A WITHIN-SUBJECTS EXPERIMENTAL EVALUATION OF THE TELEVISION ASSISTED PROMPTING (TAP) SYSTEM TO MAXIMIZE COMPLETION OF HOME-DELIVERED SWALLOW STRENGTHENING EXERCISES AMONG INDIVIDUALS WITH CO-OCCURRING ACQUIRED SWALLOWING AND COGNITIVE IMPAIRMENTS

by

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A DISSERTATION

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Each year, over 65,000 brain injury survivors are discharged home from hospitals with ongoing rehabilitation needs due to acquired impairments, such as dysphagia. Emerging empirical evidence supports the benefits of intensive swallowing exercise programs when dysphagia results from muscle weakness. However, many of these survivors cannot complete intensive home exercise programs due to co-occurring cognitive impairments in memory or initiation. This project investigated the potential benefits of a new experimental assistive technology device, the Television Assisted Prompting (TAP) system to increase completion of home swallowing exercises. The TAP system was designed as a treatment package to provide both automated prompts and multimedia motivational instructional exercise videos via a person's home television.

Three participants were recruited, all of whom had survived a hemispheric stroke and presented with neurogenic dysphagia and co-occurring cognitive impairments. Two home program delivery conditions were alternately presented on randomized days in a single-case experimental alternating treatment design: TAP delivery (e.g., TV prompting with motivational videos) or typical practice (TYP) delivery (e.g., care provider prompting as needed to follow assigned written home programs). The same exercises were presented in each condition. Measures included feasibility (e.g., reliability of the TAP system), efficacy (e.g., number of exercises completed per session), and satisfaction.

Results revealed that two of three participants showed dramatic benefits from the TAP system. Participant 1 was 17 times more likely to complete exercises when prompted by the TAP system; participant 2 was six times more likely. Participant 3 completed exercises with equal likelihood on TAP or TYP days. All three participants reported preference for TAP system delivery and requested to increase the frequency of TAP delivery to every day. Care providers unanimously reported preference for the TAP system to prompt patients and reduce their burden of care. The TAP system malfunctioned during 21.70% (23/106) of scheduled sessions; two participants needed clarifications, instruction to use the system, or customized modifications in order to interact independently with the device. Recommendations for system improvements and applications to the field of assistive technology are provided.

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DEDICATION

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CHAPTER I

SIGNIFICANCE

Each year, over 65,000 Americans are discharged from hospitals to home with ongoing rehabilitation needs produced by some type of acquired brain injury (National Association for Home Care & Hospice [NAHCH], 2007; National Center for Health Statistics, 2000). They may require home-based therapy to address changes in cognitive, language, sensory, and/or physical functioning following such events as traumatic brain injury, stroke, anoxic brain injury, cerebral infections, or myriad other neurological conditions. Of interest to this project are the approximately 60% of acquired brain injury (ABI) survivors who present with physical impairments that cause difficulty swallowing, a condition known as dysphagia (Cherney & Halper, 1996; Martino et al., 2005). Dysphagia is a serious medical condition leading to complications such as choking, pneumonia, malnutrition, dehydration, and/or death (Logemann, 1998). A majority (60%) of patients seen for home care speech-language pathology services presents with dysphagia following ABI (www.asha.org).

Dysphagia may be caused by acquired brain injury when swallowing centers in the brainstem or cortical motor pathways are interrupted (Logemann, 1998). Acquired brain injury can affect a person's ability to swallow safely and efficiently by causing muscle weakness, delayed swallow response time, and/or behavioral difficulties, such as impulsive feeding or inattention (Cherney & Halper, 1996). Neurogenic dysphagia often co-occurs with cognitive impairments given the susceptibility of intricate brain pathways supporting attention, memory, and executive functions (Sohlberg & Mateer, 2001). Cognitive impairments such as decreased attention or processing (e.g., difficulty understanding instructions), memory and learning (e.g., forgetting to complete daily exercises), or executive functions (e.g., limited initiation to follow-through with exercises) contribute to limited compliance with swallowing recommendations (Logemann, 2003).

The speech-language pathologist (SLP) provides a variety of direct and indirect treatments to individuals with neurogenic dysphagia. Direct treatments target improvements to swallowing physiology. Empirical evidence supports the provision of five specific swallowing strengthening exercises (e.g., Shaker et al., 2002). The efficacy of muscle strengthening programs depends on intensive practice to build muscle strength (Clark, 2003). Indirect treatments involve strategies that compensate for impaired swallowing ability. These include altering food and liquid consistencies (e.g., thickening liquids) or teaching specific safe swallowing maneuvers (e.g., chin tuck) (Logemann, 1998). Decisions to implement direct or indirect treatment are influenced by the severity of dysphagia, expected prognosis, and ability to comply with recommendations (Logemann, 1998). SLPs are reluctant to recommend direct treatments to individuals with co-occurring cognitive impairments due to limited compliance with home exercise programs (Crawford, Leslie, & Drinnan, 2007).

Statement of the Problem

Barriers to Intensive Home Program Completion

Individuals with neurogenic dysphagia face three significant barriers to completing intensive swallowing exercise interventions in a home care environment (Carpenedo, 2006; Houn & Trottier, 2003; NAHCH, 2007; Sohlberg & Mateer, 2001). First, patients may not have access to skilled professionals. Second, contemporary health care practices limit the number of home care visits by skilled professionals. Both of these barriers highlight the need for home exercise programs to supplement restricted therapy services. However, the third barrier underscores the difficulties with home program completion among patients with cognitive impairments.

Limited Access to Skilled Rehabilitation Services

There are two reasons why a patient may not have access to skilled rehabilitation services following ABI. First, rural or remote location may preclude availability of services. For example, Houn and Trottier (2003) described the challenges to delivering speech-language services to rural communities in North Dakota. They cited staffing limitations and travel constraints as primary barriers. In addition, Mashima and Holtel (2005) illustrated the difficulties delivering services to military personnel in Japan. Due to personnel shortages, patients typically fly to Hawaii for condensed periods of intensive service, which results in high cost and time away from active duty.

Second, experienced clinicians may not be available in many communities. Restricted availability of qualified SLPs may be due to personnel shortages, lack of sufficient experience, or requirements for advanced certifications. Carpenedo (2006) illustrated how services can be restricted in large metropolitan areas like New York City due to a combination of personnel shortages and expanding caseloads. In addition, delivery of certain therapy techniques requires expertise beyond entry-level experience. Lack of experience using specialized diagnostic equipment and limited experience treating a variety of swallowing impairments led to decreased confidence assessing and treating dysphagia for SLPs in a rural community in Kansas (Georges, Potter, & Belz, 2006). Further, specialized certification is required to implement specialized treatment programs (e.g., Lee Silverman Voice Therapy [LSVT] for patients with Parkinson's disease; Fox, Morrison, Ramig, & Sapir, 2002). Theodoros, Constantinescu, Russell, Ward, and Wootton (2006) described the challenge of delivering the LSVT program to patients throughout Australia due to lack of certified clinicians and large distances.

Restricted Funding for Home Care Services

Even when skilled clinicians are available, reimbursement restrictions limit a therapist's ability to deliver intensive therapy in a home care setting. Medicare funds a majority of patients receiving home care services (NAHCH, 2007). Beginning in 2000, Medicare implemented a prospective payment system of reimbursement, which pre-determines treatment intensity and duration based on medical diagnosis, severity of functional limitation, and presence of co-occurring medical conditions (NAHCH, 2007). According to the American Speech-Language-Hearing Association (ASHA), the average duration of home care services for speech-language interventions is 34 days (www.asha.org). An informal survey of home health SLPs in Oregon indicated that therapists see patients for an average of two or three times weekly for 50 minutes, for three to four weeks before discharge. This reduction in frequency represents a significant shift from daily intensive treatment during inpatient hospitals stays.

Delivery of intensive treatments, such as swallowing strengthening exercise programs, requires intensive daily practice. The current rehabilitation reimbursement system precludes intensive service delivery in home health care. When clinicians are unable to provide intensive daily practice, they typically assign home programs to supplement limited therapy visits (Sohlberg & Mateer, 2001). However, individuals with neurogenic dysphagia and co-occurring cognitive impairments face an additional barrier to completing daily home exercise programs.

Impact of Cognitive Impairments

Individuals with cognitive impairments following ABI demonstrate difficulty independently completing daily activities. Wilson, Emslie, Quirk, and Evans (2001) reported that individuals with memory impairments due to a variety of ABI etiologies independently completed less than half of required daily tasks, such as taking medications, watering plants, writing in journals, preparing meals, or accessing public transportation, due to impaired memory. Fish and colleagues (2007) reported that individuals with executive function impairments without supports made less than half of scheduled telephone calls at specified times. No research studies to date have reported on completion of home exercise programs among adults with acquired cognitive impairments. One would expect compliance with exercise programs to be similar to if not less than comparable to completion of other daily tasks. Thus, it is expected that individuals with cognitive impairments would complete daily home swallowing exercises less than half of the time.

Limitations of Current Potential Solutions

Effective delivery of intensive swallowing exercises to patients with co-occurring cognitive impairments in the home-care setting requires attention to the previously mentioned barriers. Any potential solution must provide automated reminders to prompt individuals to complete exercises at specific times, independent of location or presence of skilled therapists. Home-based, automated reminders can be delivered either by care providers or by assistive technologies.

Care Provider Prompting

Care providers of persons with cognitive impairments are charged with many tasks. For example, Milne (2004) described the role of care providers with following a regimented voiding schedule to reduce frequency of incontinence. Crawford and colleagues (2007) emphasized the importance of care provider supervision during meal times to provide reminders of safe swallowing strategies. Others have reported recruiting care providers to deliver intensive home programs in cognitive rehabilitation (Sohlberg & Mateer, 2001), aphasia rehabilitation (Mortley, Wade, Davies, & Enderby, 2003), and for dysphagia exercise programs (Robbins et al., 2007).

The risk of care provider burnout when therapists rely on care providers to deliver home programs may limit compliance with intensive home swallowing exercise programs. Levine and colleagues (2006) interviewed ninety-nine care providers of adults with ABI, predominantly due to stroke. Care providers reported ongoing weekly challenges across thirteen items related to care provider burden. They reported feeling significantly isolated, anxious, and depressed. Similarly, Wilson and colleagues (2001) noted increased stress levels among care providers of ABI survivors who required frequent prompts to complete routine, daily tasks. Wells, Dywan, and Dumas (2005) reported that impaired impulse control and memory contributed most significantly to care provider stress levels when caring for adults following traumatic brain injury. Milne (2004) noted that studies that recruit care providers to deliver intensive home programs often report high attrition rates due to "difficulties caregivers had adhering to the strategy" (p. 373). Programs that rely too heavily on care provider prompts therefore run the risk of overwhelming care providers.

Assistive Technologies

Assistive technologies provide a possible solution to effective completion of daily tasks. Several studies have demonstrated the efficacy of using high-tech memory aids to augment daily functioning for ABI survivors, using a range of technical devices. The strongest evidence exists to support use of alphanumeric pagers to prompt certain routine behaviors for individuals with cognitive impairments (Wilson et al., 2001). Moreover, they reported decreased levels of care provider stress when participants were prompted to complete daily activities via the pager system, rather than requiring care provider reminders. These researchers are also currently investigating the benefits of providing multimedia (e.g., pictures, video, images, photos, and text) prompts via cellular phone instant messaging (www.ozc.nhs.uk). Others have demonstrated the beneficial effects of a PDA to prompt completion of simple tasks (Szymkowiak et al., 2004) or voice organizers to improve recall of therapy goals (Hart, Hawkey, & Whyte, 2002). Evidence also supports use of customized software programs designed for use on home computers to supplement limited therapy visits (Cole et al., 2000).

However, current assistive technologies may not be the panacea for home-delivered prompting. Many ABI survivors do not own computers (Vaccaro, Hart, Whyte, and Buchhofer, 2007), and they demonstrate higher levels of anxiety when using high-tech devices (Singh, 2000). Further, assistive technology devices are unfamiliar to and not intuitive enough for individuals with cognitive impairments (Sohlberg et al., 2007). These devices may require complex menu sorting, provide too many choices, require maintenance, or have limited flexibility in their application (e.g., LoPresti, Mihailidis, & Kirsch, 2004). In addition, clinicians may be reluctant to recommend assistive devices due to their own lack of familiarity or comfort with technology (Hart, O'Neill-Pirozzi, & Morita, 2003).

Statement of Project Purpose

Individuals with ABI receiving home care services would benefit from intensive swallowing exercise programs, but face significant barriers to accessing intensive therapy programs. Existing possible solutions are insufficient to provide effective prompts and instruction for intensive home swallowing exercises. This project investigates an experimental, new solution: the Television Assisted Prompting (TAP) system. The TAP system will deliver swallow exercise instructions at specified times on a person's home television. The television represents a familiar home technology, and the customized, simple TAP interface follows best-practice guidelines for assistive technologies for users with cognitive impairments (e.g., Scherer, Hart, Kirsch, & Schulthesis, 2005). The TAP system also incorporates evidence-based principles to maximize completion of home exercise programs (e.g., Robison & Rogers, 1994).

The purpose of this research study is to evaluate the efficacy of the TAP system to improve completion of home swallowing exercises for patients with co-occurring swallowing and cognitive impairments receiving home care services. This experimental evaluation is the first of its kind to investigate an intervention package that combines external prompting with strategies to maximize completion of swallowing strengthening exercises for individuals with co-occurring cognitive impairments. To evaluate the efficacy of the TAP system, this study will utilize a within-subjects, alternating treatment experimental design to compare patient completion of exercises across two instructional conditions: (1) using the TAP system, and (2) using a typical home program (i.e., therapist provides written instructions to complete exercises at home, and relies on care providers to prompt patients to complete exercises).

CHAPTER II

REVIEW OF THE LITERATURE

An extensive literature review revealed that no previous studies have empirically evaluated methods to deliver intensive home exercise programs to individuals with cognitive impairments. Development of the new, experimental TAP device will build on theoretical evidence from two related areas: methods to maximize completion of home exercise programs for individuals without cognitive impairments, and use of technologies to prompt daily activities. This chapter presents a summary of the literature in these two areas, plus two related domains. First, the target population is described. Second, evidence supporting intensive swallowing exercise programs is presented. Third, a review of issues related to general home exercise programs is provided, including a discussion of the factors that influence adherence to home exercise programs. Fourth, possible technological solutions to enhance the effectiveness of home programs for individuals with cognitive impairments are discussed, along with their limitations and recommendations for designing effective technology solutions for individuals with cognitive impairments. The chapter concludes with a description of the TAP system as a possible solution to maximize completion of intensive swallowing exercises among ABI survivors with co-occurring cognitive and swallowing impairments receiving home care therapy services.

Description of the Target Population

Cognitive and physical (including swallowing) impairments result from a wide range of neurogenic conditions. Acquired brain injury (ABI) is a specific subclass of neurogenic conditions that encompasses non-progressive conditions, such as traumatic brain injury (TBI), stroke, cerebral infections, or anoxic brain injury (Sohlberg & Mateer, 2001). The incidence of TBI (1.4 million new cases per year; www.cdc.gov) and stroke (700,000 new cases per year; American Heart Association [AHA], 2007) is high. At least 40% of TBI survivors (www.biausa.org) and 26% of stroke survivors (AHA, 2007) report ongoing needs for rehabilitation services. Typically, patients who sustain ABI progress through a period of neurological recovery in the first six to twelve months following injury, including the period of post-acute recovery spent in home-care rehabilitation (Sohlberg & Mateer, 2001). Of interest to this project are the approximately 60% of ABI survivors who present with physical impairments that cause dysphagia (Cherney & Halper, 1996; Martino et al., 2005), many of whom also have cognitive impairments (Sohlberg & Mateer, 2001).

What are the effects of ABI? There is no single profile of symptoms for ABI (Sohlberg & Mateer, 2001). Each individual's symptoms depend on the severity of injury or damage, location of brain damage, pre-injury status, and individual brain differences (Sohlberg & Mateer, 2001). Following is a review of the common cognitive and swallowing sequelae of ABI, as well as a description of typical home-care programs for prescribing swallowing exercise programs.

Cognitive Impairments

Cognitive impairments (CI) result from brain damage affecting the overlapping cognitive systems that support attention, memory, and executive functions. Most commonly, CI result from damage to the frontal lobes, medial temporal lobes, diffuse brain pathways, and/or deep brainstem arousal mechanisms (Sohlberg & Mateer, 2001). Survivors of TBI often present with cognitive challenges, such as distractibility, amnesia, disorganization, and concrete reasoning abilities (Sohlberg & Mateer, 2001). Survivors of right hemisphere strokes often present with cognitive-communication challenges, such as distractibility, limited task persistence, egocentric and concrete reasoning, and unawareness of deficits (Tompkins, 1995). Left hemisphere stroke survivors may present with CI, such as slowed processing, perseveration, impaired recall, and aphasia (Rosenbek, LaPointe, & Wertz, 1989). More severe CI may profoundly affect a person's ability to complete daily functions, such as getting dressed, answering the telephone, or taking medications (Sohlberg & Mateer, 2001). Wilson (1991) reported that up to 70% of survivors of severe ABI presented with ongoing, chronic memory impairments that persist up to ten years following injury. Of interest to this project are ABI survivors who present with impaired memory, resulting in limited carryover of therapy recommendations.

Persons with CI due to ABI frequently report difficulties remembering and learning new information (www.biausa.org). Forgetting to complete daily tasks, such as taking medications, eating lunch, watering plants, or exercising interferes with daily living (Wilson et al., 2001). Difficulty carrying out daily tasks may be due to impairments in attention (i.e., never heard instruction due to inattention), declarative memory (i.e., instruction never stored in long-term memory), prospective memory (i.e., forgetting to carry out intentions at a future time), initiation (i.e., acting on intentions), and/or awareness (i.e., not aware of the need to use a walker) (Sohlberg & Mateer, 2001). However, despite the underlying reason for forgetting, the end product results in a similar limitation: individuals with CI frequently do not complete daily tasks.

Dysphagia: Swallowing Impairments

A variety of physical impairments may result from ABI, such as hemiplegia, incoordination, or muscle tightness (Duffy, 2005). A special subclass of physical impairments includes difficulty with swallowing. Safe and efficient swallowing of food and liquids is normally an automatic physical function (Logemann, 1998). The brain circuits responsible for swallowing include the swallowing center in the brainstem, and cortical motor areas regulating movement (Smith & Dodd, 1990). There are four phases to normal swallowing: preparatory, oral, pharyngeal, and esophageal (Logemann, 1998). During the normal swallow for solid food, individuals cut food and place it in the mouth (preparatory stage), chew the food while controlling its location in the mouth, and use the tongue to propel the food bolus posteriorly into the throat (oral stage). The preparatory and oral stages are both under voluntary control (Logemann, 1998). The pharyngeal phase consists of rapid (less than one second) succession of multiple muscle contractions within the throat (e.g., vocal folds close and larynx elevates to protect the airway, base of tongue contracts with posterior pharyngeal walls to propel bolus downward) to move the bolus from the mouth to the esophagus safely and efficiently, and in most circumstances is an automatic, involuntary response (Logemann, 1998). In the final (esophageal) stage of normal swallowing, a series of involuntary muscle contractions in the esophagus pass the bolus from the upper esophagus to the stomach (Logemann, 1998).

Dysphagia refers to a disorder of swallowing, diagnosed when a person demonstrates difficulty passing food from the mouth to the stomach (Logemann, 1998). Signs of dysphagia include the inability to recognize food, difficulty placing food in the mouth, inability to control saliva or food in the mouth, coughing before, during, or after swallowing, frequent coughing during a meal, recurrent pneumonia, wet vocal quality, and/or weight loss (e.g., Horner, Alberts, Dawson, & Cook, 1994; Lazarus & Logemann, 1987). Symptoms include penetration (i.e., entry of food or liquid into the upper airway), aspiration (i.e., entry of food or liquid into the airway, below the vocal cords), residue in the mouth or throat leftover after swallowing, and/or backflow from the esophagus into the throat (e.g., Langmore et al., 1998). Complications resulting from dysphagia include aspiration pneumonia, malnutrition, dehydration, and/or choking (Logemann, 1998).

ABI can affect a person's ability to swallow safely and efficiently. ABI can cause muscle weakness in the mouth or throat, delayed swallow response time, and/or behavioral difficulties, such as impulsive feeding or inattention (Logemann, 1998). It is estimated that 300,000-600,000 individuals are diagnosed with dysphagia due to ABI each year (Terrado, Russell, & Bowman, 2001). In particular, approximately 70% of stroke survivors present with dysphagia, most frequently when the stroke occurs in the brainstem (Martino et al., 2005). Up to 65% of severe TBI survivors present with dysphagia (Cherney & Halper, 1989). The majority (60%) of the home-care SLP's caseload is comprised of individuals with ABI who present with dysphagia (www.asha.org). These patients would benefit from continued home-based therapy to address swallowing impairments (Logemann, 1998).

Typical Home Care for Dysphagia Following ABI

When a person sustains an ABI, s/he typically proceeds through several levels of medical and rehabilitation care. These various levels of care represent a continuum from most to least intensive (www.asha.org). A person's exact journey through this continuum of care will depend on severity of impairments, level of assistance needed to complete daily tasks, availability of care provider support, and insurance coverage (Golper, 1992). ASHA describes the typical continuum for patients with ABI (www.asha.org). Most typically, this continuum starts in an acute-care hospital, where the primary goal is medical stabilization and survival. Next, the patient may proceed to an inpatient rehabilitation hospital, where s/he participates in intensive therapies for at least three hours daily. When stable, the next major shift is to community rehabilitation settings, delivered either through home-care agencies or in outpatient rehabilitation centers. To qualify for home-care rehabilitation services, the patient must be 'home-bound' and unable to attend therapy at an outpatient clinic (NAHCH, 2007).

The current rehabilitation reimbursement system precludes intensive service delivery in community-based settings, such as home health care. During inpatient stays, patients receive therapy once or twice daily; however, home-care rehabilitation services are delivered only two or three times per week (www.asha.org). Despite research to support the need for ongoing intensive rehabilitation following ABI (e.g., Robbins et al., 2007), funding restrictions limit the amount of therapy delivered to patients receiving home-care (NAHCH, 2007). According to ASHA, the average duration of home-care services for speech-language interventions is 34 days (www.asha.org). Informal interviews with SLPs working for home health agencies in Oregon revealed that therapists treat patients for an average of two or three times weekly for 50 minutes, for three to four weeks before discharge. In order to meet the needs of patients who would benefit from intensive direct therapy programs, therapists typically assign home programs to supplement limited therapy visits (Golper, 1992).

