home) will vary during training.			
	Total			

Components Observed (Sum of Yes + No)	
Total Yes Divided by Components Observed	

1. Not all components will be relevant to group treatment sessions.

Appendix F: Treatment Fidelity Observation Checklist – Cueing Hierarchy

Trial #	Correct Cue Provided	
	Yes	No
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
Subtotal		

Trial #	Correct Cue Provided	
	Yes	No
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
Subtotal		

Trial #	Correct Cue Provided	
	Yes	No
21		
22		
23		
24		
25		
26		
27		
28		
29		
30		
Subtotal		

Trial #	Correct Cue Provided	
	Yes	No
31		
32		
33		
34		
35		
36		
37		
38		
39		
40		
Subtotal		

Trial #	Correct Cue Provided	
	Yes	No
41		
42		
43		
44		
45		
46		
47		
48		
49		
50		
Subtotal		

Trial #	Correct Cue Provided	
	Yes	No
51		
52		
53		
54		
55		
56		
57		
58		
59		
60		
Subtotal		

Trials Observed (Sum of Yes + No)	
Total Yes Divided by Trials Observed	

Appendix G: Sample Clinician Treatment Log

Clinician Treatment Log

Participant: 803 **Date:** 4/30 **Session #:** 2 **Treatment Duration:** 45-60 Min

Target 5: Enter Calendar Event Using Siri
Stimuli: Using Siri, schedule:
1. A doctor appointment on Monday, May 7 at 2:45 pm.
2. A speech therapy appointment on May 10 at 2:00 pm.
3. A lunch with _____ on Tuesday at noon.
4. A meeting with your tax accountant on Friday at 10:30 am.
5. A follow-up assessment on July 12 at 4 o'clock.
6. An exercise class on June 6 at 8:15 am.

Trial Tally	Level of Cueing for Final Trial	Max Level of Cueing Provided
𝍸 𝍸 𝍸 |||	(I)	(DM)

Target 6: View Calendar Using Siri
Stimuli: Using Siri, view what's on your calendar:
1. On Saturday at 9:00 am
2. Tomorrow
3. July 3rd
4. June 16 at 3:00 pm
5. Next week

Trial Tally	Level of Cueing for Final Trial	Max Level of Cueing Provided
𝍸 𝍸 ||	(I)	(DM)

Target 7: Delete an Existing Calendar Event Using Siri Texacanna
Stimuli: Using Siri, delete your
1. Doctor appointment on Monday, May 7 at 2:45 pm.
2. Speech therapy appointment on May 10.
3. Tuesday lunch with _____.

Trial Tally	Level of Cueing for Final Trial	Max Level of Cueing Provided
𝍸 |||	(I)	(DM)

Target 8: Modify an Existing Calendar Event Using Siri
Stimuli: Using Siri, reschedule your
1. Meeting with your tax accountant to Thursday at 12:30.
2. Follow-up assessment to July 14 at 3:00 pm.
3. Exercise class to June 6 at 9:15 am.

Trial Tally	Level of Cueing for Final Trial	Max Level of Cueing Provided
||	~~DM~~ Guided	Guided

Homework: See homework log for period April 30 – May 7. Participant was briefly instructed on how to take a screenshot for tasks asking the participant to view current reminders.

1. DM = Direct model with written and graphic cues (list of steps with picture for each step); GP = Guided production with written and graphic cues; SR = Guided production at slower rate; WG = Written and graphic cues; W = Written cues; I = Independent.

Appendix H: Sample Participant Homework Log[1]

Participant: _____ **Homework Log for Period:** April 12 – April 18

Instructions:

- Complete the tasks below at home in accordance with the daily schedule.
- Use voice commands to complete each task.
- Space each of the three daily tasks out throughout the day – do not complete all three tasks at once.
  - For example, you could complete the first two tasks in the morning and the third task in the afternoon. Or, you could complete the first task in the morning, the second task in the afternoon, and the third task in the evening.
- Do your best to vary the times at which you complete tasks.