A typical home program for home-care patients with dysphagia includes completion of intensive swallowing strengthening exercises (Logemann, 2005). Therapists often provide written exercise instructions, with or without accompanying illustrations, for the patient to complete several times per day, at a prescribed intensity. The clinician will have demonstrated the exercises to the patient and ensured accurate performance before assigning them for home practice. Clinicians may periodically ask the patient to demonstrate exercises to ensure proper technique. They will also periodically reassess the patient to determine the need to change exercise content or intensity. For patients with co-occurring CI, the therapist may either be reluctant to recommend a home exercise program (Crawford et al., 2007), or will rely on care providers to prompt patients to complete exercises and instruct patients on proper technique (Logemann, 1998).

Summary

Many survivors of ABI present with co-occurring cognitive and swallowing impairments, with unmet rehabilitation needs following discharge to home care settings. These patients would benefit from ongoing intensive swallowing exercise programs, but may not complete home exercise programs due to limited recall and follow-through. This study will investigate a new method to maximize the home exercise program completion for these individuals. Next, a review of the literature to support various swallow strengthening exercise protocols for home exercises is presented.

Evidence Supporting Intensive Swallowing Exercise Programs

Strong evidence exists to support the benefits of intensive therapy programs across rehabilitation domains. For example, systematic research recommends intensive treatment programs for attention (e.g., Sohlberg et al., 2003), language (e.g., Robey, 1998), and physical (e.g., Smidt, de Vet, Bouter, & Dekker, 2005) impairments following ABI.

Directly relevant to this study are the intensive therapies addressing motor impairments, such as limb muscle weakness, voice disorders, and swallowing disorders. This section reviews the theoretical and empirical evidence across three domains to support the efficacy of intensive rehabilitation exercise strengthening programs. First, theoretical evidence to provide the foundation to any muscle strengthening program is presented. Second, evidence to support intensive exercise strengthening programs from physical therapy and voice therapy is described. Third, evidence to support intensive exercise programs for dysphagia is detailed.

Theoretical Principles of Muscle Strengthening Programs

An extensive literature exists to describe practice principles of exercise programs in physical and occupational therapy for strengthening limb muscles in healthy adults or those with acquired muscular impairments (see Burkhead, Sapienza, & Rosenbek, 2007; Clark, 2003). Muscle strengthening programs aim to increase: the amount of force a muscle can produce, the duration of sustained muscle contraction, or the speed of muscular contraction (Clark, 2003). Exercise programs must follow three key principles when improved muscle strength is the goal. Following is an overview of these three principles, as well as a review of the literature recommendations for frequency of strengthening treatment programs.

Principle #1: Overload

The first principle of exercise strengthening programs is that they must provide sufficient intensity to tax muscles beyond typical activity levels, to the point of fatigue (Clark, 2003). From a neuroplasticity perspective, Burkhead and colleagues (2007) added that "exercise efforts that do not force the neuromuscular system beyond the level of usual activity will not elicit adaptations" (p. 255). Overload is achieved by manipulating two variables: stimulus intensity and stimulus dosage.

Stimulus intensity. Stimulus intensity refers to the amount of resistance applied to the muscle to overload typical levels of activity (Sapienza, 2007). Providing resistance to muscle movements forces muscles to work beyond their typical workload, and induces neuromuscular changes. When muscles are overloaded, they respond by recruiting additional muscle fibers to counteract the resisting force. This additional muscle fiber recruitment results in muscular hypertrophy, or increased muscle bulk, and only occurs in response to overload (Clark, 2003). A related concept to stimulus intensity is progression of exercise resistance. As muscles hypertrophy and strength improves, the resistance intensity must similarly increase to tax muscles to the point of fatigue and overload. This can be achieved by increasing the resistance load altering stimulus dosage (see below). While measuring resistance load or intensity is straight-forward for limb muscle training, Sapienza warned that quantification of resistance for strengthening oropharyngeal swallowing muscles often takes form as a subjective impression of effort, rather than objective data. Burkhead and colleagues further cautioned that muscle injury may occur from over-exertion, sudden boosts in intensity, or improper exercise techniques.

Stimulus dosage. Stimulus dosage refers to the volume and structure of the exercise program. Manipulating the structure of an exercise program can also ensure progression of stimulus intensity. Burkhead and colleagues suggested increasing the repetitions, duration of contraction, or speed of muscle contraction to increase the resistance load and induce muscle overload. Other dosage factors that could be manipulated include: number of sets completed, amount of rest between sets, and number of days per week or total duration of exercising (Clark, 2003). The main principle to bear in mind with overload is that muscles must be progressively taxed beyond usual workload, to the point of fatigue.

Principle #2: Specificity of Training & Transference

In addition to overloading muscles, strengthening programs must also incorporate movements specifically related to the end goal (Clark, 2003). Burkhead and colleagues (2007) stated that "the greatest gains for a particular activity are elicited when the training goal resembles the end-goal as much as possible" (p. 259). Thus, if the goal is to achieve self-feeding skill, strengthening wrist flexion in isolation would be insufficient; similarly, strengthening the tip of the tongue to improve swallowing function would also be insufficient. In fact, Perlman, Luschei, and Du Mond (1989) stated that the best exercise and practice to improve swallowing is to swallow. However, "simply swallowing food, liquid, or saliva… is not an activity that can provide the degree of load that is necessary to force adaptations in the neuromuscular system to increase strength" (Burkhead et al., 2007, p. 261).

A related concept to specificity of training is that of muscle action transference. While specificity of training emphasizes incorporating the end goal movement, transference emphasizes benefits that can also occur by strengthening component muscles that compose end actions (Burkhead et al., 2007). For example, tennis players may strengthen their biceps muscles in order to achieve a stronger racquet stroke. An example from the SLP literature demonstrated that improving vocal quality and strength using the Lee Silverman Voice Therapy program also transferred to improved swallowing function, because similar muscles underlie both end goals (El Sharkawi et al., 2002). Additionally, evidence from the limb muscle literature suggests that isolated muscle warm-up activity to increase muscle activation may help prime muscle groups for subsequent dynamic use.

Although application to oropharyngeal musculature is presently unknown, this may imply beneficial effects of warm-up exercises on swallowing performance (Burkhead et al., 2007).

Principle #3: Timing of Exercise Interventions

The existing evidence supports the benefits of strengthening exercises both during acute and chronic (i.e., greater than one year post-injury) periods of recovery following ABI. In their review of multidisciplinary strength training interventions post-stroke, Ada, Dorsch, and Canning (2006) reported similar effect sizes post-training for stroke survivors in acute ($d = 0.40$) and chronic ($d = 0.45$) periods of recovery. Bonaiuti, Rebasti, and Sioli (2007) reviewed the evidence supporting a specific physical therapy exercise program (constraint-induced movement therapy [CIMT]) and concluded that CIMT resulted in positive outcomes across studies that evaluated patients in acute (<1 month), subacute (1-6 months), and chronic (>1 year) periods of post-stroke recovery. Similarly, Robbins and colleagues (2007) demonstrated positive effects of tongue strengthening exercises in patients in both acute and chronic periods of recovery post-stroke. Thus, ABI survivors should show benefits of intensive exercise programs regardless of time post-onset of their brain injury.

Recommendations for Frequency of Strengthening Exercises

The literature on general strengthening programs for healthy adults provides the only theoretical foundation to recommend treatment frequency for improved strength. The American College of Sports Medicine (ACSM; 1998) produced exercise guidelines for healthy adults based on research to support strengthening exercises in the limb musculature. They recommended that strengthening exercises be completed for 8-12 repetitions per set, with minimum of one set per session to achieve fatigue and overload, for three days per week. More recently, Rhea, Alvar, Burkett, and Ball (2003) conducted a meta-analysis of strength-training interventions among healthy adults to determine the best intensity and dosage for maximal strength-training effects. They found that for untrained individuals (i.e., those who had not been in strengthening programs for at least 12 months consistently), maximal strength gains were achieved when using 60% of maximal effort to complete 8-10 repetitions per set, with four sets per session, for three days per week.

No strong evidence currently exists in the rehabilitation literature to support practice recommendations for strengthening exercises among individuals with acquired physical impairments (Morris, Perry et al., 2006). Burkhead and colleagues (2007) added that "dose dependent studies investigating these parameters for exercise in oropharyngeal muscles do not exist… [and] the optimal dose has not been determined" (p. 258). Nonetheless, intensive interventions that show positive outcomes for individuals with ABI typically involve more intensive treatment schedules. For example, the CIMT program requires continuous restraint of the unaffected limb during 90% of waking hours, every day, for fourteen consecutive days, to encourage use of the affected arm (Taub et al., 1993). In addition, patients participate in intensive stimulation and practice for six hours per day, five days per week, for two weeks, plus specific home practice activities 30 minutes daily (Morris, Taub, & Mark, 2006). The Lee Silverman Voice Therapy program requires intensive voice therapy four times weekly for four consecutive weeks, and includes 20-40 minutes of daily home practice (Fox et al., 2002). Most swallowing exercise programs require practice two or three times daily, for four to eight weeks (e.g., Crary, 1995; Shaker et al., 1997). Thus, for physical exercises, the evidence also suggests that 'more is better.'

Summary: Recommendations for Strength Training Practice Principles

Incorporating the ACSM recommendations for general strengthening exercises with research into specific rehabilitation strengthening programs leads to the following recommendation. Intensive rehabilitation strengthening exercises should include progressive resistance training in sets of 8-12 repetitions at 60% of maximum strength, two to three times daily, for three to five days per week, for four to eight weeks. Exercises that induce task-specific movements or support underlying muscle function should overload muscles to induce muscle hypertrophy by progressively increasing stimulus and dosage intensity. Intensive exercises show promise to increase strength throughout acute, subacute, and chronic periods of recovery following ABI.

Efficacy of Intensive Strengthening Programs in Related Areas

Limb Muscle Strengthening Programs

Physical and occupational therapists have long acknowledged the importance of intensive rehabilitation to improve physical functioning following ABI. Specifically, intensive practice is requisite to improving muscle strength or cardiovascular fitness with therapeutic exercise programs. In their summary of 45 randomized controlled trials evaluating the effectiveness of physical therapy exercises for a variety of medical conditions, Smidt and colleagues (2005) concluded that "exercise therapy has been shown to be effective for a wide range of disorders" (p. 79). Further, they noted a trend that "intensive exercise therapy has more positive effects on the activities of daily living in patients who had suffered a stroke than less intensive exercise therapy" (p. 76). In addition, Friedrich, Gittler, Halberstadt, Cermak, and Heiller (1998) added that "full benefits can only be realized if the exercises are done… with proper intensity… and completed regularly and consistently" (p. 475).

One specific limb muscle strengthening program that has emerged in the past decade builds on principles of neuroplasticity and intensive stimulation. Constraint-induced movement therapy (CIMT; Taub et al., 1993) shows promise to improve arm strength and functioning following stroke (Bonaiuti et al., 2007). CIMT utilizes two key components: restraint of the unaffected arm in a splint to prevent use, and structured retraining of the affected arm to restore function. CIMT calls for restraint of the unaffected arm during 90% of waking hours, every day, for fourteen consecutive days, to encourage use of the affected arm. Structured retraining requires intensive stimulation and practice for six hours per day, five days per week, for two weeks. Therapy includes repeated, continuous practice using the affected arm for 15-20 minutes at a time. In addition, patients also complete specific home practice activities 30 minutes daily (Morris, Taub et al., 2006). Since this intensive schedule does not fit into current reimbursable service delivery models, Page and Levine (2007) utilized a modified CIMT protocol where therapy was delivered three times weekly for 30 minutes each, for ten weeks. However, in order to maximize intensive practice, they required an intensive home program five hours daily, five days per week, for the full ten weeks. Both the original and modified CIMT protocols have demonstrated potential for improved arm strength, daily functioning, and quality of life (Wu, Chen, Tsai, Lin, & Chou, 2007). In addition, Mark, Taub, and Morris (2006) have demonstrated altered brain activation post-treatment, such as enhanced representation of the affected arm. These studies provide further support for the benefits of intensive stimulation, practice, and exercise among ABI survivors.

Voice Strengthening Program

Speech and voice impairments respond to intensive speech therapy. The Lee Silverman Voice Therapy (LSVT) is an evidence-based intervention program for individuals with mild-moderate speech impairments due to Parkinson's disease that requires an intensive exercise regimen (Fox et al., 2002). In LSVT, patients receive 4 hours of individual intervention weekly for four consecutive weeks. In addition, patients complete daily exercises at home for additional practice and carryover. Research has demonstrated improved speech functioning up to two years following treatment cessation (Ramig et al., 2001). However, the effects are less clear for patients with more severe speech impairment or with co-occurring cognitive challenges (Fox et al., 2002). Home program completion has been the biggest challenge to intensive therapy for patients with co-occurring CI.

Efficacy of Intensive Strengthening Programs in Dysphagia

Clinicians and researchers face challenges to developing and evaluating swallow strengthening exercises. First, the muscles of the face and throat involved in swallowing differ from other limb muscles (Clark, 2003). The muscles of the face do not contain muscle spindle stretch receptors, so do not respond to massage or stretching in the same way that tight muscles in the arm or back do. Second, a clear relation between muscle strength and swallow functional ability has yet to be established (Clark, 2003). Third, attaining volitional control over pharyngeal muscles that respond automatically during a normal swallow can be challenging (Burkhead et al., 2007). Fourth, achieving muscle overload by applying progressive resistance to muscles in the pharynx presents an additional challenge (Burkhead et al., 2007). Indeed, the main challenge to developing effective interventions for swallowing "is to identify and/or develop exercises that overload the impaired muscle groups during functional movements" (Clark, 2003, p. 411).

Despite this challenge, researchers have developed and evaluated specific swallowing strengthening exercises for patients with dysphagia that adhere to theoretical strengthening practice principles. An extensive review of the dysphagia treatment literature reveals evidence to support five specific swallowing exercises. The exercises with the strongest supporting evidence are described first. The research evidence for these five exercises is summarized in Table 2.1.

Table 2.1
Summary of Research Evidence Supporting Five Swallowing Exercises

Swallowing Exercise	**Class I Evidence (True Experiment)**	**Class II Evidence (Quasi-Experiment)**	**Class III Evidence (Non-Experiment)**
Shaker Head Lifts	Shaker et al. (1997) Shaker et al. (2002)*		Easterling et al. (2005)
Tongue Strength	Lazarus et al. (2003)	Robbins et al. (2005) Robbins et al. (2007)*	
Effortful Swallow		Crary (1995)*	Kahrilas et al. (1991) Huckabee & Steele (2006)
Masako Swallow			Fujiu & Logemann (1996)
Mendelsohn Swallow			Ding et al. (2002)

Note. Classes of evidence schema adapted from Scottish Intercollegiate Guidelines Network (n.d.) *Guideline Development in Fifty Easy Steps*. Retrieved May 10, 2005, from http://www.sign.ac.uk/pdf/50steps.pdf.
* Indicates studies that evaluated patient population with dysphagia, rather than healthy adults.

Shaker Exercise

The strongest research evidence supports a head-lift exercise to improve swallowing function following CVA. Shaker and colleagues (1997) first described this exercise and demonstrated its effects in a group of healthy adults over 60 years old. This exercise program requires intensive repetitions and practice to achieve muscle overload. The therapist instructs patients to lie completely flat on the floor or a bed, and to lift their head against gravity to look at their toes without moving their shoulders three times, for 60 seconds each time. Following these three sustained contractions, patients then complete a series of thirty repetitions of smooth, rhythmical head lifts. The therapist instructs patients to complete the exercise at home three times daily for six consecutive weeks. Patients maintain an exercise diary to chart completion of exercises at home. The goal of the exercise is to strengthen muscles of laryngeal elevation that are activated during the swallow to protect the airway and open the upper esophageal sphincter muscle, allowing food or liquid to pass into the esophagus. While the exercises do achieve muscle overload, there has yet been no discussion about progression of exercises throughout the six week program to ensure continued overload. However, the movement capitalizes on the principle of transference since the muscles activated by this exercise are important for raising the larynx during the swallow to protect the airway.

In their first evaluation, Shaker and colleagues (1997) compared the effects of the Shaker head-lift exercise to a "sham" fist-clenching exercise in a group of healthy older adults using a randomized, controlled design. Participants in the experimental group demonstrated significant improvements in swallow function, measured by laryngeal movement during the swallow. Participants in the "sham" group received fist-clenching exercises of equal intensity and duration, but showed no transfer to changes in swallowing physiology. The authors concluded that pharyngeal muscles are amenable to exercise-induced changes in a healthy elderly population, and called for further research to evaluate its effectiveness among patients with dysphagia.

After showing that the exercise could induce physiological changes in swallowing for healthy adults, Shaker and colleagues (2002) next evaluated the effects of the intensive Shaker exercise program on 27 adult outpatients over 60 years old with moderate to profound dysphagia necessitating a feeding tube from a variety of etiologies, including CVA, head and neck surgery, and radiation. The authors designed a prospective, randomized, comparison group study that compared the effects of the Shaker exercises to a "sham" tongue stretching program. Of note, the stretching exercises are not the same as strengthening exercises because they do not involve muscle overload (Clark, 2003). The authors followed the same intensive six week protocol. They noted that "all 27 patients successfully completed the exercise protocols. Invariably, the patients reported some minor degree of anterior neck muscle discomfort during the first few days of real exercise. However, the discomfort was not severe enough to result in discontinuation of the exercise by any of the patients, and it resolved spontaneously" (p. 1316). None of the seven participants initially assigned to the tongue stretching group showed any changes post-treatment. After clear indications of benefit of Shaker exercises, all remaining participants were enrolled in the Shaker exercise group. Results revealed that every patient (27/27) improved with laryngeal excursion, upper esophageal sphincter opening, and functional swallowing ability following treatment with the Shaker exercises. In fact, every participant began oral feedings and was able to discontinue tube feedings following the six-week intensive exercise program. The majority of participants (74%) achieved a "functional" swallow rating at the conclusion of the study, while the other participants achieved a "mild" or "mild-moderate" rating. The authors found no relationship between swallowing improvements and time post-onset. Participants with both acute (9 days – 2 months) *and* chronic (6 months – 8 years) stage dysphagia showed improvement. The authors concluded that the Shaker exercise protocol is effective to improve swallow muscle strength and functional swallowing ability in individuals with early and late dysphagia resulting from CVA, head and neck surgery, or radiation. The effects of the Shaker exercises on functional swallowing demonstrate transference of discrete muscle strengthening on dynamic, functional swallowing. The authors further reported that the Shaker exercise protocol is "easy for the patient to learn and follow," but also added that participants were "extensively instructed" to complete the exercise correctly (p. 1320). Although they did not mention reports of compliance with the intensive exercise program, the authors did admit that variability in compliance and effort "may have influenced the outcome" (p. 1320). They called for future research to investigate compliance with the intensive home program.

The most recent study in this line of research by Easterling, Grande, Kern, Sears, and Shaker (2005) examined factors affecting compliance with the 6-week intensive Shaker exercise program among 26 healthy adults over 65 years old from a senior independent-living community. They screened participants for those able to complete exercises 3 times per day and to exercise independently. The researchers instructed participants to complete the Shaker exercises using one videotape instructional session, followed by supervised practice on the same visit. Researchers provided participants with written directions to complete the exercises at home, as well as a daily log to record the duration of sustained head lifts and the number of repetitions tolerated each time. Participants were instructed to exercise three times daily for six consecutive weeks, as in the original protocol. A researcher visited each participant weekly to check accuracy of exercise performance, collect logs, and interview participants about any complaints, difficulties, or other comments on the protocol. Seven (27%) participants dropped out of the study early on, primarily due to complaints of neck muscle soreness or difficulty fitting exercises into their daily routine schedules. Data from surface electromyography (sEMG) recordings suggested that muscle soreness may have resulted from initial recruitment of non-targeted sternocleidomastoid muscles, which fatigue faster than laryngeal elevation muscles. Neck fatigue dissipated as laryngeal muscles strengthened with the exercises. Five (25%) participants required repeat instruction, cues, and encouragement to continue. Half of the original 26 participants achieved the sustained contraction goal of 3 repetitions for 60 seconds each by the end of the study. A larger proportion (18/26; 70%) of participants achieved the repetition goal of 30 repetitions by the end of the study. The authors concluded that the "duration to obtain Shaker Exercise performance goals varies among healthy older adults" (p. 135). They also suggested that a "more structured and gradually progressive exercise plan [is needed] to attain the exercise performance goals" (p. 136). Nonetheless, the Shaker exercise protocol is an intensive exercise that shows promise to improve swallowing physiology and functional swallowing for individuals with laryngeal elevation or upper esophageal sphincter opening weakness following ABI.

Tongue Strengthening Exercise

A second line of promising research to support exercises to improve swallowing function utilizes tongue strengthening resistance exercises. Robbins and colleagues developed a specialized device facilitating progressive resistance to tongue movements within the mouth to achieve specificity of training movements and muscle overload. The device, the Iowa Oral Performance Instrument (IOPI), contains an air-filled bulb attached to a pressure transducer to measure force. The air bulb can be filled with varying amounts of air to supply progressively greater resistance to tongue movements. The bulb can be positioned against the roof of the mouth in the front or back of the mouth, with instruction for the patient to lift his/her tongue and press against the air bulb for a specified period of time. The bulb is connected to a pressure transducer, which measures the amount of force the patient used to press his/her tongue against the bulb. In addition, the IOPI can be preset to provide biofeedback via green or red colored lights when the patient achieves the targeted amount of tongue force (Robbins et al., 2005). Robbins and colleagues have reported on two successful trials using the IOPI for tongue strengthening resistance exercises.

In their first study, Robbins and colleagues (2005) explored the effects of using the IOPI to provide progressive tongue strengthening exercises to a group of ten healthy adults over age 70 years. The researchers instructed participants on use of the IOPI and requested participants to complete 30 repetitions per set, twice daily, three days per week, for eight weeks. Researchers reassessed maximum tongue strength every two weeks and re-calibrated the biofeedback mechanism in the IOPI instrument to ensure that participants exercised at 60% of their maximum strength during the first two weeks, then at 80% of their maximum strength for the remaining six weeks. These recommendations followed the guidelines of the ACSM (1998). Results revealed that participants increased tongue strength and swallow function, as measured by pressures generated in the throat during swallows. In addition, magnetic resonance imaging (MRI) revealed that tongue volume increased by an average of 5% following completion of the treatment program, likely due to recruitment of additional muscle fibers, or hypertrophy. The authors did not specifically report on home practice compliance from diary data, but stated that participants completed the eight-week protocol and "expressed delight in doing so" or "expressed a sense of empowerment through this self-help model of health care" (p. 1488).

Robbins and colleagues (2007) conducted a follow-up study to examine the effects of using the same protocol to improve swallowing function among a group of ten CVA survivors over age 50 years. This time, researchers instructed participants to complete exercises with the IOPI in sets of 20 repetitions each, three times daily, three days per week, for eight weeks. Researchers otherwise followed the same protocol. Results revealed that all ten CVA survivors also demonstrated improvements in tongue strength, swallowing pressures, improved swallow function (e.g., reduced oropharyngeal residue after the swallow, reduced airway penetration, and increased swallow response time), increased tongue mass post-treatment, as evidence by MRI scans, and improved report of swallowing quality of life. However, there was no treatment comparison or control group, and six of the ten participants remained in an acute period of recovery, so the effects of the exercise alone cannot be determined from this quasi-experimental pre-post treatment study. Nonetheless, all four of the participants in a chronic period of recovery demonstrated positive outcomes. Once again, the authors did not report any data on home program completion, but noted that participants with CVA "are capable of performing and benefiting from lingual exercise,… [and] are enthusiastic about this intervention as a complement to standard treatment" (p. 157). In addition, the authors did not comment on the cognitive status of these CVA survivors. Tongue strengthening exercises also show promise to improve swallowing function when completed on a regular, intensive schedule following ABI.

In a follow-up discussion with the authors, Robbins and Kays (personal communication, December 24, 2007) reported on additional insights into their program. While not commenting specifically on the cognitive status of their ten participants, they did note that "many patients with cognitive impairment are quite capable of performing the exercises with the assistance of a dedicated clinician and caregiver. Screening is recommended for these patients, which can consist of attempting to obtain a reliable measure of maximum lingual pressures. If the patient can successfully follow verbal instructions or a model to press the tongue to the palate, and test-retest reliability is confirmed by measuring multiple sets on the same or different days, s/he is a potential candidate for the program." In addition, they reported that they are working on building a new, patented device that is easier to use than the IOPI, and is specifically designed for tongue strengthening exercises: the Madison Oral Strengthening Tool (MOST). With regards to actual completion of home program recommendations, they reported that out of a total possible 72 sessions, "three participants never missed a session, four missed only a single session, two missed six sessions, and one participant missed 3 full days. Those participants who missed six or more sessions were residing in nursing homes and were more reliant on nursing staff to assist them in performing the exercises." These data reveal high levels of home program completion, but also clarify the important role of external supports to ensure completion among participants with co-occurring CI.

A related study to this line of research reveals that specialized equipment, such as the IOPI or MOST may not be required to achieve similar gains in tongue strengthening. Lazarus, Logemann, Huang, and Rademaker (2003) showed that tongue strengthening exercises that used the IOPI or standard tongue depressors to deliver resistance both resulted in improved tongue strength, compared to no treatment for a group of healthy young adults. There were no statistical differences in tongue strength improvements between the group that received resistance and feedback from the IOPI versus a standard tongue depressor for resistance only. Participants were instructed to complete tongue strengthening exercises with resistance for 2 seconds at a time at 10 repetitions in four directions (left, right, out, up), five times daily, five days per week, for four weeks. The authors did not report on degree of compliance with this intensive home program. The use of a tongue depressor has greater potential for bias due to subjective measures of resistance, versus the objective measures of resistance from the IOPI. The results of this study would be strengthened if the authors reported some self-reported level of effort among participants in the tongue depressor resistance group to ensure progressive levels of resistance training. Nonetheless, the results reveal that achieving tongue strength gains need not require expensive equipment.

Effortful Swallow Exercise

A third swallow exercise reported in the literature is the effortful swallow technique. For this technique, the clinician instructs the patient to "squeeze hard with all your muscles" during the swallow (Logemann, 1998, p. 221). The goal is to improve lingual and pharyngeal muscular contraction by exerting greater muscle forces. Kahrilas, Logemann, Krugler, and Flanagan (1991) introduced the technique. They reported that instructing patients simply to "swallow hard" resulted in greater muscular effort and pressures during the swallow, with resultant reduced pharyngeal residue. Lending further support, Huckabee and Steele (2006) demonstrated greater laryngeal elevation muscle contraction on sEMG recordings when healthy adult participants were instructed to "swallow really hard with your tongue" (p. 1068) versus non-effortful swallows.

In a related study, Crary (1995) used sEMG as a biofeedback tool to treat six patients with chronic, severe-profound dysphagia following a brainstem CVA. Biofeedback supplemented instructions to sustain hard swallow movements throughout the swallow duration. Patients received daily therapy for 3 weeks, followed by less frequent outpatient visits, with a three times daily home program to continue practicing effortful swallows. Results showed improved swallow pressures for all patients, improved functional swallow for 5/6 patients (i.e., removal of feeding tube and return to oral nutrition), with maintenance of functional gains noted at 2-year follow-up for 5/6 patients. The effortful swallow adheres to the principle of specificity of training by incorporating dynamic swallow movements, and attempts muscle overload by encouraging "hard" muscle contraction to overload muscles during the swallow. While the effortful swallow showed promise for a small group of patients with dysphagia in a quasi-experimental study, more research evaluating the effectiveness of the effortful swallow on patients with dysphagia is warranted.

Masako Swallow Exercise

Another promising line of research by Dr. Masako Fujiu and colleagues provides emerging theoretical evidence to support a tongue-anchor swallowing exercise to improve pharyngeal muscular contractions during the swallow. For the Masako swallow exercise, the therapist instructs the participant to swallow while maintaining the tip of the tongue extended out of the mouth. During a normal swallow, the base of the tongue retracts while the posterior pharyngeal walls contract anteriorly, until they meet (Logemann, 1998). The combined forces of the tongue base and posterior pharyngeal walls (PPW) generate pressures to push food or liquid through the throat and into the esophagus. The goal of the Masako swallow exercise is to strengthen the PPW to improve pharyngeal pressures generated during the swallow to reduce residue in the throat after the swallow. Anchoring the tip of the tongue outside of the mouth restricts posterior contraction of the base of the tongue; thus to achieve adequate swallow pressures, the PPW must exert greater force to meet the anchored base of tongue.

The idea for this swallowing exercise emerged from an observational study by Fujiu, Logemann, and Pauloski (1995). They were studying swallowing patterns of adults who had undergone resection of the tongue or floor of mouth to remove oral cancer. The researchers noted that about half (6/11) of the patients had developed a compensatory 30% increase in PPW contraction three months following surgery. They reported that greater PPW contraction correlated with the extent of oral tongue resection. They speculated that swallowing exercises that anchor the tongue in an anterior position could induce changes in PPW contraction among patients without tongue resection.

In an exploratory non-experimental study of the Masako swallow, Fujiu and Logemann (1996) explored the potential application of the anterior tongue-holding position to induce a compensatory movement of the PPW during swallowing for ten healthy adult males. No previous work had addressed direct manipulation of the PPW, as it was not thought to respond to voluntary treatment efforts. The tongue-holding maneuver was designed to "inhibit retraction of the BOT and potentially facilitate anterior bulge of the PPW in normal subjects" (p. 24). A modified barium swallow assessment evaluated the swallow function once normally and once with the tongue protruded past the incisors during the swallow for each of three food consistencies. Anterior PPW movement was enhanced during the swallow with the tongue protruded anteriorly, and was significantly greater than swallows without the maneuver. The authors concluded that the Masako swallow "provides clinicians with the possibility of actively changing the degree of muscular contraction of the PPW" (p. 29). However, this study did not assess the impact of an exercise program to induce changes in the PPW muscles over time, but did show immediate improvements in swallow function. The authors cautioned that more research is needed before wide-spread adoption of the technique as a therapeutic exercise. Nonetheless, this study provides initial theoretical support for the technique as a potential swallowing exercise that follows the principle of specificity of training and increases stimulus intensity for PPW contractions. No further studies to date have evaluated the effects of the Masako swallow for individuals diagnosed with dysphagia.

Mendelsohn Maneuver Swallow Exercise

The final swallowing exercise with emerging theoretical promise is the Mendelsohn maneuver exercise. Logemann and Kahrilas (1990) first described the technique as a method to strengthen laryngeal elevation muscles to improve the extent and duration of laryngeal excursion to protect the airway during the swallow. For this technique, the clinician instructs the patient to "Swallow your saliva several times and pay attention to your neck as you swallow. Tell me if you can feel that something lifts and lowers as you swallow. Now, this time, when you swallow and you feel something lift as you swallow, don't let your [voice box] drop. Hold it up with your muscles for several seconds" or "Hold the squeeze as you swallow" (Logemann, 1998, pp. 221-222). By maintaining the muscular contraction to elevate the larynx during the swallow, muscles are taxed beyond the usual workload (overload) and since the maneuver involves an actual swallow, the maneuver also complies with the principle of specificity of training.

One non-experimental study demonstrated the effects of the Mendelsohn maneuver on laryngeal muscles. Ding, Larson, Logemann, and Rademaker (2002) used sEMG to examine muscular changes between normal swallows and Mendelsohn swallows in a group of 20 healthy young adults. Results revealed increased laryngeal elevation muscle contractions during the Mendelsohn swallows compared to the normal swallows. The authors concluded that the Mendelsohn maneuver recruits greater muscle activity during the swallow, and thus allows for muscle overload beyond the typical workload. However, no empirical research to evaluate the effects of the Mendelsohn maneuver on patients with dysphagia has been conducted. In addition, Ding and colleagues noted that "teaching this technique can be particularly difficult with patients who show impaired receptive language and/or cognition" (p. 1).

Summary

Empirical and theoretical research evidence supports intensive exercise programs to achieve and maintain improvements in muscle strength and swallowing function. Five specific swallowing exercises adhere to theoretical guidelines to achieve muscle overload using specific swallow-related muscles and movements. Empirical evidence supports the benefits of the Shaker, tongue strengthening, and effortful swallow exercises among individuals with ABI. Basic science studies provide theoretical support for using the Masako and Mendelsohn maneuver exercises. Cross-disciplinary rehabilitation strengthening programs emphasized intensive practice to achieve positive outcomes.

Issues with Home Exercise Program Completion

The term *compliance* is often used to describe a person's fulfillment of a prescribed treatment or exercise regimen (Dishman, 1994b). However, contemporary researchers have adopted the terms *adherence, participation, cooperation,* or *completion* to connote the same meaning without judgment or implication that the health care provider must dictate goals or the process (Chen, Neufeld, Feely, & Skinner, 1999; Dishman, 1994b; Friedrich et al., 1998). The latter terms will be used throughout the remainder of this manuscript.

Home therapy programs serve at least five functions. First, home programs provide supplemental practice to promote intensive therapy, especially when rehabilitation funding precludes intensive therapy home visits (Enderby & Petheram, 1992). Second, home programs help reinforce therapy goals by providing additional practice on targeted skills (Marvin & Privratsky, 1999). Third, they may help encourage self-monitoring and self-corrections by promoting independent practice of skills (Holmes, Fletcher, Blaschak, & Schenck, 1997). Fourth, they may help patients maintain progress by providing periodic stimulation of trained skills (Enderby & Petheram, 1992). Finally, home programs address generalization of treatment targets to real-life contexts (Sohlberg & Mateer, 2001). With regards to exercise strengthening programs, the main goal is to promote intensive, regular practice.

Several researchers acknowledge the importance of measuring and studying exercise adherence when evaluating effectiveness of any exercise intervention. For example, Sluijs, Kok, and van der Zee (1993) noted that "the efficacy of therapeutic exercises can only be established when patients comply with the exercise regimen" (p. 771). Chen and colleagues (1999) added that adherence to intensive treatment recommendations is linked to improved outcomes. Robison and Rogers (1994) reported that "understanding what motivates people to become physically active may be a prerequisite for designing effective exercise interventions" (p. 41). However, Kirwan, Tooth, and Harkin (2002) more recently added that exercise adherence is "the most unpredictable, least controllable variable… [that] can strongly sway the outcome of any treatment" (p. 31). Each of these researchers called for future studies to investigate factors that influence participation in exercise programs, such as the complexity of recommended exercises (e.g., number of sessions required to complete exercise correctly or complaints associated with exercises), effectiveness of interventions (e.g., number of sessions to achieve targeted outcomes), or rate and reason for exercise dropouts. Typically, these outcomes are not considered, but "are highly relevant to our understanding of whether patients are successful in using an exercise and whether they have any difficulties throughout their exercise program" (Logemann, 2005, p. 139). Fatouros and colleagues (2005) provided further support for this idea. In their study, high-intensity exercise training programs resulted in less regression to baseline than low-intensity programs following program completion.

An extensive review of the literature revealed no empirical studies evaluating factors to promote home swallowing exercise completion among individuals with CI. This section will provide theoretical evidence to promote home exercise program completion from three areas. First, evidence illustrating the need for supports in order to achieve exercise program adherence is presented. Second, factors that influence home exercise program completion among cognitively intact adults are reviewed. Third, this section concludes with theory-based recommendations to maximize completion of home exercise programs, such as intensive swallowing strengthening exercises.

The Need to Provide Supports for Home Exercise Program Completion

Unfortunately, the evidence suggests that many individuals are unable to complete intensive home exercise programs. In physical therapy, Sluijs and Knibbe (1991) estimated that 40-70% of patients do not adhere to home exercise program recommendations for intensity. In occupational therapy, Chen and colleagues (1999) reported that 65% of patients did not adhere to recommendations for intensive arm exercise programs. Researchers conducting swallowing exercise research have reported higher levels of program completion.

Easterling and colleagues (2005) were the only authors to specifically study compliance with swallow strengthening exercises. They examined factors affecting program adherence with the 6-week, intensive Shaker exercise program among 26 healthy adults over 65 years old from a senior independent-living community. Participants self-reported daily practice in an exercise diary. A researcher visited each participant weekly to check accuracy of exercise performance, collect logs, and interview participants about any complaints, difficulties, or other comments on the protocol. Seven (27%) participants dropped out of the study early on, primarily due to complaints of neck muscle soreness or difficulty fitting exercises into their daily routine schedules. Five (19%) participants required repetition of instructions, instructional cues, and encouragement to continue. Half of the original 26 participants achieved the sustained contraction goal of 3 repetitions for 60 seconds each by the end of the study. A larger proportion (70%) of participants achieved the repetition goal of 30 repetitions by the end of the study. They noted that the structure and difficulty of the exercise program prevented several participants from adherence to the recommended intensive schedule.

Although Robbins and colleagues (2007) did not include data on program adherence in their published reports for tongue strengthening exercise programs, a follow-up discussion with Dr. Robbins provided additional data (personal communication, December 24, 2007). She reported that out of a total possible 72 sessions, "three participants never missed a session, four missed only a single session, two missed six sessions, and one participant missed 3 full days. Those participants who missed six or more sessions were residing in nursing homes and were more reliant on nursing staff to assist them in performing the exercises." These data reveal high levels of home program participation, but also reveal additional challenges due to CI. Participants with CI appear to need external supports in order to follow through with prescribed home exercise programs (e.g., Wilson et al., 2001; Logemann, 1998).

Factors that Influence Home Exercise Program Completion

There exists a dense literature on factors that influence adherence to general exercise programs. Researchers have attempted to predict or explain exercise adherence in healthy adults (e.g., Dzewaltowski, 1994; King, 1994; Robison & Rogers, 1994), elderly adults (e.g., Dishman, 1994a; Henry, Rosemond, & Eckert, 1998), and patient populations receiving physical therapy (e.g., Campbell et al., 2001; Friedrich et al., 1998), occupational therapy (e.g., Chen et al., 1999), or dysphagia therapy (Easterling et al., 2005). Across studies, over 200 variables contributing to exercise adherence have been identified (Meichenbaum & Turk, 1987). The consensus seems to be that several factors contribute to short or long-term adherence to exercise programs, although no single factors have consistently predicted adherence. Disagreements with defining adherence, measurement, and differing research designs across studies make cross-study comparisons difficult (Dishman, 1994b). Nonetheless, studies and consensus opinion agree that adherence influences can be categorized into three factors: personal, environmental, and program characteristics.

Personal Characteristics

The first factor influencing participation in an exercise program encompasses intrinsic characteristics of the individual. Personal demographic variables (e.g., gender, age, education, SES) have *not* been shown to be useful predictors of compliance (Morris & Schulz, 1992); however, researchers have identified five personal characteristics that predict adherence. These are described next.

Self-efficacy. The most widely accepted and discussed of these personal characteristics is self-efficacy. Self-efficacy refers to the belief that one can perform a particular task, and is related to self-confidence (Chen et al., 1999; Driver, 2006; Dzewaltowski, 1994; Robison & Rogers, 1994). It is based on the assumption that individuals can determine and control their own behavior (Dzewaltowski, 1994). A related concept proposed by Driver is self-regulatory efficacy, or the belief that one can perform a particular task despite the presence of barriers. Self-efficacy can be influenced by previous experiences performing a task, observational experiences of others performing a task, social context, and physiological reactions to exercise, such as pain (Driver, 2006). Research has shown positive correlations between self-efficacy, affect, and participation in exercise programs (e.g., Chen et al., 1999; Driver, 2006). Others have suggested that high self-efficacy may be more important to beginning an exercise program than to sustaining it (e.g., Jette et al., 1998).

Locus of control. Related to self-efficacy, research has also shown that an internal versus external locus of control related to health responsibility and control over change predicts completion of exercise programs (Robison & Rogers, 1994; Dzewaltowski, 1994; Jette et al., 1998). With an internal locus of control, individuals believe that they have control over change, and take responsibility for making active behavioral changes. An internal locus of control predicts greater short-term completion of exercise routines (Campbell et al., 2001; Friedrich et al., 1998). In general, older persons perceive less control over being active than younger counterparts (Dishman, 1994a). Holmes and colleagues (1997) suggested that reducing the frequency of therapy visits can encourage self-monitoring and internalize the locus of control for adults receiving occupational therapy outpatient services.

Exercise beliefs & expectations. An individual's beliefs and expectations about the benefits of exercising also influence adherence (Berg, Dischler, Wagner, Raia, & Palmer-Shevlin, 1993; Dzewaltowski, 1994; Robison & Rogers, 1994). Positive attitudes toward exercise predict greater willingness to accommodate exercise into daily routines (Campbell et al., 2001). Expected recovery influenced participation more for individuals with acute onset of symptoms than for those with chronic impairments (Sluijs et al., 1993). In addition, persons with higher adherence to exercise programs also believed that exercises were effective to improve strength or relieve symptoms (Campbell et al., 2001). Motivation can be difficult to sustain when immediate benefits are unlikely (Friedrich et al., 1998). Kosma, Cardinal, and McCubbin (2005) added that the perceived benefits need to outweigh perceived cons of exercising to achieve long-term adherence.

Disease characteristics. Disease characteristics may also help predict adherence. For example, individuals who are symptomatic, experience pain, or who present with greater functional limitations are more likely to participate in physical therapy exercise programs (Campbell et al., 2001; Jette et al., 1998). In addition, perception of severity of symptoms can influence participation in exercise programs (Berg et al., 1993; Sluijs, 1991; Warren, Fey, & Yoder, 2007).

Cognitive status. The individual must possess knowledge of how to complete exercises properly (Robison & Rogers, 1994; Morris, Taub et al., 2006). Cognitive status can affect one's knowledge of how to correctly complete exercises (Logemann, 2005). For example, Jette and colleagues (1998) indicated that elderly participants with confusion demonstrated lower participation "likely because they were not certain what was expected of them" (p. 419). In addition, CI may cause individuals to fail to complete exercises daily, even when patients recall exercise techniques, due to prospective memory failures (Sohlberg & Mateer, 2001).

Environmental Characteristics

The second factor that influences participation in an exercise program reflects two external characteristics of the environment that may promote or hinder participation in exercise programs.

Facilities. Characteristics of the exercise facility, such as proximity, convenience, appearance, and comfort can influence participation (Kirwan et al., 2002; Robison & Rogers, 1994; Sluijs et al., 1993). In fact, Dishman (1994a) reported that access to facilities is an important influence on participation for older adults. The number of people present and wait times also influence participation (Kirwan et al., 2002).

Social influences. Social and community supports also influence an individual's participation in exercise programs. Positive persuasion from immediate family members or close significant others has been linked to increased exercise participation (Robison & Rogers, 1994). For individuals with brain injury, Driver (2006) reported that persuasion influenced participation to a greater extent when the persuader was perceived to be an expert. Group exercise classes also incorporate positive social influences to augment adherence (Olney et al., 2006). Additionally, community supports that endorse and support exercise may also positively influence participation (King, 1994). Berg and colleagues (1993) added that external reminders of the benefits of continued participation, such as advertisements or brochures, positively influenced long-term adherence.

However, while social influences from close family members may promote exercise program adherence in a healthy population, Warren and colleagues (2007) cautioned that intensive treatment that relies on care provider assistance could increase care provider stress or family burden. Care providers of stroke survivors report feelings of social isolation, anxiety, and depression (Levine et al., 2006). Care providers of TBI survivors reported high levels of stress when required to frequently prompt family members to complete daily tasks (Wilson et al., 2001). Programs that rely too heavily on care provider prompts therefore run the risk of overwhelming care providers, leading to decreased completion of home programs.

Program Characteristics

The third and final factor influencing completion of exercise programs describes characteristics of the program itself. The literature discusses seven program characteristics that influence exercise adherence.

Program intensity. The intensity of the exercise program influences participation. The recommended level of intensity and duration of the exercise program may deter some individuals from completing exercise programs (Jan et al., 2004; Morris & Schulz, 1992; Robison & Rogers, 1994). Jan and colleagues reported less than 50% participation when home hip exercises were prescribed for one hour daily for 12 consecutive weeks. In addition, high-intensity exercises may increase the risk for injury or side effects (Berg et al., 1993; Robison & Rogers, 1994). Dishman (1994a) reported that older persons fear exercise injury more than younger persons.

Exercise complexity. The complexity of the exercises also influences completion (Berg et al., 1993; Sluijs et al., 1993). For example, patients who find exercises too difficult to complete at home may stop doing them (Campbell et al., 2001). Provision of clear instructions has augmented exercise program participation (Berg et al., 1993; Sluijs, 1991; Sluijs et al., 1993). In addition, Henry and colleagues (1998) showed that older adults were better able to perform exercises when assigned two at a time, versus 8 at a time, at a one week follow-up.