Day	Task[2]	Time Completed[3]
Mon.	1. Set a reminder to pay the electricity bill on Tuesday, May 15 at 9:00 am.	
	2. Set a reminder to leave for your speech therapy appointment on Monday, April 19 at 1:00 pm.	
	3. Set a reminder to call your doctor tomorrow at 3:30 pm.	
Tues.	4. View your current reminders (take a screen shot of the screen by pressing the home and power buttons at the same time).	
	5. Set a reminder to complete your first homework assignment at 9:00 am tomorrow.	
	6. Clear the reminder to call your doctor today at 3:30 pm.	
Wed.	7. Set a reminder to pick up milk today at 11:00 am.	
	8. Clear the reminder to complete your first homework assignment at 9:00 am today.	
	9. Clear the reminder to pick up milk today at 11:00 am.	
Thur.	10. Set a reminder to leave for your exercise class at 2:30 pm on Saturday, April 17.	
	11. Set a reminder to send your grandchild a birthday card on June 1 at 10:15 am.	
	12. View your current reminders (take a screen shot of the screen by pressing the home and power buttons at the same time).	
Fri.	13. Set a reminder to take your medications today at 6:45 pm.	
	14. Set a reminder to complete your first Sunday homework assignment at 8:45 am.	
	15. Clear the reminder to take your medications today at 6:45 pm.	
Sat.	16. Set a reminder to mail your mortgage payment at 10:30 am on Wednesday, April 28.	
	17. View your current reminders (take a screen shot of the screen by pressing the home and power buttons at the same time).	
	18. Clear the reminder to leave for your exercise class at 2:30 pm today.	
Sun.	19. Set a reminder to take your medications today at 12:15 pm.	
	20. Clear the reminder to complete your first Sunday homework assignment at 8:45 am today.	
	21. View your current reminders (take a screen shot of the screen by pressing the home and power buttons at the same time).	

1. Homework logs were provided to participants in a larger font.
2. Homework assignments were developed by the clinician in advance of each session. Depending on participant performance during the treatment session, the clinician modified homework assignments.
3. If participants had difficulty writing, they were permitted to take a screenshot of their phone following task completion. The clinician then used the screenshots to complete this column at the next treatment session on behalf of the participant.

Appendix I: TSS Application Probe Error Coding Instructions

General Guideline: In the event that multiple attempts are made, calculate all errors for each attempt

Errors:

- Saying, "Hey Siri" while Siri is already listening
- Saying, "Siri" instead of "Hey Siri" (unless Siri is already activated)
- Pressing the button to activate Siri AND saying "Siri" or "Hey Siri" (unnecessary extra step)
- Activating Siri before the participant is ready with the verbal instruction. There will be a long enough pause after the participant says "Hey Siri" that Siri might stop listening and/or prompt the individual again to begin his instruction.
- Speaking to Siri when she isn't listening
- Not speaking clearly / loudly enough for Siri to understand what was said
    - Exception: When a name isn't included in the individual's contact list and the reminder is about calling someone, Siri will change the spoken name to one that is similar to a name in the contacts list. It should not be counted as an error if this occurs.
- Including, "when I leave the house" in verbal instruction for time-based reminder to Siri – it triggers a location-based reminder
- Not including a time with the reminder (a time frame like in the morning or in the evening is okay. It is also okay to not have a specific time as long as the participant includes a day/date)
- Not saying "remind me" *at the beginning* of the instruction to Siri when adding a reminder, regardless of whether it works. More often than not, Siri will either add an extra step ("Okay, just tell me what you want to be reminded about") or will think the individual is looking for an existing appointment
    - Occasionally, not saying "remind me" at the beginning will still work (e.g., "at [time], remind me to [action]"), but it is rare / inconsistent. Therefore, even if the reminder is added successfully, continue to count this as an error
- Not following the format in any other way other than the ways listed above that results in an incorrect entry or an extra step **(**I'd like to be reminded, please; remind me followed by the time instead of the reminder – once Siri hears the time, she's done listening**)**, including when responding to, "Okay, just tell me what you want to be reminded about" (e.g., restating "Remind me to…" instead of just responding with "action, date, time" – Siri will include "please remind me to" in the reminder title)
    - Using different verbs that result in the appropriate outcome is okay (e.g., cancel instead of delete, erase instead of delete, read instead of view, show instead of view, move instead of reschedule, change instead of reschedule). This one has more to do with the syntax of the instruction.
        - Exception 1: when the verb would result in a different skill (e.g., view instead of delete is still an error and delete instead of mark as complete or completed is still an error)

    - Exception 2: add an appointment or put an appointment on my calendar is an error because it results in a non-specific appt title
- Using the "remind me" command to add a calendar event
- Completing a calendar skill when instructed to complete a reminder skill (pay attention to how Siri refers to what happens – does she say she scheduled something or added an appointment? Does she indicate she's looking for an appointment or can't find an appointment?
- Entering calendar application and navigating to date with finger before saying Hey Siri (adds unnecessary extra steps)
- Not beginning with "schedule a" and beginning instead with "at time (and date)", so Siri thinks the person is looking for an existing appointment – adds an extra step
- Including the date/time of the old appointment when rescheduling / modifying an existing appointment (Siri will ignore the new time if the old time is given)
- Responding "no" when Siri asks, "Shall I update it?" when the changes / additions to a calendar event are correct
- Not responding at all when prompted (don't count as an error if the participant eventually responds after Siri repeats the instruction or after Siri stops listening, only if the participant never responds or reacts to the question in any way)
- When changing the time of an event, including two times (e.g., from 3:00 to 4:00) instead of just the start time and duration (e.g., at 3:00 for 1 hour)