Program structure. Dishman (1994a) emphasized that programs need to offer sufficient variety to prevent boredom and maintain interest. Others emphasized that programs must allow for scheduling flexibility, due to daily changing circumstances

(Robison & Rogers, 1994). Jette and colleagues (1998) added that the ability to individualize and customize the pace of an exercise program correlated with greater motivation, reduced boredom, and increased participation in home exercise programs. They also noted the challenge of keeping an intensive intervention "fresh, interesting, and fun" (p. 75) to maintain the client's motivation and interest, requisite to learning. Logemann (2005) emphasized that specific exercise programs need to be individualized to the individual's impairment and lifestyle.

Instructional modality. Research has demonstrated the equivalency of static (written) and dynamic (multimedia, such as videotapes) exercise instructions to complete exercise programs for individuals without cognitive impairments (Gagliano, 1988; Lysack, Dama, Neufeld, & Andreassi, 2005; Roddey, Olson, Gartsman, Hanten, & Cook, 2002; Weeks et al., 2002). Jenny and Fai (2001) delivered their dynamic instructions via home computer rather than videocassette and also reported no significant advantages on ability to complete or recall exercise techniques, compared to static written instructions.

Despite a lack of differences in promoting short-term exercise completion, participants across all of these studies reported preference for dynamic instructions. Reported advantages of dynamic instructions include: the ability to provide clear, consistent, personal models of desired behaviors; provision of easy-to-follow video examples of exercise models; more interesting content delivery; self-guided instruction at a personalized pace; ability to exercise in one's own home; and cost-effective service delivery because the clinician was not required to be present for videotaped instruction.

Supervision. The level of supervision provided in the exercise program can influence adherence (Robison & Rogers, 1994; Sluijs & Knibbe, 1991; Sluijs et al., 1993). Supervised programs allow for monitoring and feedback by professionals, and are associated with higher compliance rates (Olney et al., 2006; Sluijs et al., 1993). Home programs that are supervised by professionals have achieved over 70% participation for up to 12 months (Jette et al., 1998). Unfortunately, however, participation decreases after supervision stops for most programs because of lack of feedback or motivation (Friedrich et al., 1998). Sluijs and Knibbe (1991) reported a dramatic decline in home exercise program completion following discharge from supervised physical therapy programs. Similarly, patients reported preference to complete home exercises on a daily basis when they knew a professional was monitoring their performance, even without regular face-to-face interactions (Wade, Mortley, & Enderby, 2003). Infrequent maintenance programs may help promote long-term adherence (Fatouros et al., 2005; Trappe, Williamson, & Godard, 2002).

Relationships. The development and fostering of interpersonal relationships between the therapist and patient can also influence home program adherence in therapy programs (Berg et al., 1993; Sluijs, 1991). The therapist must be able to motivate the patient while patient must be open to these efforts and understand the rationale for doing prescribed exercises (Friedrich et al., 1998). Clinicians should understand the patient's individual needs, enable open communication to allow for mutual goal setting and problem-solving, and provide feedback and encouragement (Kirwan et al., 2002).

Cost. The cost of exercising may also affect participation. The cost of purchasing equipment or joining a gym may be a deterrent to some individuals (Robison & Rogers, 1994). Therapy programs that provide more intensive rehabilitation require increased funding to cover staffing costs (Graff, Green, & Libby, 1998). Unfortunately, decisions about treatment intensity in clinical practice are often made by third-party payers or based on client and family preferences, rather than the empirical evidence (Ramsberger & Marie, 2007).

In summary, a combination of personal, environmental, and program-specific factors influence short and long-term adherence to home exercise programs. However, no factor alone can predict exercise completion. As Robison and Rogers (1994) stated, "despite nearly 10 years of study in this area, it is still not possible to predict with consistency who will adhere to exercise [programs]" (p. 42). Approaches that *combine* influencing factors are supported over single-factor approaches (Chen et al., 1999; Jette et al., 1998; Morris & Schulz, 1992). For example, Jette and colleagues achieved 93% adherence with a 26-week home exercise program for healthy elderly adults when incorporating dynamic video presentations with behavioral incentives, clear instructions, motivational prompts, and intermittent telephone supervision.

Recommendations to Promote Home Exercise Program Completion

Important to the current study, any intervention package to deliver home based swallowing exercises should follow evidence-based guidelines. Maximizing the likelihood of completing intensive swallowing exercises promotes exercise adherence, and therefore supports beneficial outcomes, such as the reduction of risk for pneumonia, dehydration, malnutrition, and improved quality of life (Easterling et al., 2005). Following is a list of specific strategies based on theoretical evidence to promote exercise program adherence. These strategies are organized according to influences on personal, environmental, and program characteristics.

Recommendations to Maximize Personal Characteristics

1. Encourage self-efficacy and an internal locus of control by encouraging early success, empowering patients to manage their own program, and making decisions to fit recommendations into their belief system and lifestyle (Berg et al., 1993; Driver, 2006; Morris & Schulz, 1992).
2. Encourage patients to evaluate their ability compared to their current status (with disability) rather than their pre-injury status to reduce chances of negative affect and reduced self-efficacy (Driver, 2006).
3. Encourage motivation by exposing patients to successful examples with models who are similar to the patient in terms of age, gender, and ability (Driver, 2006).
4. Use behavioral incentives, rewards, & reinforcements (verbal or tangibles) to encourage motivation (Robison & Rogers, 1994).
5. Remind patients early and often of the benefits and goals of exercises (Chen et al., 1999; Dishman, 1994a; Robison & Rogers, 1994; Sluijs, 1991).
6. Prepare patients to cope with temporary lapses by making alternative plans to exercise despite challenges that may arise (Chen et al., 1999; Dishman, 1994a; Dzewaltowski, 1994).
7. Reduce potential anxiety by instructing patients about upcoming activities and potential physiological responses (e.g., pain or fatigue) to exercises (Driver, 2006).

Recommendations to Maximize Environmental Characteristics

1. Establish a relaxed, but "upbeat" environment (Driver, 2006, p. 158).
2. Significant others should offer positive praise and support for completing exercise programs (Driver, 2006).
3. Include social supports and encourage exercising with others (Chen et al., 1999; Dishman, 1994a; Robison & Rogers, 1994).
4. Use environmental cues to prompt exercise behavior, such as stickers, reminder notes, calendars, associations (Morris & Schulz, 1992; Sluijs & Knibbe, 1991).

Recommendations to Maximize Program Characteristics

1. Clearly instruct patients on exercise completion, frequency, and progression of exercises with dynamic information (Chen et al., 1999; Dzewaltowski, 1994; Lysack et al., 2005; Weeks et al., 2002).
2. Minimize levels of difficulty and pain for independent home exercises (Easterling et al., 2005).
3. Individualize or customize exercise programs (Chen et al., 1999; Dishman, 1994a; Driver, 2006; Morris & Schulz, 1992; Robison & Rogers, 1994; Sluijs, 1991; Sluijs et al., 1993).
4. Ensure age-appropriate activities (Dishman, 1994a).
5. Help patients establish a routine to fit the exercise program into their schedule (Chen et al., 1999; Robison & Rogers, 1994; Sluijs, 1991).
6. Use written contracts to increase accountability (Robison & Rogers, 1994).
7. Provide feedback on completion of activities (Sluijs, 1991).
8. Monitor adherence regularly and attempt to resolve challenges to program adherence (Dishman, 1994a; Sluijs, 1991).
9. Provide personalized attention, education, and support as needed (Dzewaltowski, 1994; Robison & Rogers, 1994).

Summary

Intensive treatment results in gains when participants maximally adhere to the full program, which often includes intensive home practice. Research to support exercise program adherence from several related disciplines provided theoretical evidence for recommendations to promote swallowing exercise program adherence. However, even the most motivating and interesting exercise program with clear instructions may not be effective for the target population, due to the co-occurrence of CI (e.g., Robbins et al., 2007). The remaining challenge is how to effectively prompt individuals with co-occurring cognitive impairments to complete their exercise programs.

Technology Options for Prompting Home Exercise Completion

As previously discussed, many ABI survivors with CI demonstrate persistent difficulty completing daily tasks, including daily exercises. Two methods of providing external sources of prompting include care provider prompts and technology aids. Given the risk of burnout with requirements for care provider of ABI survivors to provide frequent reminders, this project focuses on developing a technology aid to promote home practice of intensive swallowing exercises.

This section presents a summary of the current literature supporting the efficacy of assistive technologies for prompting ABI survivors. First, the range of technology options is described. Second, the limitations of current technologies to promote home swallowing exercise completion are discussed. Third, recommendations for designing effective technologies for individuals with CI are presented.

Range of Technology Options for Prompting Behaviors

Assistive technology for cognition (ATC) refers to technological devices that support memory, organization, and other cognitive functions, designed to improve or maintain functional abilities in daily activities (LoPresti et al., 2004; Scherer et al., 2005). These devices range in technical complexity (e.g., alarm clock vs. handheld computers), design (specialized functions vs. commercial applications), and functionality (single-use vs. multi-purpose). The burgeoning market of business tools to prompt non-injured people to complete tasks and attend meetings suggests that it is not only the population of people with CI who rely on prompting. A number of electronic prompting systems are currently available for both populations: Personal Data Assistants (PDAs), pagers, time management software, voice organizers, cellular phones, and alarm watches and clocks. There are also electronic prompting systems specialized for people with CI, such as 'smart' medication boxes (www.homemed.com) or customized task-guidance PDAs (www.ablelink.com).

Strong evidence supports the recommendation to use low- and high-tech external aids to prompt activity completion for ABI survivors with CI (Sohlberg et al., 2007). The strongest evidence is from a randomized, controlled trial evaluating the use of alphanumeric pagers to prompt certain simple, routine behaviors for individuals with CI (Wilson et al., 2001). When prompted with these pagers, individuals increased completion of daily tasks from approximately 47% of the time to over 75% of the time. The authors reported that the pagers enabled "people with memory or planning problems to use strategies taught by therapists by providing consistent and reliable prompting that no family or carer [could] provide" (p. 481). In keeping up to date with contemporary technologies, this research group is also currently investigating the benefits of providing multimedia (e.g., pictures, video, images, photos, and text) prompts via cellular phone instant messaging (www.ozc.nhs.uk). Other researchers have demonstrated the beneficial effects of a PDA to prompt individuals with dementia to complete simple tasks (Szymkowiak et al., 2004).

Another promising line of technology research to provide external prompts comes from the field of telerehabilitation. Telerehabilitation refers to the delivery of rehabilitation services using technology (e.g., such as computerized videoconferencing, home sensors, computer software, and Internet data transferring) for the purposes of assessment, treatment, prevention, and/or monitoring of patients in distant locations (ASHA, 2005). Most telehealth applications to date have been used for patient consultations in remote areas, specialist referrals, remote patient in-home monitoring, continuing education, or consumer health education (www.atmeda.org).

While a wide variety of telerehabilitation options currently exist, only one application to date has provided home-based prompting. The Motiva TV system, designed by Philips, (www.medical.philips.com/goto/motiva) uses a dedicated cable channel to deliver prompts, interactive educational information, and motivational messages for in-home symptom management of persons with congestive hearth failure. The television provides timed prompts to use health-monitoring sensors (e.g., blood pressure cuff), and transmits this data to health care providers. Patients can also scroll through menus using a cable-TV remote control to access multimedia instructional videos for information about their disease and symptoms. Although no systematic research has evaluated the Motiva system, results of an unpublished pilot study on their Web site suggest that this home-based monitoring system is feasible and effective to reduce hospitalizations and health care costs among cognitively-healthy adults with congestive heart failure living at home.

Limitations of Technology Options

While research demonstrates the promise of assistive technologies to prompt completion of daily tasks, high-tech devices are still not widely used by many ABI survivors (Evans, Wilson, Needham, & Brentnall, 2003). Significant barriers remain before technologies become common rehabilitation applications. These barriers have been classified into four categories, based on the current literature: device, patient, clinician, and system characteristics.

Device Characteristics

The first set of barriers to wide-spread implementation of technology relates to the devices themselves. While computers (especially hand-held computers and newer "wearable" technologies) provide great promise for non-injured or mildly impaired persons, they are not intuitive enough and present great challenges to learning-to-use the device before they can help patients with CI become more successful. For example, the Motiva TV system uses a 'standard' cable remote control with several multi-functional buttons, and requires complex on-screen menu sorting. Computerized home systems require maintenance, which many users with acquired CI cannot manage independently. Additionally, home computers are often not at the center of home life; they are located in a separate office or tucked into a corner, limiting their viability to attract attention to provide regular prompts. However, portable devices may be too difficult to manage due to cognitive, language, sensory, or physical impairments (e.g., distracting layout, cannot read text, or cannot access buttons) (LoPresti et al., 2004; Wilson et al., 2001).

Many of the more successful applications use devices (e.g., alphanumeric pagers) that limit the provision of multimedia exercise instructions. Only discrete tasks (e.g., medication management) can be prompted with static instructions. In addition, cognitive and language impairments that are common following ABI (Sohlberg & Mateer, 2001) limit the ability of many patients to follow complex or multi-step instructions. Other devices, such as cellular phones or PDAs are capable of providing dynamic instructions, but the risk of losing the device and physically accessing these small devices precludes their utility for many ABI survivors (LoPresti et al., 2004). Finally, many of these devices provide prompts that may not be perceived by ABI survivors, such as inaudible alarms (LoPresti et al., 2004).

Patient Characteristics

Extra care must be taken when one envisions introducing new technologies, such as computers, to persons with learning challenges due to ABI. Individuals with cognitive and language impairments following ABI demonstrate considerably higher levels of stress and anxiety when using high-tech devices (Singh, 2000). Vaccaro and colleagues (2007) reported that a majority of participants (57%) with moderate-severe, chronic CI due to TBI were not comfortable with computerized technology. Wade and colleagues (2003) reported that some patients with more severe aphasia could not independently operate their home computer to access practice software. They reported that care providers needed to provide support to operate the computer, problem solve technical barriers, reassure patients, and motivate patients to use the software. Fink, Brecher, Sobel, and Schwartz (2005) added that "computers still represent an unfamiliar and intimidating technology for the majority of our patients and families, and access in the home remains limited" (p. 943).

Clinician Characteristics

Another reason ABI survivors may not adopt technology aids reflects lack of comfort or understanding on the part of their therapist (Evans et al., 2003; Hart et al., 2003). In their survey study of 81 clinicians who specialize in TBI rehabilitation, Hart and colleagues reported that while many clinicians believed that ATC devices show promise for improving memory functioning, less than one-third of respondents reported feeling confident to recommend and train use of technological devices to ABI survivors. Those clinicians with previous exposure to and use of technology at home reported higher levels of confidence with recommending technology to patients. Clinicians may further hesitate to recommend telecommunications systems for assessment and treatment include: lack of hands-on access to patients; lack of portability of computerized desktop systems; and fear of being replaced by technology (ASHA, 2005; Cochran & Masterson, 1995).

System Characteristics

The fourth barrier to increased use of technology aids to prompt behaviors relates to systematic problems of funding and time restrictions. Third-party payers do not reimburse patients for assistive technology prompting devices or customized programming that may be required for many off-the-shelf devices (LoPresti et al., 2004). In addition, teaching a patient with significant CI following ABI to successfully use a new technology device requires sufficient staffing resources since multiple training sessions will be required (Sohlberg & Mateer, 2001). In fact, Wilson and colleagues (2001) reported that clients with more severe memory impairments required additional training to operate their simple one-button pager system.

Technology Design Recommendations for Users with Cognitive Impairments

The development of assistive technologies needs to avoid the pitfalls produced by not accommodating device, patient, clinician, and system characteristics. Development should also follow the general principles of universal design as well as specific practice recommendations for cognitive orthoses. Unfortunately, when devices are not designed with these precautions in mind, risk for device abandonment increases (Harniss, Brown, & Johnson, 2005; Hart, Buchhofer, & Vaccaro, 2004; Johnson, Inglebret, Jones, & Ray, 2006).

Universal Design Principles

Universal design refers to the design of products that can be used by all individuals without the need for adaptations or specialized design (www.design.ncsu.edu). There are seven principles of universal design (www.universaldesign.org):

1. Equitable Use: The design must be useful and marketable to people with diverse abilities.
2. Flexibility in Use: The design must accommodate a wide range of user preferences and abilities.
3. Simple and Intuitive Use: The design must be easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level.
4. Perceptible Information: The design must communicate necessary information effectively to the user, regardless of sensory abilities or ambient conditions.
5. Tolerance for Error: The design must minimize hazards and the adverse consequences of unintended actions.
6. Low Physical Effort: The device must be used efficiently and comfortably, with a minimum of fatigue.
7. Size and Space for Approach and Use: Appropriate size and space must be provided for approach, reach, manipulation, and use of the device, regardless of the user's body size, posture, or mobility.

Additional Practice Principles for Designing Assistive Technologies for Cognition

Many of the newer, 'sexy' technology applications contradict best practices for designing assistive technologies as cognitive orthoses (Bickmore, Mauer, Crespo, &

Brown, 2007; Kirsch et al., 2004; LoPresti et al., 2004; Murphy, 2005; Scherer et al., 2005). According to best practices, ATC should be inexpensive, and should:

- Capitalize on familiar, accessible technologies
- Present low sensory, physical, language, and cognitive demands
- Allow for automated or context-dependent scheduling of reminders
- Provide a pre-interruption warning or allow a snooze feature
- Use polite, simple language to make requests
- Allow for information to appear in text, graphic, auditory, or combined modalities
- Allow for simple, intuitive interfaces that minimize choices and complexity
- Allow for customized and flexible use

Summary

Assistive technology devices provide promise to prompt completion of home exercises without inducing undue care provider burden. Several options are currently available to prompt home exercise completion, but all present with limitations. Any potential technology solution to provide dynamic prompts that promote exercise adherence must follow both universal design and specialized practice principles for users with CI. Technological devices that prompt dynamic behaviors must be simple, intuitive, customizable, familiar, and easy to use.

The Television Assisted Prompting (TAP) System as a Potential Solution

The research cited earlier in this chapter provides evidence for delivering intensive swallowing exercises to patients in a home care setting. In particular, the evidence supports five swallowing exercises that induce muscle overload for specific muscles or those that promote transference to functional swallowing. Evidence also provided guidelines to develop effective exercise programs that maximize program adherence and design technologies to prompt completion of tasks for individuals with CI.

The TAP system is a novel, experimental device that holds the promise to deliver a variety of instructions or prompts via a person's own home television. The TAP system was designed with evidence-based practice principles in mind. The TAP system builds on familiar technology, provides a simple interface, and has been designed with input from persons with CI. This system is well-suited for delivering swallowing exercise instructions to individuals with CI receiving home-care services because it can: automate prompts at pre-determined times to help relieve care provider burden; and provide dynamic video exercise instructions with clear instructions and motivating content to promote home program adherence.

Development & Description of the TAP System

The TAP system is a customized device developed by Drs. Fickas and Sohlberg at the University of Oregon and Life Technologies, LLC. The TAP system consists of an elegantly simple, customized device. A small, computerized, set-top "box" (see Figure 2.1) contains a programmable microcomputer capable of taking over a person's television to deliver a variety of multimedia prompts or instructions. The small TAP box attaches to the user's home television, so the only new piece of technology is the TAP box; patients would already be familiar with their home television sets. The system capitalizes on the home television as a familiar, intuitive, centrally-located assistive device (Goodman, Syme, & Eisma, 2003). Importantly, the patient does not need to own or maintain a home computer. The system automatically provides prompts at scheduled times to capitalize on the need for external prompting. When the television is off, the TAP box can turn it on. If the patient is watching the TV, the TAP box can take over the television to deliver prompts. Moreover, the interface is simple: two large buttons on the front of the box.

Figure 2.1. Picture of the TAP box attached to TV from pilot study to prompt individuals to gather needed items for a trip. Notice the circled two-button simple interface on front of box.

The TAP system has been designed with end users in mind, following the Cognitive and Incremental Design Engineering Rehabilitation (CIDER) model. The CIDER model combines Participatory Action Research (PAR) (Balcazar, Keys, Kaplan, & Suarez-Balcazar, 1998; Hall, 1984) with incremental product design (Larman & Basili, 2003). PAR is a qualitative methodology that encourages the active research and development partnerships with those most affected by the work (Balcazar et al., 1998).

Commitment to a PAR approach ensures that the research and development efforts will result in direct and positive benefits for the target population and that the findings will be more socially usable, having been produced collectively (Hall, 1984). Incremental product design is an engineering process by which a subset of software requirements evolves with each iteration of a system. User feedback and testing lead to revised system requirements. The new requirements are then fed back into the development process resulting in a new iteration of the system. The CIDER process takes incremental design one step further by integrating the PAR approach to ensure that the end users are involved in all iterations of system development.

One previous pilot investigation evaluated the feasibility of the TAP system to deliver home-based prompts. In that pilot project, researchers installed the TAP system on the home televisions of two adults with CI due to ABI. Multimedia prompts, including audio, text, and pictures, offered a variety of community outing suggestions to encourage the two participants to navigate to novel destinations in the local community. This pilot project revealed that participants frequently remained in their homes, responded positively to the TV prompts, and demonstrated ability to interact with the simple 2-button interface. The prompts even encouraged one participant to travel to an interesting, new local destination. However, technical issues with the wireless Internet connection to deliver content to and receive data from the device prevented consistent system functioning.

Based on the pilot evaluation, user input, and the literature reviewed in this chapter, the original TAP system prototype has been modified for this project. The system currently possesses the following features and capabilities:

- *TAP is a set-top box that requires no home computer.* Users of the system will not be required to own or maintain a home computer. The TAP system is self-contained, ready to plug in and operate independently. Since the TAP box interacts with the user's familiar home TV set, the TAP system should require zero operation effort. This adheres to ATC recommendations to utilize familiar technology (e.g., LoPresti et al., 2004) and the "simple and intuitive use" universal design principle (www.universaldesign.org).

- *The TAP system does not require Internet access.* Given previous connection difficulties during pilot evaluations, the current TAP system is self-contained. The researcher can download data from the system and upload new software to the system using a thumb drive in the USB port on the back of the TAP box. Therefore, the TAP system does not require a subscription to cable, satellite, or the Internet. This feature enables equitable use (www.universaldesign.org), and also adheres to ATC recommendations for simple technology solutions (e.g., LoPresti et al., 2004).

- *The TAP system does not disrupt current home TV configurations.* The output port is to the *Aux* port of a TV. A user does not need to disturb any cable or antenna cables that are currently connected to the TV. The box does have a pass-through port that allows the user to connect any peripheral device (e.g., VCR, DVD player) to the TV through the box. This feature helps ensure flexible and simple use (www.universaldesign.org).

- *The TAP box is able to sense whether the TV is on or off.* If it is off and the prompting system demands it, the box can turn the TV on. This control allows for active prompting in-the-moment, which is known to be effective for prompting individuals with CI (e.g., Scherer et al., 2005).

- *When a scheduled prompt is ready to be shown, the TAP box will switch the TV to the Aux port, and then deliver the content.* When the user signals that they are finished, the box will switch back to the user's preferred port/channel. This allows for a simple and intuitive interface (www.universaldesign.org; Kirsch et al., 2004).

- *The TAP box uses a simple remote-control interface.* Since patients receiving home care therapy are by definition home-bound, they may demonstrate difficulty standing up to interact with the buttons on the TAP box itself. In addition, patients will be completing swallowing exercises from their seat, so requiring them to stand up between each exercise may fatigue them. Rather, patients may prefer to interact with the TAP system from their chair using a simplified remote control. The TAP box can read the infrared signals from any remote control. The simplified remote control developed for this project contains four large buttons, without the complexities of other contemporary remote controls. This feature adheres to universal design principles of flexible use, simple and intuitive use, perceptibility of information on the remote control itself, and low physical effort (www.universaldesign.org). It also accommodates the physical needs of patients, provides low cognitive demands, and allows for information access through multiple modalities (e.g., button number or color) (Kirsch et al., 2004; Scherer et al., 2005).

- *TAP can deliver multimedia content.* The computerized TAP box can deliver any content that a computer could, directly onto the patient's home television screen. This allows users to program audio, text, pictures, images, and videos to prompt or instruct patients about their swallowing exercises. This feature enables flexibility of use (www.universaldesign.org), maximizes multi-modal instructional presentation for users with CI (Scherer et al., 2005), and allows for dynamic motivators to maximize home program adherence (Lysack et al., 2005).

Summary of Current Study

The current project will compare the efficacy of two instructional modalities on completion of home swallowing exercises among patients with CI due to ABI. The two instructional modalities will include: (1) TAP: a multi-faceted package that delivers swallowing exercise instructions and motivational content videos at specified times on the patient's home television, and (2) TYP: typical therapy practice that relies on caregivers to provide motivation and prompting to complete written exercise instructions. The TAP system will incorporate evidence-based practice principles to maximize exercise adherence and device design to promote use among users with CI. The TYP condition will utilize worksheets and prompts currently recommended by the treating

SLP. A within-subjects alternating treatment design, replicated across five participants, will be employed to examine differences in the efficacy and perceived benefits of each modality.

It is hypothesized that provision of multimedia prompts delivered via the TAP system will result in superior adherence to prescribed intensive home exercises than the typical worksheet condition, due to regularly scheduled prompts and provision of multimedia instructional exercise videos to ensure comprehension of the task and increase motivation. In addition, it is hypothesized that patients, care providers, and therapists will report higher levels of satisfaction when prompts are delivered via the TAP system due to the increased motivation provided by the system. Finally, it is hypothesized that care providers will report reduced burden of care when prompts are delivered automatically via the TAP system because of reduced pressure to provide consistent reminders as well as reduced feelings of 'nagging' the patient.

Research Questions

This investigation will evaluate the TAP system for its: feasibility to deliver multimedia exercise prompts on a patient's home television; efficacy to improve completion of intensive home swallowing exercise programs; and perceived utility for delivering effective, efficient home exercise prompts. The five research questions addressed in this study are:

Feasibility

1. What are the technical barriers to delivering therapy exercise programs via a patient's home TV?
2. What are the usability barriers to delivering therapy exercise programs via a patient's home TV?

Efficacy

3. Do patients complete a greater number of home program swallowing exercises with the TAP system over typical practice home program delivery (e.g., handouts and care provider prompts)?

Perceived Benefits

4. Do patients, care providers, and therapists report greater levels of satisfaction with therapy home exercise programs delivered via the TAP system over typical practice?
5. Do care providers report lower burden of care with the TAP system versus typical practice delivery of home exercise programs?

CHAPTER III

METHODOLOGY

This study was conducted in two phases in order to answer the five research questions. In Phase I, pilot investigations explored the content development and initial feasibility of the TAP system. In Phase II, experimental evaluations with three participants examined the feasibility, efficacy (i.e., increased home swallowing exercise program adherence), and perceived benefits of the TAP system compared to typical practice. The TAP and TYP (typical practice) conditions were compared using a within-subjects alternating treatment design to establish experimental control for home-care patients with co-occurring cognitive and swallowing impairments following ABI.

Phase I – Pilot Investigations

Content Development

In order to ensure that the swallowing exercise videos delivered via the TAP system provided clear instruction with motivating content, practicing speech-language pathologists (SLP) who specialize in treatment of acquired brain injury provided feedback on an initial prototype. An actor was hired to portray the swallowing exercise therapist on video. The actor followed a script written by the researcher, based on the evidence reviewed in Chapter II. Ten local SLPs were recruited through word-of-mouth to provide feedback on the TAP system prototype and made recommendations for content development during structured focus groups of one hour duration. Participants completed informed consent forms in accordance with approved IRB standards, and were compensated $10 each for participation. A mock-up version of the TAP system was created as a multimedia PowerPoint slide show. SLPs were asked to interact with the presentation to advance screens and follow exercise instructions. A researcher encouraged the SLPs to provide honest feedback about the system in order to make improvements or modifications before creating the final iteration of motivation and instructional swallowing exercise videos. Participants completed surveys and provided additional narrative suggestions. Results of the survey are summarized in Table 3.1. SLPs reported that the videos were clear, motivating, enjoyable, and not annoying. They also offered several narrative suggestions for system improvements:

- Keep the videos brief and concise; avoid excess verbiage.
- Avoid overly technical descriptions of swallowing exercises; the therapist has already taught the exercises, just remind participants how to complete them.
- Use higher visual contrast for exercise demonstrations so patients can clearly see. Use arrows to focus their attention on the larynx.
- Do not play the "motivational/efficacy" video every time – it could lose its effect; consider playing it only once per day.
- Do not include background music when the actor is speaking, only in between. Do not use music with lyrics (instrumental only).
- Do not have the actor speak while trying to do the exercises; instead, shoot the video then add a voiceover for coaching or instructions.
- Avoid the term "feel the burn;" instead, try muscles *working* or *aching*.
- Consider sets of five exercise repetitions instead of ten; sets of ten repetitions of exercises that require swallowing (e.g., Masako swallows) are too difficult.
- Provide the graph of completed exercises for the week to the therapist for interpretation, rather than on the TV. Let the therapist discuss it with the client.

Table 3.1
SLP Feedback on TAP Video Content from Surveys

Survey Question	Mean Response*
I would know which buttons I needed to press.	4.44
The instructions to complete exercises were clear.	4.22
I enjoyed watching the videos.	4.33
I would have continued exercising until my muscles were fatigued.	4.00
The TAP System encouraged me to keep going.	4.38
I found the TAP System annoying.	1.56
I would have completed more than one set of each exercise.	3.56
I did not want to complete the exercises because I did not like the videos.	1.43
I was able to read all the written text clearly.	4.17
I was able to hear and understand the audio contents clearly.	4.06
I thought the exercise organizer at the top of the screen was confusing.	1.67
The pace of the exercise videos was too fast.	2.33
I wanted more control over my exercise program.	2.11
This system would be too overwhelming for a person with cognitive impairments.	2.22

*Responses were scored on a 5-point Likert scale, where 1=Strongly Disagree and 5=Strongly Agree.

Based on SLP feedback, the researcher modified the actor's script to incorporate suggestions. The videos were recorded in a quiet room with a simple setting (e.g., black backdrop) to minimize distractions. The videos were recorded using a Canon HV20 high definition digital camcorder with Fujifilm MiniDV cassettes. The videos were uploaded to a MacBook computer and edited with iMovie software from Apple. Video files were then converted to MPG configuration for delivery through the TAP system. Videos were created for the Shaker, Mendelsohn, Masako, and effortful swallowing exercises, as well as for tongue strengthening exercises, oral warm-up exercises, and motivational segments.

Initial Feasibility Assessment

The initial feasibility and satisfaction with the TAP system was assessed with an 82 year-old male, status-post a mild left cerebrovascular accident (CVA) three months prior to the study. This participant presented with mild dysarthria (i.e., slurred speech) and was referred by his home-care SLP for oral exercises to improve the strength of his face and tongue muscles (although this SLP had recently discharged the client). He also presented with mild cognitive impairments, characterized primarily by occasional memory lapses for recent information. He lived in his own home with a hired care provider, who assisted him primarily with physical tasks, such as bathing, grooming, house-keeping, and meal preparation. He agreed to participate in this study in accordance with approved Institutional Review Board (IRB) procedures.

The TAP system was programmed to prompt and instruct this participant to complete facial and tongue exercises three times per day, at times chosen by him (9:30 am, 1:00 pm, and 7:00 pm). A schedule of TAP or TYP days was created using a random number table: even numbers became TAP days, and odd numbers became TYP days. The participant was provided with a schedule of days the TAP system would come on, and was instructed to follow a written worksheet of exercises provided by his SLP on TYP days. The researcher provided a data log for the participant to record the number of exercises he completed on TYP days. A computer programmer set-up and installed the TAP system in the participant's home. The participant's own home TV was not compatible with the TAP system, so his TV was replaced with a loaner TV for the duration of the pilot study, which lasted four weeks. The participant was instructed on how to use the new TV and TAP system, along with two new remote controls. He was then asked to demonstrate how to use each piece of equipment five times to help ensure understanding.

The researcher called the participant daily on TAP days to inquire about technical issues or barriers to using the system. The researcher visited the participant at least once weekly to collect TAP data from the computer or TYP data from written worksheets. At these visits, the researcher also conducted fidelity observations of the TAP system (using a fidelity checklist, see Appendix A) and asked clarification questions to the participant and his care provider to ensure reliability of recorded data. Fidelity of implementation of the TAP system was initially low (86%) due to unforeseen double-clicking of buttons on the TAP remote control. Once this problem was solved, the remainder of weekly fidelity observations all showed 100% reliability of the TAP system functionality with complete, correct execution of the prompted exercises. The participant and care provider reported no difficulties using the TAP system other than initial remote control challenges.

Weekly exercise completion data from both TAP and TYP conditions were immediately plotted onto a graph for visual analysis (see Figure 3.1). The participant completed exercises on a more consistent basis (three times per day) when prompted with the TAP system. Interestingly, after two weeks (session 11), the participant began to exercise more frequently on TYP days, but at a lower frequency (twice daily). The three lowest data points in the TAP condition represent problems with the remote control not responding (sessions 4-2 and 12-3) or one occasion when the participant was not home (session 12-2). Data were missing for the three sessions on day eight. Additionally, the

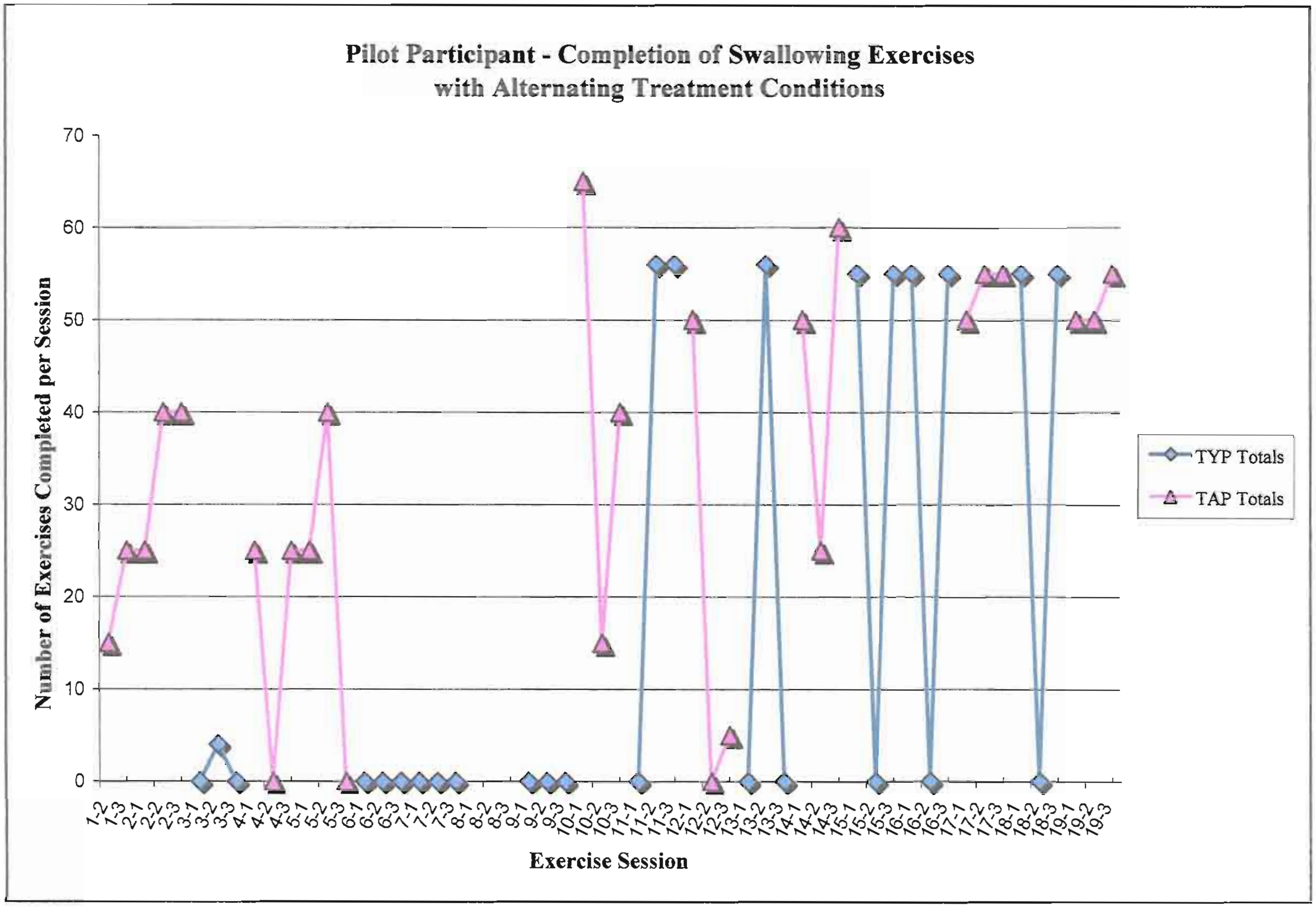

Figure 3.1. Exercise completion data for pilot participant in an alternating treatment design.

participant was ill for sessions 5-1 thru 10-3; nonetheless, he completed exercises when prompted by the TAP system.

At the end of the one-month trial, the TAP system was removed from the participant's home. His own TV was re-connected and the researcher ensured proper functioning. The researcher administered a closing satisfaction questionnaire to the participant. The participant reported high satisfaction with using the TAP system. He rated 16/16 TAP system features (e.g., use of music, motivational content, clarity of instructions) as highly effective. He stated that his favorite feature was that the TAP system "would come on by itself. I never missed a session!" He stated the system was "easy to use and understand," instructions were "clear and easy," and that the TAP system "gave me something to do." He stated preference for the TAP system over typical practice because the TAP system was more motivating; he requested to receive TAP prompts every day. He stated he would highly recommend the TAP system to others who would benefit from home prompting, "because it's easy to forget sometimes." Finally, the participant reported that several of his friends and family members stated that his speech had improved; the participant attributed this to completion of the exercises. His care provider was not available to complete final data as she had been in a car accident.

Summary of Pilot Investigation

Following the one-month pilot investigation, an initial TAP system prototype was deemed feasible and measures were finalized for experimental evaluations. Therapists and one patient and care provider provided feedback on the content and functionality of the system, all reporting high satisfaction.

Phase II – Experimental Evaluations

Participants

Participants included patients, their care providers, and their referring therapists. Patient participants were recruited through home health care agencies providing speech-language therapy services in three cities in Oregon. Therapist participants signed letters of informed consent according to approved IRB procedures. They referred patients who met the following selection criteria:

- Age 18 years or older
- Minimum one month recovery since neurological injury to minimize medical fragility
- Perceived medical stability (e.g., no seizure activity within past 3 months), reported by treatment professional
- No history of alcoholism or drug abuse, nor significant psychiatric disturbance within 1 year of the study
- No diagnosed learning disability prior to injury; no other significant neurological impairments
- No evidence of difficulty with arousal or basic vigilance
- Documented need for ongoing home health SLP services
- Documented need for ongoing therapeutic swallowing exercise program due to neurogenic dysphagia
- Absence of odynophagia (i.e., painful swallowing)
- Documented cognitive impairment due to acquired brain injury
- Confirmation by significant other or treatment professional of impaired ability to independently perform daily activities, due to impaired prospective memory
- Available care provider at home to help with home exercise program reminders
- Adequate reading comprehension to follow 1-2 step written instructions in English
- Adequate hearing to follow 1-2 step auditory instructions in English from the TV
- Ability to discriminate among and press 4 large buttons on the TAP remote control
- Has a television at home and reports regular TV viewing during daytime

Therapists referred a total of six potential participants for this study. Of these, one refused participation, one was discharged from therapy due to rapid recovery, and one was discharged from therapy due to medical complications. The remaining three patient and care provider participant pairs were contacted and signed letters of informed consent prior to beginning the study. Pseudo-names have been assigned to each participant to protect their identities. A summary of these three experimental participants is presented in Table 3.2.

Participant #1 (Jonas)

Jonas was a 77 year-old male, status-post left CVA four years prior to the study with mild right hemiparesis and chronic obstructive pulmonary disease. He was seen by a home care SLP twice weekly for dysphagia therapy due to onset of aspiration pneumonia one month prior. At the time of referral to this study, he presented with moderate dysphagia, and was consuming a mechanical soft textured diet with nectar thick liquids due to aspiration risk. He presented with moderate cognitive impairments, characterized by impaired memory for recent events, slowed information processing, and impaired reasoning. He lived with his wife in an assisted living facility; his wife was his primary care provider, though she was legally blind. The SLP recommended four exercises to be completed three times daily: effortful swallows, Mendelsohn swallows, face stretches, and tongue stretches. The SLP had instructed Jonas to complete these exercises prior to the study. The SLP's goals were to increase Jonas' ability to control secretions, recover from his pneumonia, and improve his swallowing to return to thin liquid textures. Jonas and his wife together selected three times per day for the TAP system to turn on and music preferences for TAP videos. Their TV set was not compatible with the TAP system, and they allowed researchers to replace their TV with a loaner TV for the duration of the study.

Table 3.2
Summary of Participant Characteristics

Participant	Age	Care Provider	Living Situation	ABI Diagnosis	Time Since Onset	Severity of Dysphagia*	Severity of Cognitive Impairment*	Recommended Exercises
1. Jonas	77	Spouse	Assisted Living with Spouse	L CVA	50 mos	Moderate	Moderate	Effortful Face Stretch Mendelsohn Tongue Stretch
2. Gerald	62	Spouse	Home with Spouse	L CVA	2 mos	Severe	Mild	Effortful Face Stretch Masako Tongue Strength Tongue Stretch
3. Timothy	86	Staff	Adult Foster Care	R CVA	1 mo	Moderate	Moderate	Effortful Mendelsohn

*As reported by referring therapist.

Participant #2 (Gerald)

Gerald was a 62 year-old male, status-post left CVA two months prior to the study resulting in severe dysphagia and dysarthria. He was seen by a home care SLP twice weekly for dysphagia and speech therapy. At the time of referral to this study, he maintained his nutrition from tube feedings due to severe risk for aspiration with any food or liquid intake. He presented with mild cognitive impairments, characterized primarily by impaired memory for recent events. He lived at home with his wife; his wife was his primary care provider. The SLP recommended five exercises to be completed three times daily: tongue strengthening exercises, effortful swallows, Masako swallows, face stretches, and tongue stretches. The SLP had instructed Gerald to complete these exercises prior to the study. The SLP's goals were to increase Gerald's speech intelligibility, ability to control his secretions, and improve his swallowing to return to some form of oral intake. Gerald and his wife together selected three times per day for the TAP system to turn on, and music preferences for TAP videos. Their TV set was compatible with the TAP system.

Participant #3 (Timothy)

Timothy was an 86 year-old male, status-post right CVA one month prior to the study with mild left hemiparesis due to diabetic neuropathy and small vessel disease. He was seen by a home care SLP twice weekly for dysphagia therapy due to onset of aspiration pneumonia one month prior. At the time of referral to this study, he presented with moderate dysphagia, and was consuming a mechanical soft textured diet with thin liquids due to aspiration risk. He presented with moderate cognitive impairments, characterized by impaired memory for recent events, slowed information processing, and impaired reasoning. He lived in an adult foster home with twenty-four hour staff. His primary care provider worked with him during the day shift seven days per week; she was bilingual, and her native language was Spanish. The SLP recommended two exercises to be completed three times daily: effortful swallows and Mendelsohn swallows. The SLP had instructed Timothy to complete these exercises prior to the study. The SLP's goals were to increase Timothy's ability to recover from his pneumonia, and tolerate his current diet without recurrence of pneumonia. Timothy specified three times per day for the TAP system to turn on and music preferences for TAP videos. The TV set in his room was not compatible with the TAP system, and they allowed researchers to replace their TV with a loaner TV for the duration of the study.

Research Design

Given the heterogeneity of the ABI population, the complexity of studying technology use in real-world environments, and the nascent stage of this TAP application, traditional between-subject group designs involving random selection were not appropriate for this project (Ylvisaker et al., 2002). This project therefore used a within-subject, alternating treatment experimental design. Advantages of within-subject evaluations include: allowing researchers to evaluate functional changes over time; helping reveal individual differences; emphasizing practical, clinical significance of effects; and allowing for increased understanding of the process of change by using repeated measures, rather than the standard pre/post-test measurements of group designs (Sohlberg & Mateer, 1989; Wilson, 1987). When single-subject experiments are well designed and executed, they provide strong evidence of treatment efficacy to support evidence-based practices for specific client profiles (Horner et al., 2005; Ylvisaker et al., 2002). Since assistive technologies often require customized matching to individual client profiles, single-subject designs are ideal for evaluating novel assistive technologies.