Appendix J: TSS Application Probe Rate Calculation Instructions and Sample Data for P1

General Guidelines:

- Begin counting time for the first step immediately after the end of the clinician's verbal instruction for the skill (see special issues below for one exception)
- Begin counting time for all subsequent steps immediately after the end of Siri's response/question
- Stop counting time for all steps immediately after the end of the participant's verbal instruction to Siri (Siri's lag time to "think" and Siri's responses should *not* be included in the time calculation)
- Total time for a skill is calculated as the sum of the time for all steps in that skill

Special Issues:

- If verbal instructions are not provided for each individual skill (e.g., lab probes for 803 included an initial task instruction but then the participant read stimuli for each individual skill on his own), calculate two types of time: (i) planning time and (ii) skill completion time.
    - *Planning time* for the first skill should be calculated beginning immediately after the end of the clinician's instruction for the task until the participant picks up his phone to begin the first skill.
        - If the participant sets down his phone at any point during the task, calculate additional planning time from the moment the phone is set down until the moment the participant picks up his phone to begin the next skill.
        - If the participant says "Siri" or "hey Siri" or otherwise speaks to Siri to initiate a skill without picking up his phone, stop calculating planning time at that moment.
    - *Skill completion time* for the first skill should be calculated beginning immediately after the participant picks up his phone (or initiates a verbal instruction to Siri if the participant does not pick up the phone).
        - As noted above, if the participant sets his phone back down, begin calculating planning time again until the participant picks his phone back up.
        - If the participant does not set his phone back down between skills, begin calculating skill completion time for the first step of the next skill at the end of Siri's last response to the final step from the last skill.
- If the participant asks a question to the clinician at any point, start the time for the question at the initiation of the question by the participant and stop the time at the end of the clinician's response. Then, back this question time out of the overall time for the specific step during which the question was asked.
- If the participant is completing a probe for adding calendar events but instead adds a reminder (i.e. "remind me to…" instead of "schedule…"), time should be marked as "N/A"
- If Siri adds an extra step to a skill for reasons that could not be controlled by the participant (e.g., asking "which Steve" if there are multiple Steve's in the participant's contact list), calculate time for the participant's response to this question but do not include it in the total time for the skill. Instead make a note about what happened and the amount of time that was not included in the total time for the skill.
- If the individual makes multiple attempts to complete a given skill, continue calculating time for each step in each attempt per the guidelines above. The total time for the skill will be calculated as the sum of all steps across all attempts. This will be the case regardless of whether or not the individual is completing different skills in order to correct the first attempt (e.g., modifying and/or deleting). However, be sure to note the specific skill for each attempt.
- If the participant refers to an appointment instead of a reminder or adds an appointment instead of a reminder.

Appendix J: TSS Application Probe Rate Calculation Instructions and Sample Data for P1

801 TSS Acquisition Probe BASELINE	**Skill 1**	**2**	**3**	**4**	**5**	**6**	**7****	**8**
Total Time	9.507	7.505	18.715	10.541	13.045	13.543	N/A	10.775
Planning Time	3.235	5.370	11.509	6.338	5.728	10.575	N/A	6.238
Procedure Time	6.272	2.135	7.206	4.203	7.317	2.968	N/A	4.537
Step 1	*0.434*	*0.333*	*0.368*	*0.467*	*0.610*	*0.407*	*N/A*	*0.433*
Step 2	*5.838*	*1.802*	*6.838*	*3.736*	*6.707*	*2.561*	*N/A*	*4.104*

801 TSS Acquisition Probe MID-TX	**Skill 1**	**2**	**3**	**4**	**5**	**6**	**7****	**8**
Total Time	30.459	3.070	6.473	14.377	27.623	6.305	N/A	7.006
Planning Time	26.556	1.3	2.635	10.142	21.152	3.402	N/A	2.769
Procedure Time	3.903	1.77	3.838	4.235	6.471	2.903	N/A	4.237
Step 1	*0.767*	*0.668*	*0.835*	*0.833*	*0.733*	*0.768*	*N/A*	*0.733*
Step 2	*3.136*	*1.102*	*3.003*	*3.402*	*4.338*	*2.135*	*N/A*	*3.504*
Step 3					*1.4*			
Step 4								
Avg Time per Step	1.9515	0.885	1.919	2.1175	2.157	1.4515	N/A	2.1185