In particular, the alternating treatment design allows researchers to compare the effects of two different treatments on the same outcome measure, and can be highly effective when seeking to determine differential effects of two treatments (Richards, Taylor, Ramasamy, & Richards, 1999). There are two basic requirements of alternating treatment designs. First, the two treatment conditions must be rapidly alternated in a counterbalanced sequence. Second, participants must be able to clearly distinguish between the two treatment conditions. In this experiment, the efficacy research question compared the differential effects of two methods of home program delivery (TAP system versus typical practice) on completion of intensive swallowing home exercise programs. This design meets the two basic requirements for alternating treatment studies. The order of the two prompting conditions was randomly assigned and alternated by day of the week.

Power

Power refers to the statistical probability of demonstrating a treatment effect when there is a true experimental effect (Franklin, Allison, & Gorman, 1996). Experimental power in single-subject experiments is influenced by the α level of statistical significance, effect size, and number of observations per phase (Franklin et al., 1996). An *a-priori* power analysis for high power (0.80) assumed a medium effect size with Type-I error risk set to $\alpha = 0.05$. Consultation of a power table recommended 85 observations to detect the treatment effect (Franklin et al., 1996, p. 350). This required at least 42 observations per condition.

Independent Variable

Mode of home exercise program delivery was the independent variable (IV) manipulated in this experiment. Two modes of exercise delivery were alternated and compared: TAP (TAP system) and TYP (typical practice). The choice to prompt in one modality versus the other was pre-determined and conditions were randomly assigned to treatment day by consulting a table of random numbers (e.g., Gall, Gall, & Borg, 2003, p. 172). Even random numbers were assigned to the TAP condition; odd random numbers were assigned to the TYP condition, with the added constraint that one condition does not occur for more than three consecutive days.

TAP Delivery Condition

In this condition, prompts to complete swallowing exercises were delivered via the patient's TV using the TAP system at pre-selected times. Based on the literature reviewed, the TAP system prompted the patient to begin the exercise program (Sohlberg et al., 2007), provided motivation and feedback to maximize potential for exercise adherence (e.g., Olney et al., 2006), and provided dynamic video instructions for each exercise (Lysack et al., 2005). Patients pressed buttons on the TAP system remote control to advance through the exercise program and answer simple questions. Care providers were instructed to *not* provide any prompting or encouragement during TAP sessions. Occasionally, the TAP system did not turn on to provide prompts. When this occurred, participants were asked to complete their exercises according to the typical practice condition. However, this did not represent *pure* typical practice since participants may have been primed to complete exercises. Therefore, data were coded into a separate "TAP Malfunction" category for these sessions.

The initial TAP prototype required customization and modifications during the first one to two weeks of the experimental trial in order to meet the needs of individual patient participants. These modifications are presented with the results to the feasibility research questions in Chapter IV.

TYP Delivery Condition

In this condition, prompts (i.e., reminders or motivation) to complete swallowing exercises could be delivered by the patient's care provider. For Jonas and Timothy, the TYP condition relied on patient and care provider memory for completing exercises. The SLP typically did not provide any written supplemental materials; instead, the SLP demonstrated how to complete the exercises and instructed patients to complete them several times daily. For Gerald, the SLP provided written instructions to complete the exercises, and instructed the patient to complete exercises several times daily. The treating therapist was allowed to instruct care providers to remind and motivate patients on TYP days as part of typical practice.

Both Conditions

The patient's SLP determined the content (i.e., which exercises) and frequency (i.e., repetitions per set) of the swallowing exercise home program for each patient participant. Exercise programs were consistent across TAP and TYP conditions.

Fidelity of Implementation

Establishing fidelity of implementation of the IV is important to establishing experimental control, and strengthens internal validity of the experiment (Gall et al., 2003; Wolery, 1994). Fidelity of the TAP condition to ensure proper system functioning was measured by weekly observations of participants interacting with the TAP system. The fidelity checklist for the TAP condition, with up to 11 binary points of observation, is included in Appendix A. The TAP system malfunctioned, preventing delivery of the TAP exercise program, during 23/106 (21.70%) scheduled TAP sessions. The TYP condition was carried out as prescribed by the treating SLP; hence, there was no need for fidelity observations of typical practice.

Equipment

Experimental evaluation of the TAP system required at least three pieces of equipment for each patient participant. All patients received a TAP system, including: a Dell Vostro 200 computer (2GHz Intel Core processors and 1GB of RAM) running Windows XP and configured only to run the TAP software; a custom-built TAP set-top box to allow the Dell computer to control and display content on the TV (includes an external power supply; connects to a computer via serial port; has a power sensor for detecting if a TV is turned on or off; has infrared remote control and sound sensors; converts video output from a computer to composite video format so that it can be displayed on a TV; has a built-in speaker and two buttons on the front; all input data sent to the computer via the serial port; accepts commands and data via the serial port to play video on the TV, sound on the box, or send IR signals to the TV); and a custom-built

TAP remote control used to send commands to the TAP box (includes four buttons and will give light and sound feedback when a button is pressed). In addition, Jonas and Timothy were provided with a loaner TV set (Panasonic 26" wide screen LCD TV with six video inputs and built-in digital and analog tuners) for the duration of this study. (The development and description of the TAP system was detailed in Chapter II; the device is pictured in Figure 2.1.)

Dependent Variables

To answer the five research questions in this study, dependent variables (DV) measured four areas: feasibility, adherence, satisfaction, and burden of care. Table 3.3 lists the measures that were used for each DV.

Feasibility Measures

TAP performance log. The TAP system recorded and stored the following quantitative data: (1) number and time of program "start" activations; (2) number and time of program advancements (i.e., patient presses "next" button); (3) number and time of program cessations; and (4) time and type of system malfunctions (e.g., power failure). These data were summarized and analyzed by the computer software programmer only when participants reported system errors or TAP log data indicated no exercises were completed. The researcher verified reliability of interpretation of these data with 100% agreement for these 34 sessions.

Weekly check-in. The researcher visited each participant's home once or twice weekly to observe TAP system performance and interview patient and care provider participants about system performance. In addition, the researcher telephoned participants

Table 3.3
Tools Used to Measure Dependent Variables across Data Sources

Dependent Variable	Measurement Tools by Data Source			
	TAP Box	Patients	Care Providers	Therapists
Feasibility	TAP Performance Log*	Weekly Check-In†	Weekly Check-In†	Bi-Weekly Check-In†
Adherence	TAP Log *	TYP Log* TAP Features Survey*	TYP Log* TAP Features Survey*	
Satisfaction		Survey* & Interview†	Survey* & Interview†	Interview†
Burden of Care			Pre/Post *CBI* Survey*	

* Quantitative data
† Qualitative data

one additional time weekly on a TAP day to inquire about TAP system functioning. The researcher telephoned the patient's therapist bi-weekly to ask about any known issues with the TAP system that may have surfaced during therapy appointments. These qualitative data were recorded as field notes, summarized, and used to make iterative changes to improve the reliability of the TAP system during the first one to two weeks of implementation. Together, corroboration of the weekly check-in performance data with TAP performance log data led to data trustworthiness.

Adherence Measures

TAP log. Completion of swallowing exercises in the TAP condition was determined by evaluating the TAP logs. The TAP system collected information each time it prompted the patient to complete exercises. Patients had the option to snooze their exercises for 15 minutes if the time was not convenient by pressing the button #2 on the

TAP remote. They also had the option to cancel out of the exercise program if they chose to not exercise by pressing button #3 on the TAP remote. The researcher collected quantitative log data from the TAP system on a USB portable disk during weekly visits. These log data included: date and time of reminder; number of snoozes; number of cancellations; the duration spent on each exercise screen; and patient responses to questions (see Appendix B for an example).

The researcher summarized these log files to determine number of exercises completed at each session. It was inferred that patients completed a set of exercises when they spent an amount of time equal to or greater than the duration of the exercise instructional video on each screen. The number of each exercise completed was summed for each session for simplicity of data display. Raw data showing completion of each set of exercises for each participant are presented in Appendices C-E. To ensure reliability of measurement, a second researcher also summarized TAP logs for more than one-third of sessions for each participant across the duration of the study. As indicated in Table 3.4, inter-rater agreement was high (79%, 92%, and 100%). All disagreements were easily resolved and were most frequently due to mis-reading the log data. The trustworthiness of these log data was corroborated through both weekly fidelity observations by the researcher and self-report by patients and care providers during weekly check-ins. Observations and self-reports revealed that participants always completed exercises with the TAP videos.

Table 3.4
Reliability of Interpretation for TAP Performance Log Data

Participant	No of TAP Sessions Checked	Percentage of TAP Sessions Checked	Percent Agreement
Jonas	14	47%	79%
Gerald	12	43%	92%
Timothy	18	72%	100%

TYP log. Completion of swallowing exercises in the TYP condition was determined by examining the TYP logs (see Appendix F for an example). The researcher provided patients and care providers with a written log to record the date, time, and number of repetitions of each exercise on TYP days. Care providers completed the written TYP logs for Gerald and Timothy; written logs were collected during weekly visits. For Jonas, TYP information was reported by interview during weekly visits since his wife was legally blind and unable to record this written information. That interview information was immediately transferred to a written TYP log. Care providers corroborated that reported data were accurate.

TAP features survey. At the conclusion of the study, patients and care providers completed a TAP features survey to analyze which TAP features were felt to be most effective to motivate and maintain patients' interest (see Appendix G). On this survey, participants indicated the effectiveness of each of 14 features on a five-point rating scale, with a rating of 1 equal to "Highly Ineffective," through a rating of 5 equal to "Highly Effective."

Satisfaction Measures

At the completion of the one-month trial, the researcher administered both a quantitative survey and qualitative semi-structured interview to patient and care provider participants (see Appendices H-J). Interviews inquired about reasons for satisfaction or dissatisfaction with each condition (TAP, TYP), perceptions of therapeutic benefits of each prompting condition, preferences for continued use, recommendations for TAP system improvements, care providers' perceptions of role differences on TAP versus TYP days, comparison of the TAP system to other evidence-based assistive technologies for prompting (e.g., pager, telephone reminders), and comparison of swallowing exercise program completion to other prescribed exercise home programs (e.g., physical therapy exercises). The researcher took written notes during the interviews and recorded both summary statements and direct quotations.

A survey was imbedded into the interview to quantitatively evaluate participants' satisfaction with the TAP system and the TYP condition. The survey allowed for additional, concise gathering of impressions about the TAP system, comparison to typical practice, generalization to changes in swallowing function, ease of using the TAP system independently, preference for use of the TAP system over typical practice, potential changes in care provider roles, and additional information about the effectiveness of the TAP exercise videos. Participants rated each statement on a five-point rating scale, with a rating of 1 equal to "Did not enjoy at all" or "Strongly disagree," through a rating of 5 being "Completed enjoyed" or "Strongly agree."

Since therapists had not directly interfaced with the TAP system, they were unable to respond to the quantitative surveys. Therapists were interviewed to gain their perspectives on: the utility of the TAP system to deliver home swallowing exercise programs, comparisons to typical practice, recommendations for system improvements, preferences for continued use, and potential expanded applications of the TAP system.

Burden of Care

The *Caregiver Burden Inventory* (*CBI*; Novak & Guest, 1989) is a multi-dimensional 24-item survey that care providers completed. The *CBI* has been shown to have high content validity (Novak & Guest, 1989) and internal consistency (Caserta, Lund, &Wright, 1996) among care givers of adults with CI. It presented a sensitive measure to detect changes in burden of care among care providers of adults in the first year post-stroke (Tooth, McKenna, Barnett, Prescott, & Murphy, 2005). It measured burden of care across five factors: time, social, emotional, physical, and developmental domains. Each item was scored on a five-point scale, where a rating of 0 equaled "Does not describe me at all," through a rating of 4 being "Describes me very accurately." Items were summed to give a total for each domain, with higher scores indicating greater burden of care. Bugge, Alexander, and Hagen (1999) suggested that a score of 6/20 or greater on any single domain indicated 'considerable' burden of care. Results were not shared with patient participants.

Procedures

The Phase II experimental evaluations were conducted over a four week period.

The following procedures were followed for each participant.

Before beginning the evaluation, the researcher:

- interviewed potential participants and completed informed consent forms,
- administered the baseline *CBI* survey to care providers, and
- customized the TAP system content to contain recommended exercises and frequency for each participant.

At the initial set-up session, the researcher:

- installed the TAP system in the patient's home and instructed the patient and care provider on its use,
- provided a schedule of prompting conditions by day, and
- instructed care providers to not provide prompts during TAP sessions.

During the subsequent four weeks of the evaluation, the researcher:

- called patients or care providers to ensure proper functioning of TAP system,
- visited the patients' homes on a TAP day to ensure fidelity of implementation and conduct weekly check-ins,
- collected completed TAP and TYP logs,
- provided new copies of TYP logs and updated TAP system software as needed,
- changed remote control batteries after two weeks to ensure continued proper functioning,
- compensated patient participants at the completion of week two, and
- phoned the therapist for bi-weekly check-ins.

Upon completion of the study, the researcher:

- collected final TYP and TAP logs,
- removed the TAP hardware from participants' homes,
- compensated patient, care provider, and therapist participants,
- administered end-of-study measures (interview, surveys, and *CBI*) to patients and care providers in their homes
- administered end-of-study interview to therapists at a time and location convenient to them.

Data Analysis

Quantitative data were entered in a Microsoft Excel spreadsheet. Qualitative data from weekly check-ins and interviews were transcribed into Microsoft Word documents for qualitative analysis. Feasibility data were analyzed and summarized by theme. Adherence data from logs were immediately graphed for visual analysis using the graph application in Microsoft Excel following weekly data collection.

Fine-grained visual analysis allowed for investigation of functional significance and exploration of subtle differences across time in level, trend, variability, and overlap of the data across the TAP and TYP conditions (Parsonson & Baer, 1986). In addition, the magnitude of the effect size of the TAP system over typical practice was estimated with two measures: percentage of non-zero data points and Cohen's *d* (Cohen, 1988). Percentage of non-zero data was calculated by tallying the number of sessions with greater than zero exercises completed divided by the total number of sessions, for each condition. The *d* statistic was calculated by comparing the mean scores from TAP versus TYP conditions divided by the pooled standard deviation across all three conditions (i.e., TAP, TYP, and TAP malfunction sessions). While many researchers disavow the *d* statistic in single-subject research because it overestimates effect sizes (due to auto-correlation of within-subject data), there is yet no agreed-upon method to accurately analyze effect sizes for single-subject research (e.g., Jenson, Clark, Kircher, & Kristjansson, 2007; Schlosser, 2005). Therefore, Cohen's *d* served as an *estimate* of effect size, despite its limitations in single-subject evaluations. Adding to adherence data interpretation, the TAP features survey was summarized with descriptive statistics.

Satisfaction data from surveys were summarized and reported descriptively; qualitative data from interviews were summarized and reported by theme. Care provider burden data from the *CBI* were summarized and reported descriptively. Additionally, dependent *t*-tests allowed for analysis of changes in care provider reported burden over time (Gall et al., 2003).

CHAPTER IV

RESULTS

Both quantitative and qualitative data were gathered throughout the duration of the experimental evaluation to answer questions about the feasibility, effectiveness, and satisfaction with the TAP system. Results of graphic visual analysis, descriptive analysis, statistical analysis, and qualitative analysis are presented below in response to the five research questions.

Research Question #1: What are the technical barriers to delivering therapy exercise programs via a patient's home TV?

There were two technical barriers that surfaced during this study: system malfunctions and TV compatibility. The TAP system presented a generally reliable (78.30%) means to deliver home exercise reminders and instructions during scheduled sessions. The system malfunctioned during 14/44 (31.82%) of scheduled TAP sessions for Jonas, during 1/29 (3.45%) of scheduled TAP sessions for Gerald, and during 8/33 (24.24%) of scheduled TAP sessions for Timothy. Reasons for TAP system malfunctions included:

- TAP system failure, requiring system replacement for Jonas at session 11-3
- TAP remote control failure, requiring replacement for Timothy at session 9-1

- TAP system failure, requiring system reset
- TAP system turned TV off instead of on, leading to challenges with accessing the correct *Aux* input to show the TAP videos
- TAP system failed to turn on TV for unknown reasons
- TAP computer shut down on its own for unknown reasons
- TAP system failed to send commands to TV for unknown reasons

Second, three of the four home television sets from pilot and experimental trials were not compatible with the prototype TAP system due to connectivity challenges. Jonas' television did not have RCA input jacks. Timothy and the pilot participant's televisions did not offer a consistent method to change the TV input to the *Aux* input. These three participants utilized a loaner TV for the duration of this study. The TAP system was compatible with Gerald's home TV set, but an additional challenge arose that required a computer programmer to reset the remote control codes mid-way through the study. Gerald also reported that the TAP videos were occasionally off-centered.

Research Question #2: What are the usability barriers to delivering therapy exercise programs via a patient's home TV?

Usability barriers posed challenges to independent use of the TAP system, especially for Jonas and Timothy. These barriers included difficulties interfacing with the TAP system or following exercise video instructions. Results of the TAP fidelity observations are presented in Table 4.1.

TAP Interface Barriers

Jonas and Timothy both encountered three interface barriers. First, these two participants demonstrated difficulty pressing buttons on the TAP remote control. Clarifications and instructions were required to teach the participants how to use the TAP

Table 4.1
Fidelity of Implementation of TAP System during Structured Observations

	Jonas				Gerald				Timothy			
Week	1	2	3	4	1	2	3	4	1	2	3	4
Number of observations	2	2	2	1	1	1	1	1	2	2	0	1
Correct use of TAP remote	0%	0%	0%	0%	100%	100%	100%	100%	50%	50%	.	0%
Able to follow program independently	0%	0%	0%	0%	100%	100%	100%	100%	50%	50%	.	0%
No care provider motivation	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	.	100%
Correct exercise techniques	33%	83%	100%	100%	50%	100%	100%	100%	0%	100%	.	100%

remote control correctly (e.g., press a button when instructed; point remote control at TAP box; be sure to press hard on the button). The addition of Velcro for tactile feedback on the TAP remote control buttons helped participants place their fingers in the correct location for button presses.

Second, these participants demonstrated difficulty consistently pressing the button they intended to press. For example, Timothy and his care provider both explained that the only reason for not completing all of his exercises during sessions 3-2, 3-3, 5-2, and 8-3 was due to pressing the wrong remote control button. He pressed button #3 to exit the program instead of pressing button #1 to continue the program despite a stated desire to continue exercising. Elimination of the exit option during exercise videos prevented further button-press errors.

Third, both Jonas and Timothy required regular prompts from their care providers to respond to the system by pressing a button on the remote control. They would forget to press a button after an idle period of about 15 seconds. Jonas became distracted by the music during exercise videos and needed prompts to pay attention. Timothy needed prompts to stay awake if he did not press a button right away.

TAP Content Barriers

The participants in this evaluation required customized modifications during the initial two weeks in order to correctly follow TAP exercise video instructions. All three participants required a slowed pace of presentation during swallowing exercise videos by inserting longer pauses between exercise repetitions. Jonas and Timothy further required the addition of verbal cues as a voice-over at each repetition to both maintain attention and reinforce correct techniques (e.g., "Here's #3. Be sure to gather some saliva and swallow hard."). The researcher informed treating therapists when participants were unable to complete exercises with proper technique.

Research Question #3: Do patients complete a greater number of home program swallowing exercises with the TAP system over typical practice home program delivery?

Performance data are presented in graphed form for each participant. Visual analysis of changes in level and overlap of data is presented for each participant. In addition, Table 4.2 provides descriptive statistics summarizing changes in level across treatment conditions for each participant. Finally, survey data demonstrating the most influential TAP features are presented.

Jonas

Visual analysis of TAP and TYP log data (see Figure 4.1) revealed a functional relation between TAP system delivery of swallowing exercise prompts and instructions and greater completion of swallowing exercises. Jonas completed swallowing exercises more frequently and with more repetitions on TAP days than TYP days. He completed four different exercises, each in sets of five repetitions. He generally completed one set of each exercise when prompted by the TAP system. The reason that he completed fewer repetitions during the first two sessions was due to the rapid pace of the initial videos. The only overlap of data between TAP and TYP conditions occurred during the seven TAP sessions that he did not complete any exercises. He opted to not complete exercises

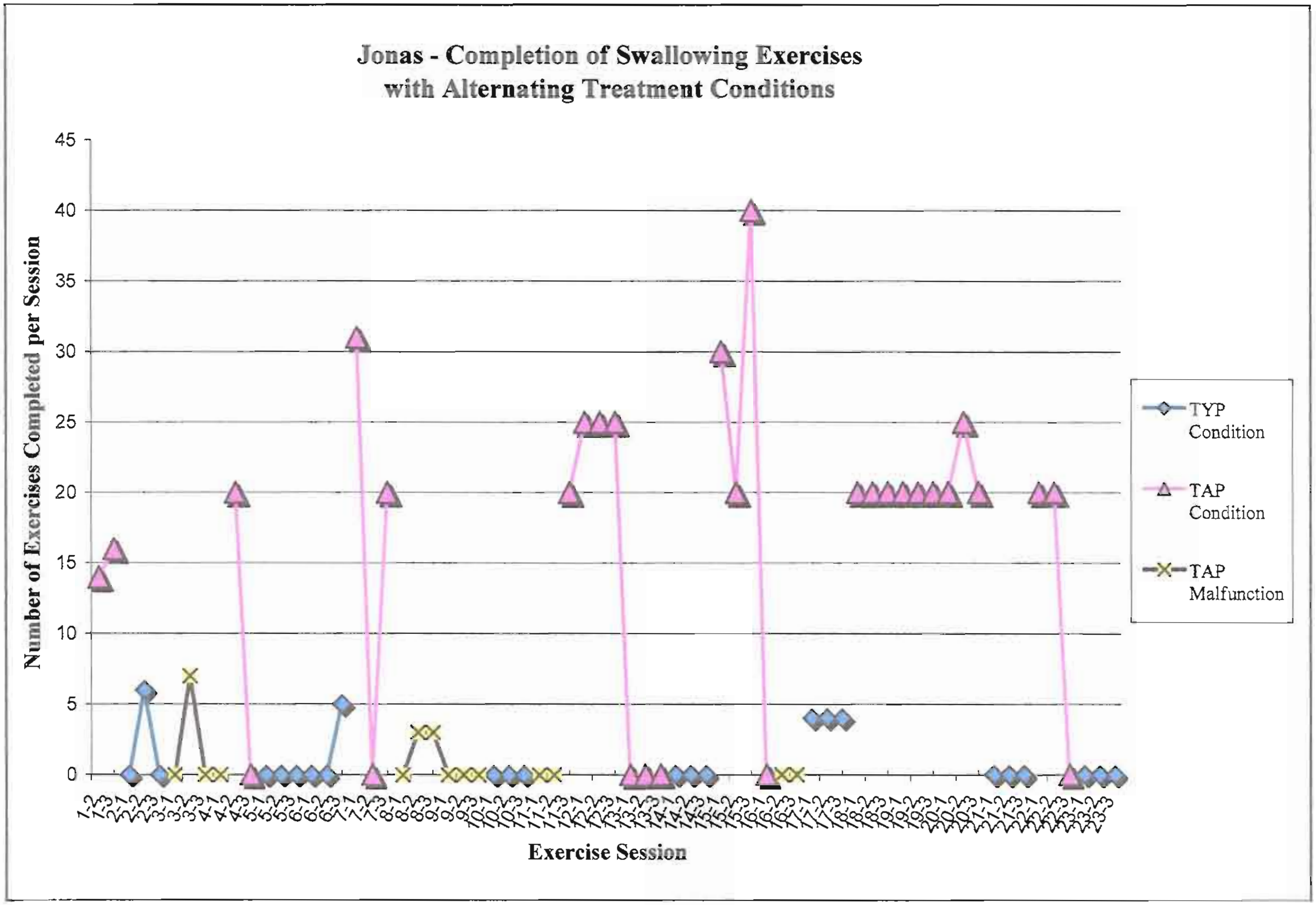

Figure 4.1. Swallowing exercise completion data for Jonas during TAP or TYP sessions.

during two sessions (4-3 and 22-3). He was at a medical appointment and not home for session 7-2. He was ill and unable to participate in any exercises between sessions 13-1 and 14-3. His care provider used the wrong remote control during session 16-1, which escaped out of the TAP program.