801 TSS Acquisition Probe POST-TX	**Skill 1**	**2**	**3**	**4**	**5**	**6**	**7****	**8**
Total Time	12.543	11.641	N/A	N/A	12.943	6.470	N/A	N/A
Planning Time	8.806	9.573	N/A	N/A	6.937	4.703	N/A	N/A
Procedure Time	3.737	2.068	N/A	N/A	6.006	1.767	N/A	N/A
Step 1	*0.633*	*0.767*	*N/A*	*N/A*	*0.633*	*0.7*	*N/A*	*N/A*
Step 2	*3.104*	*1.301*	*N/A*	*N/A*	*5.006*	*1.067*	*N/A*	*N/A*
Step 3					*0.367*			
Step 4								
Avg Time per Step	1.8685	1.034	N/A	N/A	2.002	0.8835	N/A	N/A

Appendix K: Compensatory Techniques Inventory Responses Across Time for P1 and P2

P1			
Independence Screen			
Life Tasks	**Baseline**	**Post-Treatment**	**2-Month Follow-Up**
Help making appointment	3	2	2
Financial management	2	3	2
Social arrangements	3	3	2
Shopping	3	3	2
Meal planning and preparation	3	3	3
Cleaning	2	3	3
Laundry	-	-	-
Driving	1	1	1
Personal care	3	3	2
Functional Cognitive Screen			
Cognitive Issue	**Baseline**	**Post-Treatment**	**2-Month Follow-Up**
Don't know the date	2	3	2
Miss appointments	4	4	4
Lose keys	4	4	4
Double schedule	4	4	4
Forget to complete tasks at home or work	3	3	3
Don't know what appointments are coming up next week	1	2	1
Have trouble organizing days and tasks that need to be completed	2	2	2
Start but don't finish tasks	2	3	3
Lose track of time	4	3	2
Cannot stay focused and return to task when interrupted	2	2	3
Forgot what I did yesterday	3	2	2
Don't know the date	2	3	3
1 = happens constantly; 2 = happens frequently; 3 = happens occasionally; 4 = rarely happens; 5 = not an issue			

Appendix K Continued: Compensatory Techniques Inventory Responses Across Time for P1 and P2

P1						
Compensation Use						
External Aid (Scheduling)	**Baseline**		**Post-Treatment**		**2-Month Follow-Up**	
	Frequency	**Usefulness**	**Frequency**	**Usefulness**	**Frequency**	**Usefulness**
Wall Calendar						
Enter scheduled events	0	0	0	0	0	0
Enter things to do	0	0	0	0	0	0
Refer to entries	0	0	2	2	2	2
Check off entries	0	0	0	0	0	0
Reschedule as needed	0	0	0	0	0	0
Planner						
Enter scheduled events	0	0	0	0	0	0
Enter things to do	0	0	0	0	0	0
Refer to entries	0	0	0	0	0	0
Set alarm	0	0	0	0	0	0
Check off entries	0	0	0	0	0	0
Reschedule as needed	0	0	0	0	0	0
Electronic scheduler: Siri						
Enter scheduled events	0	0	2	2	1	2
Enter things to do	0	0	2	2	2	2
Refer to entries	0	0	2	2	2	2
Set alarm	0	0	0	0	0	0
Check off entries	0	0	0	0	0	0
Reschedule as needed	0	0	1	2	0	0
Frequency: 0 = never, 1 = 1x/week, 2 = a few times/week, 3 = most days *Usefulness: 0 = N/A or not useful, 1 = rarely helps, 2 = pretty helpful, 3 = very helpful*						