On TYP days, he rarely completed any exercises independently. His care provider preferred not to prompt him, and allowed him to remain independent. There were five occasions when he initiated practicing the effortful swallow exercise. In addition, he did complete effortful swallow exercises on his own during three TAP malfunction sessions.

Mean level of exercise completion per session was greater during TAP (*M* = 17.03 repetitions) than for TYP (*M* = 0.96 repetitions) (see Table 4.2). This effect was further corroborated by effect size estimates. A greater percentage of sessions was completed in the TAP condition (76.67%) than the TYP condition (20.83%). Cohen's *d* estimated a large treatment effect of the TAP system over typical practice (*d* = 1.49).

Table 4.2
Summary of Swallowing Exercise Completion Data across TYP and TAP Conditions

	Jonas		Gerald		Timothy	
	TYP	TAP	TYP	TAP	TYP	TAP
Number of sessions per condition	24	30	27	28	30	25
Mean number of exercises completed per session	0.96	17.03	3.56	24.25	8.80	9.60
Standard deviation	1.94	10.68	8.73	6.87	6.18	5.19
Percent non-zero sessions	20.83%	76.67%	14.81%	96.43%	70.00%	88.00%
Effect Size (*d*)	1.49 (Large)		1.59 (Large)		0.13 (Small)	

Gerald

Visual analysis of Figure 4.2 revealed a functional relation between TAP system delivery of swallowing exercise prompts and instructions and greater completion of swallowing exercises. Gerald also completed swallowing exercises more frequently and with more repetitions on TAP days than TYP days. He completed five different exercises, each in sets of five repetitions. However, even with the longer pauses inserted into his exercise videos, he demonstrated difficulty initiating swallows during the effortful and Masako swallow exercises. He completed two to three of the five repetitions during these exercise videos. He generally completed one to two sets of each exercise when prompted by the TAP system. He was not home due to a medical appointment at session 14-3, which was the only time he did not complete exercises during a TAP session.

On TYP days, he rarely completed any exercises independently. His care provider occasionally reminded him, but the patient reported feeling fatigued and chose not to exercise. The main overlap of data between TAP and TYP conditions occurred during the four TYP sessions that he did complete independent exercises. On those occasions, he completed an equal number of exercises. However, the data clearly show that Gerald exercised with greater consistency on days when prompted by the TAP system.

Mean level of exercise completion per session was greater during TAP (M = 24.25 repetitions) than for TYP (M = 3.56 repetitions) (see Table 4.2). This effect was further corroborated by effect size estimates. A greater percentage of sessions was completed in the TAP condition (96.43%) than the TYP condition (14.81%). Cohen's d estimated a large treatment effect of the TAP system over typical practice (d = 1.59).

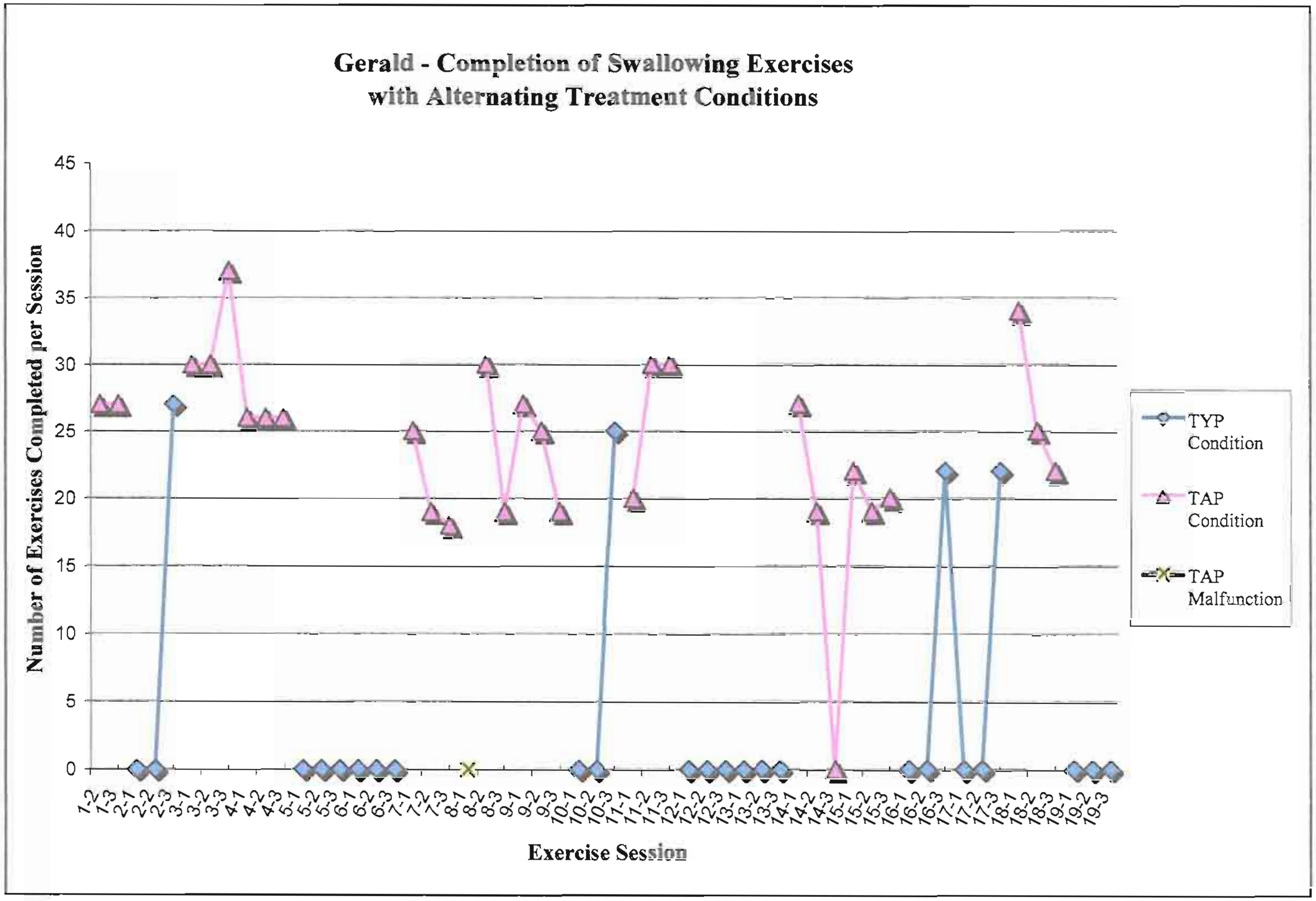

Figure 4.2. Swallowing exercise completion data for Gerald during TAP or TYP sessions.

Timothy

Visual analysis of Figure 4.3 revealed no clear differentiation between TAP and TYP conditions for Timothy. He lived in an adult foster care home with a staff care provider. This care provider was diligent about following all medical and rehabilitation recommendations for her residents. Timothy generally completed exercises regardless of whether he was prompted by the TAP system or by his care provider.

He completed two different exercises, in sets of five repetitions each. He generally completed one to two sets of each exercise when prompted by the TAP system. The reason TAP performance was lower than TYP performance during the first two weeks (through session 9-3) was due to user challenges with the TAP system (see above). During sessions 3-2, 3-3, 5-2, 7-3, and 8-3, TAP log data revealed that Timothy pressed the wrong button (e.g., pressed #3 to exit instead of #1 to continue). This was verified by both Timothy and his care provider. He benefited from the longer and cued video modifications, as well as elimination of the exit option during the exercise videos described above.

There were three TAP sessions during which he did not complete any exercises. In session 7-3, he pressed the wrong button on his remote control. His care provider reported during a weekly check-in that Timothy was ready to exercise, but the system "did not work." The TAP logs showed that he had mistakenly pressed button #3 to exit. At session 21-2, he reported not being available due to late dinner. For the final session, his care provider reported using the wrong remote control, which changed the *Aux* input back to the TV; the TAP program was therefore unable to run.

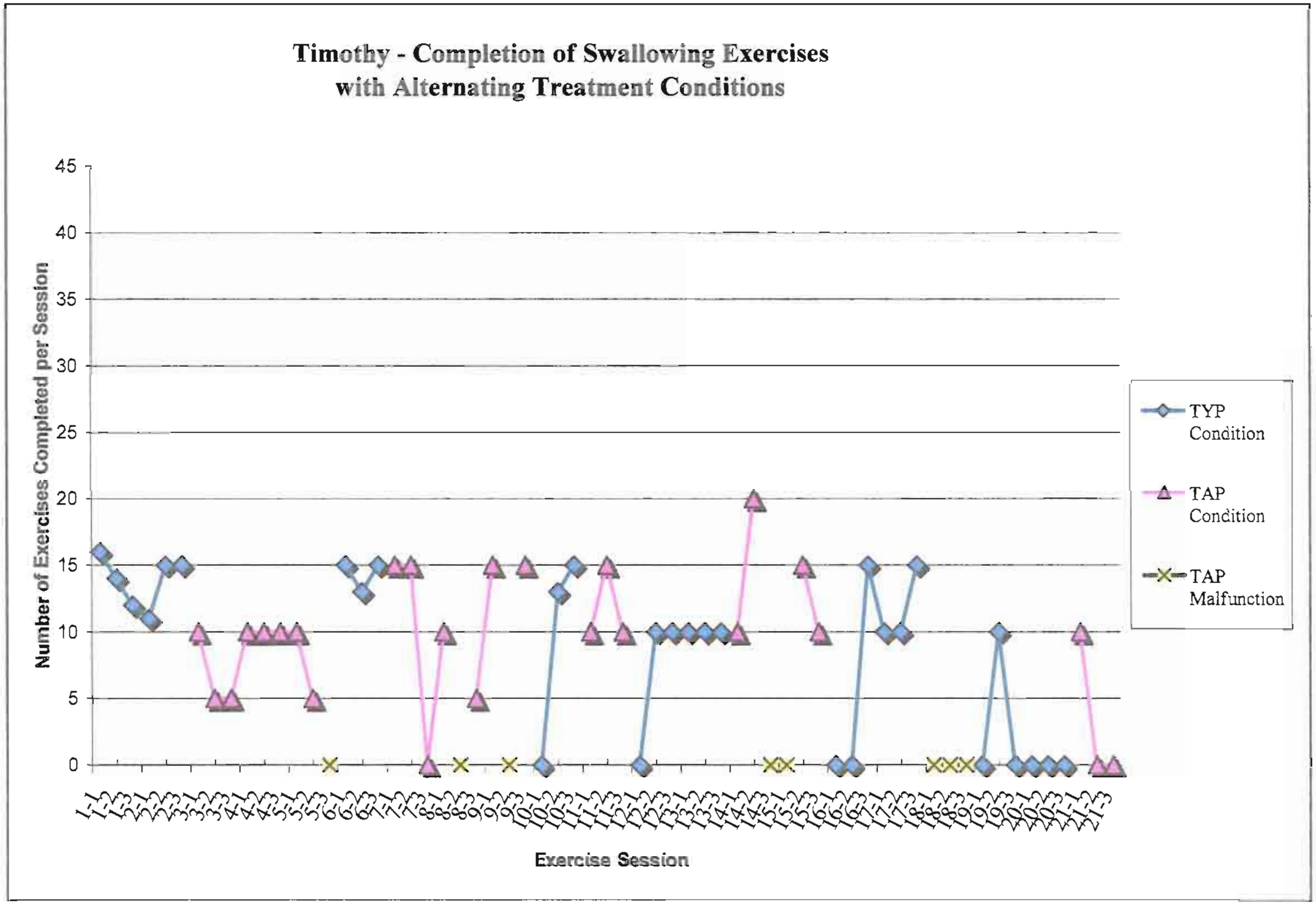

Figure 4.3. Swallowing exercise completion data for Timothy during TAP or TYP sessions.

Timothy completed exercises when prompted by his care provider on TYP days. When he completed exercises, he generally completed an equal number of repetitions. However, the data also indicate a trend toward greater inconsistency following session 10-1 (i.e., after two weeks). While he completed exercises during 91.67% (11/12) TYP sessions during the first two weeks of the experiment, this decreased to 55.56% (10/18) of TYP sessions completed for the final two weeks.

Mean level of exercise completion per session was approximately equal during TAP ($M = 9.60$ repetitions) and TYP ($M = 8.80$ repetitions) sessions (see Table 4.2). The lack of differentiation across conditions was further corroborated by overall effect size estimates. Cohen's *d* estimated a small treatment effect of the TAP system over typical practice ($d = 0.13$), further supported by the small increase in percentage of sessions completed with the TAP system (88.00%) over typical practice (70.00%).

TAP Features Survey

Patients and care providers completed a TAP features survey designed to identify any TAP features that significantly increased or decreased motivation to complete exercises. Results are presented in Table 4.3. Participants reported that the most effective TAP features included: customized selection of times of day, exercise instructions, preparation warnings (e.g., "Your exercise program will start in fifteen seconds") or instructions (e.g., "Be sure that you have something to drink and are sitting up in a comfortable chair"), and use of music. Relatively ineffective features included: lack of variety of content (reported by two participants), use of self-rating questions (e.g., "Are you feeling your muscles working hard?"), and use of the on-screen counter.

Table 4.3
Results of TAP Features Survey from Patient and Care Provider Perspectives

Question	Jonas		Gerald		Timothy		Mean
	Pt	CP	Pt	CP	Pt	CP	
1=Highly Ineffective ← → 5=Highly Effective							
Choice of times of day	5	4	5	5	5	5	4.83
Exercise demonstrations & instructions	5	4	5	5	5	5	4.83
On-screen cues for instructions	5	3.5	5	5	5	5	4.75
15-second warning to prepare	4	4	5	5	5	5	4.67
Get ready instruction video	4	4	5	4	5	5	4.50
Use of music to motivate	5	2	5	5	5	5	4.50
Cues for breaks or drink	5	3	5	4	4	5	4.33
Pace of overall program	4	2	5	5	5	5	4.33
Choice of music	4	3.5	5	5	5	3	4.25
Verbal encouragement to motivate	4	3	4	4	4	5	4.00
Pace of exercise videos	2	2	5	5	5	5	4.00
Exercise counter to motivate	3	2	4	3	5	5	3.67
Questions for self-rating to maintain interest	4	2	4	3	4	5	3.67
Variety of content to maintain interest	1	2	5	5	1	5	3.17

Note. Pt = Patient Participant, CP = Care Provider Participant

Research Question #4: Do patients, care providers, and therapists report greater levels of satisfaction with therapy home exercise programs delivered via the TAP system over typical practice?

Patients and their care providers were asked to complete a satisfaction survey and participate in an interview at the completion of the experimental evaluation. Results of the survey are presented in Table 4.4. Overall, participants reported high levels of satisfaction with using the TAP system to complete swallowing exercises (M = 4.83), greatly exceeding reported levels of satisfaction on TYP days (M = 2.17). Participants

Table 4.4
Results of Satisfaction Surveys from Patient and Care Provider Participants

Question	Jonas		Gerald		Timothy		Mean
	Pt	CP	Pt	CP	Pt	CP	
1=Did not enjoy at all ← → 5=Completely Enjoyed							
How much did you enjoy, or not enjoy, completing your swallowing exercises on days that the TAP system came on?	4	5	5	5	5	5	4.83
How much did you enjoy, or not enjoy, completing your swallowing exercises on days that the TAP system did *not* come on?	4	2	1	2	3	1	2.17
1=Strongly Disagree ← → 5=Strongly Agree							
I believe my swallowing improved because I completed these swallowing exercises.	5	5	3	4	5	5	4.50
I believe I completed more exercises when the TAP system came on.	5	5	5	5	5	5	5.00
I believe I completed more exercises on days that the TAP system did *not* come on.	1	1	1	2	3	5	2.17
I believe I practiced the exercises more correctly when the TAP system came on.	5	5	5	5	5	5	5.00
I believe I practiced exercises more correctly when the TAP system did *not* come on.	1	1	1	3	3	3	2.00
I think the TAP system was easy to use.	2	3	5	5	5	5	4.17
After I learned to use the TAP system, I needed help to use it.	1	5	3	4	1	1	2.50
I would rather complete exercises with the TAP system.	5	5	5	5	5	5	5.00
I was more motivated to complete my exercises when the TAP system came on.	5	5	5	5	5	5	5.00
I feel better about my relationship with my care provider because the TAP system was the one to provide reminders.	5	3	5	5	3	5	4.33
I would recommend TAP to another person who needed to complete a home exercise program.	5	5	5	5	5	5	5.00
The actor was motivating.	5	4	5	3	5	5	4.50
The actor was dynamic.	5	4	4	4	3	5	4.17
The videos were interesting.	5	4	4	3	5	5	4.33
I felt accountable to complete the exercises.	5	3	4	3	3	5	3.83

Note. Pt = Patient Participant, CP = Care Provider Participant reported that the TAP system helped to improve their swallowing function ($M = 4.30$), especially for Jonas and Timothy. Participants unanimously endorsed the TAP system as a tool to increase both frequency and accuracy of swallowing exercise completion over typical practice. They also unanimously reported preference for the TAP system over typical practice, and would highly recommend the TAP system to other users. However, Jonas and his care provider both reported that the TAP system was difficult to use, and half of the participants reported they needed additional help to use the TAP system. Finally, participants reported that the TAP system could help improve relationships between patients and care providers by delivering automated reminders and instructions over the television.

Additional satisfaction data were gathered through semi-structured interviews with patients, care providers, and referring therapists. Detailed notes from interviews with all participants are included in Appendices K-M.

Summary of Patient Satisfaction Interview Results

All patients commented that the TAP system was easy to use, and that it offered advantages over other potential types of technology used for prompting (e.g., pagers, telephone) because it was easy to use and delivered through familiar, central technology. For example, Jonas said, "It's good on the TV because it reminds us of what we have to do. Without the video, it's too easy to forget. You need to keep it fresh in your mind. You know how a tired mind can get!" Gerald added, "I'm a TV guy. I like it on the TV." Timothy commented that, "…it would be good to get a review and a reminder of any exercises." Both Jonas and Gerald reported a desire to continue to use the TAP system for swallowing exercises, and would prefer to increase the frequency to every day, three times each day.

Jonas was the only patient to express dislikes for the TAP system, including limited variety of exercise videos and a desire for greater TAP session frequency: "Have it come on every day."

Summary of Care Provider Satisfaction Interview Results

Care providers emphasized the benefits of the TAP system to encourage patients to complete exercises, especially for Jonas and Gerald. For example, Jonas' care provider said, "Its presence was helpful – otherwise, he would not have done the exercises at all." Gerald's care provider emphasized that the program was quick, clear, and easy to use. She stated, "It didn't take a big effort to use… it was quick and straight-forward." All care providers endorsed the TAP system as effective, and stated preference to increase its frequency to every day.

All care providers commented that participants enjoyed the TAP system and completed exercises when it was on. Gerald's care provider emphasized that on TAP days, "It's all right there, coming on the TV. The TV does it all, right in front of you. You can't not do it." However, on TYP days she reported, "I had to prod him to do exercises. Sometimes he just didn't want to do them, or we'd both forget." All three care providers endorsed the TAP system over other assistive technologies because the TAP system was easy to use, visual, present, and because telephone call reminders would increase stress for at least two of them. In addition, all three care providers expressed interest in potentially continuing to use a reliable TAP system because they felt it benefited the patients.

In terms of dislikes, Jonas' care provider commented that the sound was distorted because it was too loud, colored text was difficult to read, and the pace was too rapid. Timothy's care provider commented that the system was not reliable, and that she was still required to prompt the patient to use the remote control during the program. Gerald's care provider stated no dislikes.

Summary of Therapist Satisfaction Interview Results

Neither therapist ever observed a patient interacting with the TAP system, but both offered general comments based on their own impressions and from what patients or care providers reported. Gerald's therapist reported that the TAP system was positive, interesting, and novel. He stated that both Gerald and his care provider reported compliance with completing exercises on TAP days. He was not surprised by the clear advantage of the TAP system over typical practice when shown the graph of Gerald's performance data. He stated that low levels of compliance with home exercise programs in typical practice are "common" and "expected." He stated that the TAP system showed strong potential for further clinical applications in a home care environment, even though he saw minimal functional change in Gerald's swallowing.

A second therapist referred both Jonas and Timothy to this study. This therapist offered several comments on the TAP system. He commented that both patients enjoyed the TAP program: "They both did the program and were interested… the fact that they independently reported problems with the system also tells me that they were interested in the program. If they just didn't want to do it or weren't interested, they just let it slide.... They got a smile on their face whenever I asked about the system. They were really excited to use it, and they really felt they were helping themselves." He reported that care providers also enjoyed the TAP system, "because it gave the patients something to do. I think they liked it more than the patients. It helped to regiment [the patients'] lives."

When asked about the potential advantages of the TAP system over typical practice, this therapist commented that the TAP system "keeps them honest [and] motivated. It reminds them to do their exercises." He commented that the videos helped because "the visual of someone doing exercises with them is helpful." He added that, "with the TV system, I see much better improvements in getting their exercises done. In my typical experience, it is rare to get even 50% success with home exercise programs." He strongly endorsed the TAP system, and made three additional referrals for home care patients on his caseload to use the TAP system "once it's up and running."