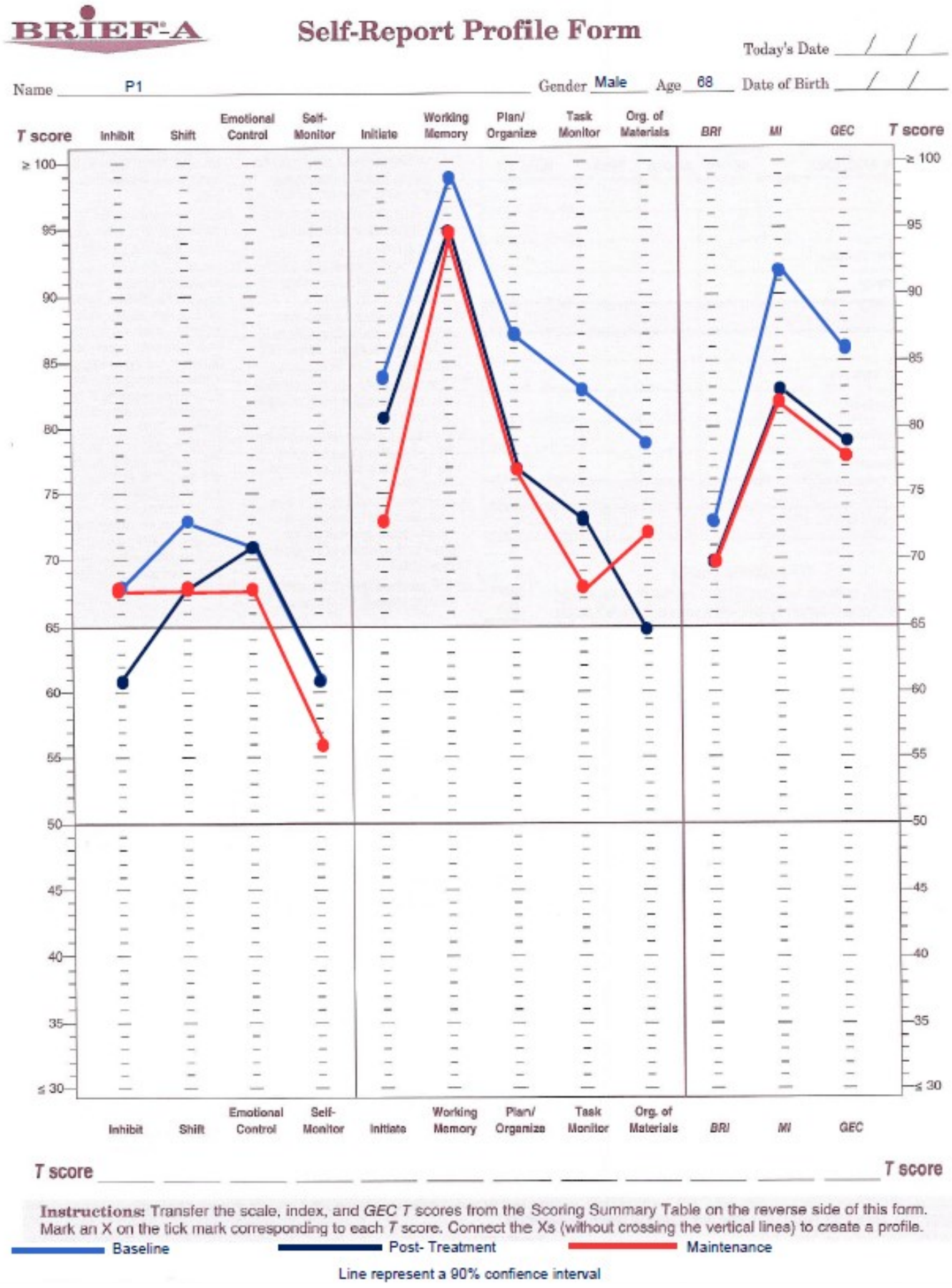
Appendix K Continued: Compensatory Techniques Inventory Responses Across Time for P1 and P2

P2			
Independence Screen			
Life Tasks	**Baseline**	**Post-Treatment**	**2-Month Follow-Up**
Help making appointment	5	5	4
Financial management	5	4	5
Social arrangements	2	4	3
Shopping	-	-	-
Meal planning and preparation	-	-	-
Cleaning	-	-	-
Laundry	-	-	-
Driving	5	5	5
Personal care	5	5	3
Functional Cognitive Screen			
Cognitive Issue	**Baseline**	**Post-Treatment**	**2-Month Follow-Up**
Don't know the date	5	4	4
Miss appointments	5	5	4
Lose keys	5	5	5
Double schedule	5	5	5
Forget to complete tasks at home or work	4	4	3
Don't know what appointments are coming up next week	4	5	4
Have trouble organizing days and tasks that need to be completed	3	4	3
Start but don't finish tasks	1	3	2
Lose track of time	3	3	2
Cannot stay focused and return to task when interrupted	-	5	2
Forgot what I did yesterday	-	3	3
1 = happens constantly; 2 = happens frequently; 3 = happens occasionally; 4 = rarely happens; 5 = not an issue			

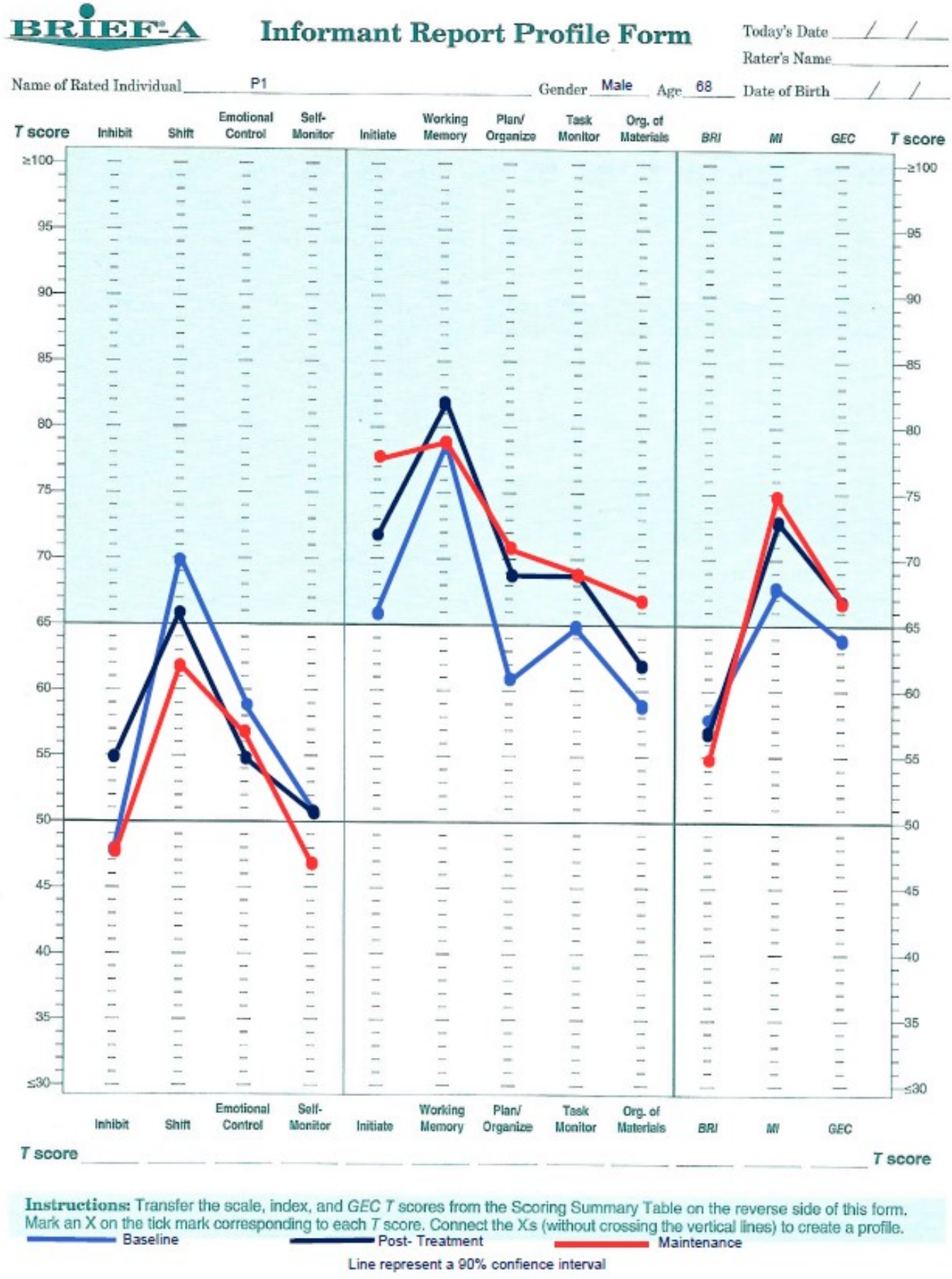
Appendix K Continued: Compensatory Techniques Inventory Responses Across Time for P1 and P2

P2						
Compensation Use						
External Aid (Scheduling)	**Baseline**		**Post-Treatment**		**2-Month Follow-Up**	
	Frequency	**Usefulness**	**Frequency**	**Usefulness**	**Frequency**	**Usefulness**
Wall Calendar						
Enter scheduled events	0	0	1	1	1	3
Enter things to do	0	0	0	0	0	0
Refer to entries	0	0	0	0	1	3
Check off entries	0	0	0	0	0	0
Reschedule as needed	0	0	1	1	1	3
Planner						
Enter scheduled events	0	0	0	0	0	0
Enter things to do	0	0	0	0	0	0
Refer to entries	0	0	0	0	0	0
Set alarm	0	0	0	0	0	0
Check off entries	0	0	0	0	0	0
Reschedule as needed	0	0	0	0	0	0
Electronic scheduler	Outlook Calendar		Outlook Calendar		Outlook Calendar & iPhone Calendar	
Enter scheduled events	2	3	1	2	3	3
Enter things to do	0	0	0	0	3	3
Refer to entries	2	2	1	2	3	3
Set alarm	2	2	0	0	3	3
Check off entries	2	2	0	0	3	3
Reschedule as needed	2	2	1	2	3	3
Other	To Do Lists		To Do Lists, Reminders, Calendar		To Do Lists, Reminders	
iPhone	3	3	3	3	3	3
Frequency: 0 = never, 1 = 1x/week, 2 = a few times/week, 3 = most days *Usefulness: 0 = N/A or not useful, 1 = rarely helps, 2 = pretty helpful, 3 = very helpful*						

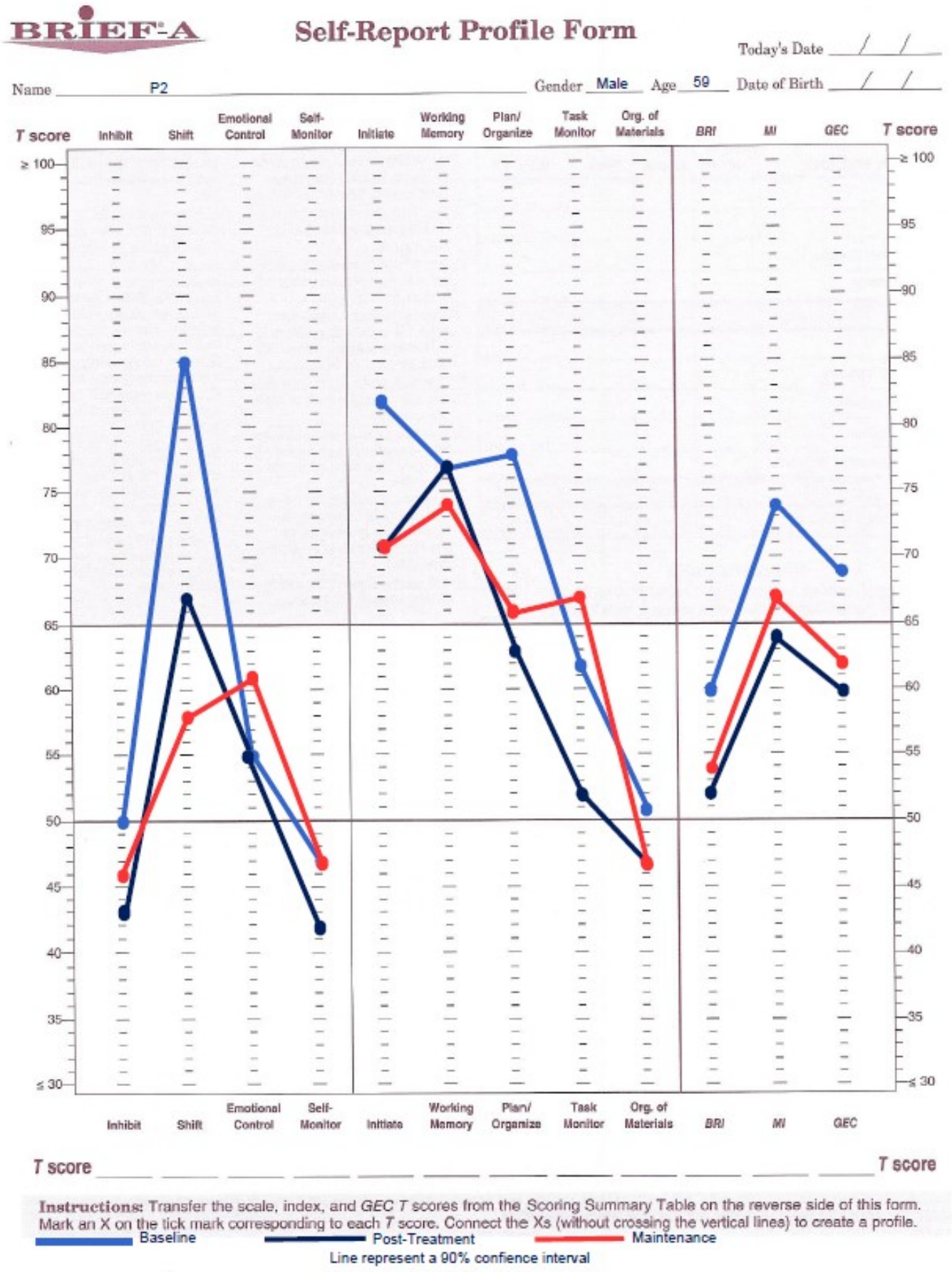
Appendix L: BRIEF-A Self- and Informant Report Ratings Across Time for P1 and P2



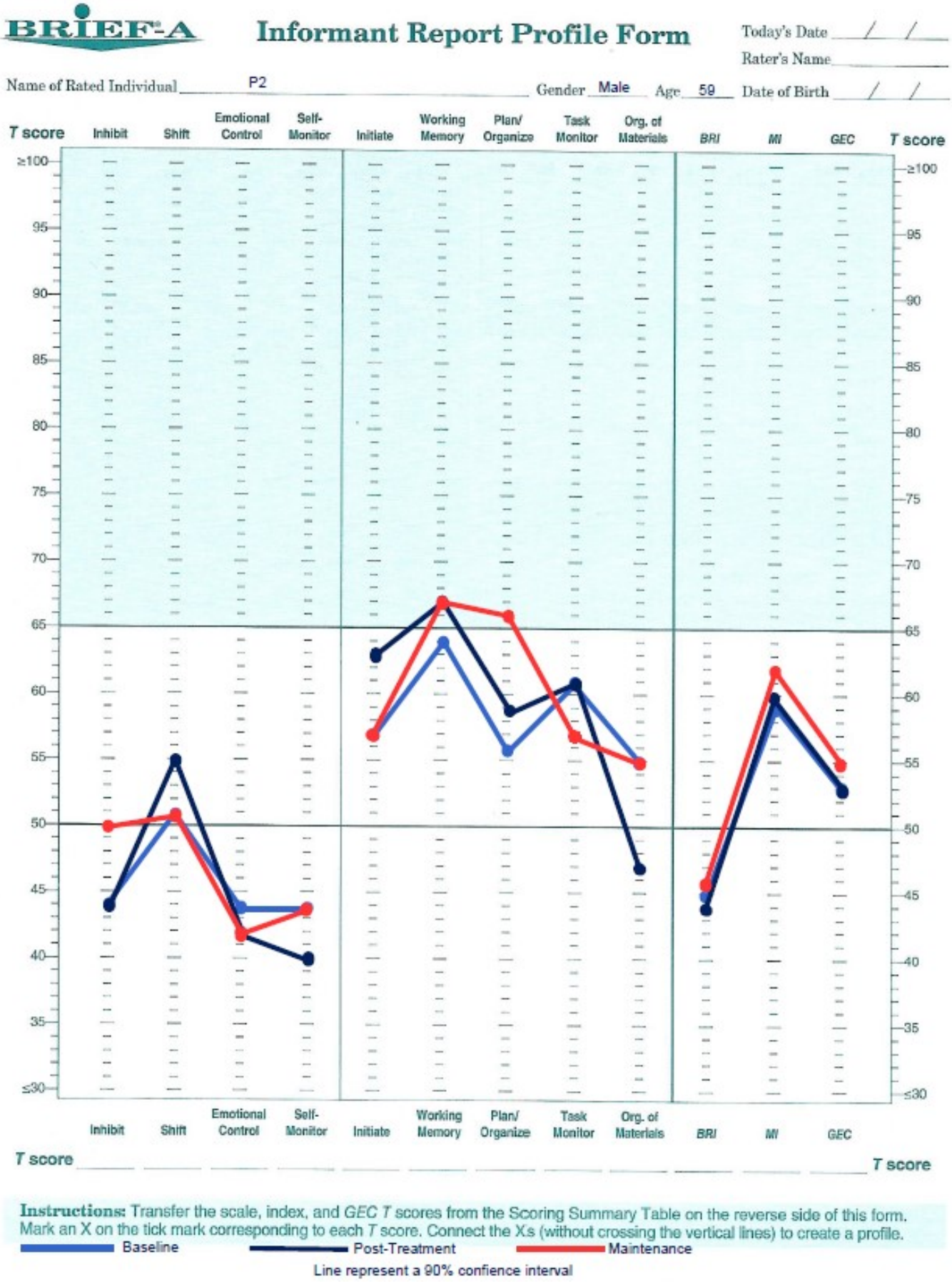
Appendix L Continued: BRIEF-A Self- and Informant Report Ratings Across Time for P1 and P2



Appendix L Continued: BRIEF-A Self- and Informant Report Ratings Across Time for P1 and P2



Appendix L Continued: BRIEF-A Self- and Informant Report Ratings Across Time for P1 and P2



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