While the majority of feedback he heard was positive, "only 1% was negative feedback when the machine didn't work... but they had no ongoing frustrations, and seemed to enjoy the system."

Research Question #5: Do care providers report lower burden of care with the TAP system versus typical practice delivery of home exercise programs?

The final research question addressed whether or not the TAP system could reduce reported care provider burden. Results from the main measure of care provider burden, the *Caregiver Burden Inventory* (Novak & Guest, 1989), are presented in Table 4.5. At baseline, Gerald's care provider reported the highest level of burden (total score = 61.00), followed by Jonas' care provider (total score = 23.75) and Timothy's care provider (total score = 16.00). However, they reported minimal to no changes at the completion of the study (total scores of 61.00, 28.50, and 16.00, respectively). Dependent *t*-tests to investigate changes from baseline to post-evaluation revealed no change for all three care providers ($p > .05$). However, the researcher posed one additional question on the post-trial questionnaire. When specifically asked, two care providers reported feeling *less burden* on TAP compared to TYP days, while one care provider (for Timothy) reported no change.

Table 4.5
Pre- and Post- Ratings of Care Providers on *Caregiver Burden Inventory*

Question	Jonas' CP		Gerald's CP		Timothy's CP	
	Pre	Post	Pre	Post	Pre	Post
Time Domain						
My care receiver needs my help to perform many daily tasks.	1	3	4	4	4	4
My care receiver is dependent on me.	1	4	4	4	4	4
I have to watch my care receiver constantly.	2	2	4	3	4	4
I have to help my care receiver with many basic functions.	2	2	4	4	4	4
I don't have a minute's break from my care giving chores.	.	0	3	3	0	0
Time Domain Subtotal	6 †	11 †	19 †	18 †	16 †	16 †
Social Domain						
I don't get along with other family members as well as I used to.	0	0	0	0	N/A	N/A
My care giving efforts aren't appreciated by others in my family.	0	0	0	0	N/A	N/A
I've had problems with my marriage.	2	3	3	4	0	0
I don't do as good a job at work as before.	N/A	N/A	N/A	N/A	0	0
I feel resentful of other relatives who could but do not help.	2	2	0	2	N/A	N/A
Social Domain Subtotal	4	5	3	6 †	0	0
Developmental Domain						
I feel that I am missing out on life.	1	1	4	4	0	0
I wish I could escape from this situation.	1	2	4	4	0	0
My social life has suffered.	1	1	4	4	0	0
I feel emotionally drained due to caring for my care receiver.	2	0	3	4	0	0
I expected that things would be different at this point in my life.	0	0	4	4	0	0
Developmental Domain Subtotal	5	4	19 †	20 †	0	0

Table 4.5 (con't)
Pre- and Post- Ratings of Care Providers on *Caregiver Burden Inventory*

Question	Jonas' CP		Gerald's CP		Timothy's CP	
	Pre	Post	Pre	Post	Pre	Post
Emotional Domain						
I feel embarrassed over my care receiver's behavior.	2	2	0	0	0	0
I feel ashamed of my care receiver.	2	2	0	0	.	.
I resent my care receiver.	1	1	1	2	0	0
I feel uncomfortable when I have friends over.	.	0	0	0	0	0
I feel angry about my interactions with my care receiver.	.	1	4	0	0	0
Emotional Domain Subtotal	5	6 †	5	2	0	0
Physical Domain						
I'm not getting enough sleep.	0	0	3	4	0	0
My health has suffered.	0	0	2	2	0	0
Caregiving has made me physically sick.	0	0	3	2	0	0
I'm physically tired.	3	2	4	4	0	0
Physical Domain Subtotal*	3.75	2.50	15 †	15 †	0	0
Total Score	23.75	28.50	61.00	61.00	16.00	16.00
Dependent *t*-test for change	$p = 0.38$		$p = 1.00$		$p = 1.00$	
I felt *less burden* to remind or motive my care receiver to complete swallowing exercises on days that the TV Box came on.	4		4		0	

Note. Rating scale ranged from 0-4 with 0 = "Does not describe me at all" through 4 = "Describes me very accurately."
* Physical domain scores receive weighting (x1.25 each) since there are only four questions in this domain.
† Indicates a domain score above the cutoff (6/20) for considerable burden of care (Bugge et al., 1999).

CHAPTER V

DISCUSSION

Results of this within-subjects experimental evaluation revealed that the Television Assisted Prompting (TAP) system was more effective than typical practice for completing and sustaining home swallowing exercise programs. For both Jonas and Gerald, the TAP system led to a large treatment effect. The total number of exercises completed when delivered through the TAP system compared to typical practice was seventeen times greater for Jonas, and six times greater for Gerald. For Timothy, the TAP system allowed him to complete home swallowing exercises at an overall level equivalent to typical practice, although evidence also suggests greater sustained exercise completion throughout the duration of the study with the TAP system.

Feasibility Findings

Jonas clearly stated the main conclusion of the feasibility portion of this study: "Make sure you have a working TV." The results demonstrated high levels of program completion, but only when the TAP system functioned properly (78.30% of scheduled sessions). According to the best practice recommendations cited in Chapter II, assistive devices should: present low cognitive, physical, and sensory demands (LoPresti et al., 2004); allow for simple, intuitive interfaces that minimize choices and complexity (LoPresti et al., 2004; www.universaldesign.org); allow for customized, flexible use (Scherer et al., 2005; www.universaldesign.org); and be tolerant of errors (www.universaldesign.org). In addition, best practices also recommended a combined iterative engineering (Larman & Basili, 2003) and participant action research (PAR; Balcazar et al., 1998) approach to help ensure that end users were involved in testing and development to maximize the benefits of the TAP system. However, both technical and usability challenges surfaced during the experimental evaluation.

Technical challenges surfaced despite the best intentions to create a functional prototype. The pilot investigation allowed researchers to make initial modifications to the TAP remote control to ensure proper functionality and ease of use. The system functioned well during the pilot evaluation; it presented a reliable, feasible option. However, the same prototype TAP system used in the experimental evaluation was not error-free. The system malfunctioned due to both hardware (e.g., system did not send signal to TV) and software (e.g., system froze) issues. Ongoing trouble-shooting was required to ensure continued functionality of the TAP system, especially for Jonas and Timothy.

Usability challenges also emerged despite designing the TAP exercise program and videos based on evidence-based principles and eliciting initial feedback from practicing speech-language pathologists. Iterative adaptations during the first two weeks of the experimental evaluation led to the following system modifications: (1) adjust the pace and content of video instructions; (2) eliminate the exit option and simplify choices;

and (3) customize the remote control. These modifications were sufficient to allow Gerald to interface with the TAP system independently. Unfortunately, Jonas and Timothy, who presented with relatively greater (moderate) cognitive impairments, required continued care provider prompts to interact with the TAP system. Further system modifications beyond the scope of this project would be required to develop a more intuitive interface for these participants. For example, Timothy may have benefited from a precautionary screen that asked, "Are you sure you want to exit now?" before closing the program. To relieve the need for care provider prompts, the software might also include automated system prompts to "press a button on your remote control" after a specified duration for users such as Jonas with limited initiation.

Efficacy and Satisfaction Findings

When the TAP system functioned correctly, results clearly demonstrated an experimental relation between automated prompting with the TAP system and completion of swallowing exercises. The clearest effect was demonstrated with Jonas and Gerald, showing greater exercise completion with the TAP system than during typical practice. Timothy showed greater sustained adherence to his exercise program with the TAP system. The pilot participant demonstrated a strong initial effect, and results also suggest that the TAP system may have been effective to help establish a regular exercise routine for the pilot participant. These results are consistent with reports in the literature. Wilson and colleagues (2001) demonstrated that participants continued to complete routine tasks after withdrawal of the pager prompts. While evidence of a functional relation between variables in a single participant is sufficient to demonstrate an experimental effect with an alternating treatment design, results were strengthened with replication (Horner et al., 2005). In addition, effect size estimates revealed a large treatment effect for Jonas and Gerald. While equivocal for Timothy, he at least completed exercises at a level comparable to typical practice.

In addition to increasing the intensity and follow-through of exercise completion over typical levels, the evidence further suggested that the TAP system allowed the three participants to practice their exercises with improved technique. Swallowing exercises may be difficult for many patients to complete given the generally automatic nature of swallowing and multiple steps required to complete each exercise, especially the Mendelsohn maneuver; they can be particularly challenging for brain injury survivors with cognitive impairments (Logemann, 1998). In fact, when recruiting participants for this study, several therapists reported they did not typically prescribe swallow strengthening exercises to patients with cognitive impairments because they may be too difficult to learn. However, results of the fidelity observations revealed that all participants demonstrated correct technique while completing swallowing exercises using the TAP system within one or two weeks. Survey and interview data further supported the claim that the TAP system facilitated correct technique, especially for Timothy. Timothy initially completed neither of his swallowing exercises correctly, often stating that he did not know if he had swallowed. After using the TAP system for one week, he was able to complete exercises correctly. His therapist also reported that the TAP system was better than care provider prompts on typical practice days because the TAP system provided a consistent, clear model of the proper exercise technique.

The results revealed high satisfaction with the TAP system. All participants, including patients, care providers, and therapists, unanimously endorsed the TAP system as effective, useful, and worthy of continued use. Perhaps most convincing, all care providers requested an increase in the frequency of TAP delivery to every day midway through the month-long evaluation, despite ongoing modifications to the program during the initial two weeks. Two participants expressed a continued desire to use the TAP system after cessation of the project. Timothy did not request continued use stating, "now that I know how to do [the exercises], I don't need it. I took these lessons to learn how to do it correctly, and now I can." All participants highly recommended the TAP system for other patients needing to complete home exercise programs.

Features Contributing to TAP System Effectiveness

The TAP system was designed based on research evidence. Three bodies of literature were reviewed in Chapters I and II and provided a foundation for the current study. This study adds to the literature in the areas of rehabilitation access, assistive technologies for prompting, and home exercise program adherence. Each of these is discussed next.

Increased Access to Intensive Rehabilitation Practice

Survivors of acquired brain injury face significant challenges to accessing ongoing intensive rehabilitation services following discharge to home (e.g., Carpenedo, 2006), yet the literature supports intensive practice to maximize rehabilitation outcomes (e.g., Burkhead et al., 2007). Therapists often assign home practice programs in an attempt to augment limited therapy sessions, but individuals with cognitive impairments either may not complete home programs (e.g., Easterling et al., 2005) or require care provider prompts to initiate and complete practice regimens (e.g., Levine et al., 2006). The TAP system was designed as a tool to deliver both automated prompts and motivation to initiate and complete home swallowing exercise programs.

The participants in this study were referred by home-care SLPs in order to increase the amount of exercise they completed at home. Each patient was seen twice weekly for SLP sessions. Therapists reported that they would not have recommended home exercise programs to these patients with impaired cognition due to potential for limited comprehension of exercise technique and typically low adherence. Therapists were not surprised by the relatively low levels of adherence in the typical practice condition. Most significantly, the TAP system showed potential to either greatly exceed (Jonas and Gerald) or at least match (Timothy) levels of home exercise completion. Therapists endorsed the TAP system for its utility and potential to increase completion of home practice regimens. With further refinement, the TAP system will provide a novel means of making home practice programs accessible to a variety of patients who could benefit from continued intensive in-home rehabilitation practice.

Adding to the Power of Assistive Technologies for Prompting

This study replicated previous findings by Wilson and colleagues (2001), showing that automated prompts delivered via assistive technologies (e.g., alphanumeric pager, TAP system) can increase activity completion over baseline or typical levels. In addition, the TAP system surpasses other current assistive technologies for two reasons. First, it can deliver multimedia content accessible to a variety of users. The alphanumeric pager studied by Wilson and colleagues (2001) was capable of delivering only simple, static reminders (e.g., "take your medications" or "do your exercises"). Patients unable to read small printed text or manipulate the small buttons on the pager were unable to benefit from this technology (Wilson et al., 2001). Universal design principle #1 requires technologies to be useful and marketable to users with diverse abilities; principle #4 requires that information be perceptible (www.universaldesign.org). The TAP system expanded on the pager idea to deliver automated prompts at pre-specified times, but using multimedia. Thus, TAP video demonstrations that included visual, auditory, and kinesthetic information provided for clear instructions that allowed users to learn correct exercise techniques and complete exercises on a regular basis. Results of the TAP features survey revealed that patients and care providers highly valued the exercise demonstration and clear instructions (auditory and textual) to complete exercises.

Second, the TAP system capitalizes on familiar, accessible technology (i.e., the television) to help ensure physical and sensory access (LoPresti et al., 2004) and reduce fears or anxiety that may surface when introducing new technologies (e.g., Vaccaro et al., 2007). This allowed the TAP system to avoid the barrier of owning, maintaining, and initiating use of computers used to support other home rehabilitation programs (e.g., computerized language rehabilitation exercises described by Mortley et al., 2003). All participants reported that use of the TV was effective and useful to deliver exercise program reminders and instructions. The only reason participants missed a session was when they were not home.

When asked to compare the benefits of the TAP system to other potential assistive technologies, such as pagers or cell phones, participants unanimously reported preference for the TAP system because they felt it was motivating, clear, and easy to use. Jonas was not interested in the idea of a pager, while Gerald and Timothy both reported that pagers would be more difficult because they do not provide instructions and because it would be easy to forget what to do after dismissing the message. Care providers reported preference for simple systems that allow for independent practice to reduce their burden. In particular, they felt that patients would have greater difficulty manipulating or communicating via a telephone, thus requiring care providers to answer the telephone and relay messages. All three care providers reported that these patients were currently unable to use a 'regular' telephone independently, and were cautious about the idea of introducing a cellular telephone due to its smaller size and greater complexity.

Increased Motivation to Complete Home Rehabilitation Exercise Programs

Development of the content for the swallowing exercise program delivered through the TAP system in this study built on evidence-based principles to motivate individuals to complete independent home exercise programs. The literature revealed over 200 factors (categorized into personal, environmental, and program characteristics) thought to influence home program adherence (Meichenbaum & Turk, 1987). The swallowing exercise videos delivered by the TAP system incorporated several of the best-practice recommendations, such as: reminding patients early and often of the benefits of exercising (e.g., Chen et al., 1999); instructing patients about upcoming events and potential pain or fatigue with exercises (e.g., Driver, 2006); encouraging patients to invite friends or family to join in exercises (e.g., Robison & Rogers, 1994); and individualizing the exercise program to each patient (e.g., Sluijs, 1991).

The present study is the first to systematically evaluate an evidence-based motivational home exercise package for delivering automated swallowing rehabilitation exercises. Participants endorsed the TAP exercise videos as motivating, dynamic, and interesting. Patients completed their exercises with greater frequency and sustained intensity when prompted with the TAP system. Care providers and therapists corroborated this finding, adding that the video instructions increased both the likelihood of completing exercises and the quality of performing the exercises. TAP features reported as highly influential to enhance motivation replicated those in the literature, including: customization, clear instructions, and preparatory warnings. Thus, the results of this study support the TAP system as an effective assistive device used to deliver home rehabilitation programs with enhanced, motivational automated prompts.

Issues of Candidacy

An advantage of single-subject research is that results may reveal individual differences that would otherwise be lost in group comparison studies (Wilson, 1987). Varied performance across participants in the current study allowed for additional interpretation of the findings. Perhaps the more interesting question to ask is not: "Was the TAP system effective?" but rather, "For whom does the TAP system offer the greatest benefit?" Although this study was not designed to predict performance based on any hypothesized factors, nonetheless the data suggest that the efficacy of the TAP system to improve exercise completion over typical practice varied by environmental and cognitive factors.

The living environment appeared to lead to varied performance across the three experimental participants. Jonas and Gerald both lived with spouses in their own homes; Timothy lived in an adult foster care setting with a staff care provider. Timothy's care provider reported that she "always follow[s] the doctor's orders… we work as a team to benefit him." This care provider reported the lowest level of overall burden on the *Caregiver Burden Inventory (CBI)*, indicating burden only on the time domain. On the other hand, Jonas and Gerald's wives reported significant burden across domains on the *CBI*. Gerald's wife reported, "I had to prod him to do exercises" on TYP days while Jonas' wife stated, "I didn't push him too hard. The more I push, the more backwards he goes." The dynamics of spousal relationships, in addition to higher reported overall burden of care, appeared to influence lower performance in the typical practice condition.

Individual patient differences in cognitive abilities may have also differentially affected performance with the TAP study. Participants in this evaluation did not undergo formal cognitive assessment; cognitive impairments were described by the referring SLP. Nonetheless, a trend between severity of cognitive impairment and system usability merits discussion. Gerald presented with mild cognitive impairments, characterized primarily by impaired memory; his attention and reasoning skills were reported to be grossly intact. In contrast, both Jonas and Timothy presented with moderate cognitive impairments, characterized by impaired memory, slowed information processing, and decreased reasoning. Both Jonas and Timothy required additional system modifications, yet were never fully independent with interfacing with the TAP system. Jonas required prompts to initiate use of the remote control, and Timothy required supervision to remain alert and press the correct buttons on his remote control. Further system development and customization would likely allow for intuitive, independent use of the system by users with moderate cognitive impairments. In its current state, the ideal candidate for the TAP system is a patient with mild cognitive impairments who does not already have a care provider available to remind and motivate him or her to complete a home exercise program.

Study Limitations

There were several significant limitations to the experimental evaluation study. The first three relate to the internal validity of the experiment; the fourth relates to its external validity. First, ongoing modifications to adapt the TAP system to individual users during the first two weeks of the trial may have compromised exercise adherence. The goal of this study was to evaluate an assistive technology system designed to maximize adherence to intensive home swallowing exercise programs. Unfortunately, the pilot participant did not present with either swallowing impairments or moderate cognitive impairments, and may not have been the best pilot participant. Additional detailed pilot testing with the ideal target population may have prevented the need for initial modifications during the experimental phase. Nonetheless, participants remained positive about the TAP system and showed clear benefits with increased exercise program adherence and high satisfaction ratings despite the technical challenges and iterative modifications.

Another limitation relates to the treatment fidelity procedures. The researcher conducted fidelity observations during TAP but not TYP sessions. The presence of the researcher on TAP days may have increased the likelihood of participants completing exercises over TYP levels due to reactivity (Gall et al., 2003). However, patients sustained high levels of exercising with the TAP system, above TYP levels, even when the researcher was not present for a fidelity observation. In addition, the high levels of reported satisfaction with the TAP system indicated that patients enjoyed the TAP condition and would have likely completed exercises even without the researcher's presence.

A related limitation relates to the satisfaction measures. The researcher administered the end-of-study satisfaction surveys and interviews. He asked participants to provide honest feedback that would be used to improve the TAP system for future users. Despite this request, it is possible that participants under-reported negative comments in an effort to please the researcher.

An additional limitation of this experimental evaluation relates to the external validity, or generalizability, of the results. The goal of this evaluation was not to generalize the findings to the whole population of brain injury survivors, but rather to assess the feasibility, efficacy, and perceived benefits of the TAP system. Further replication with additional participants would be required before broader statements about the population can be made (Horner et al., 2005). The within-subjects alternating treatment design served as an appropriate evaluation methodology for this study. When designing and evaluating assistive technology tools, it is important to tailor them to and assess their benefits with individual users (Sohlberg et al., 2007). Traditional between-subjects group designs do not allow for investigation of functional changes over time and emphasize statistical over functional significance (Horner et al., 2005). Therefore, limiting this experimental evaluation of an initial TAP system prototype to three "typical-case" participants (Gall et al., 2003) allowed for accurate interpretation of the five research questions. These results do provide strong evidence to support use of the TAP system for other patients with similar profiles (Ylvisaker et al., 2002).

Future Directions

Further research and evaluation are required before wide-scale dissemination of the TAP system can occur. The first priority must investigate methods to improve the reliability of TAP system functioning. In this evaluation, the TAP system malfunctioned during 21.70% (23/106) of scheduled sessions. Continued research and development following an iterative design model with PAR influences (see above) will ensure delivery of a reliable and user-friendly TAP system. Future iterations should also explore features to make the TAP system fully intuitive and error-tolerant.

Another idea involves improving the trustworthiness of data collected. Including a second researcher who is blinded to the study to administer satisfaction surveys and interviews would decrease potential bias in reported data. Two additional solutions may help to avoid possible differential performance due to unequal fidelity observations across conditions. First, the use of some minimally-intrusive home monitoring system (e.g., video camera or exercise motion sensors) could verify that patients are completing exercises on TAP or TYP days, without the researcher's presence. Second, integrating Internet connectivity into the TAP system would allow the researcher to upload system updates or download TAP performance data remotely without directly interacting with or influencing patient participation.

Once developed, a reliable system that collects and reports trustworthy data would provide a useful method to answer several research questions. Robey (2004) provided a useful framework for clinical evaluation, as research progresses from initial development to demonstration of clinical efficacy, effectiveness, and efficiency. The current study demonstrated that the TAP system is both feasible and efficacious to increase follow-through and completion of a home swallowing exercise program. Next steps should include an evaluation of candidacy using predictive models, such as correlational studies (Gall et al., 2003). Another important next step involves the effectiveness of using the TAP system in *actual* clinical practice, without research support. Additionally, once the TAP system proves to be a reliable and efficient means to deliver home rehabilitation practice programs, the TAP system should be expanded to deliver a variety of evidence-based intensive rehabilitation programs. Use of the TAP system to motivate and track completion of home programs will allow researchers to evaluate adherence with home programs and conduct dose-dependent outcome studies. Such studies could evaluate the impact of completing intensive home programs on functional abilities. Specific research questions to be addressed in future studies include:

- Which environmental and personal characteristics predict high levels of intensive home program adherence with the TAP system?
- Which TAP system program features predict maximum adherence to intensive home rehabilitation programs?
- How can the TAP system be efficiently customized to maximize home program completion for individual users?
- Which additional rehabilitation home programs could be effectively delivered through the home TAP system?
- Does completion of intensive home exercise programs lead to functional improvements in the post-acute recovery for brain injury survivors?

APPENDIX A

FIDELITY OF IMPLEMENTATION OF IV CHECKLIST

(for TAP condition observations only)

Date of Observation: _______________ Participant # ___________

Observation	Yes	No
Did the TAP system turn on at the specified time?	☐	☐
Did the TAP system respond to patient button presses without delay, interruption, or system failure?	☐	☐
Did the patient respond to the TAP system using the remote control?	☐	☐
Was the patient able to use the TAP-system independently?	☐	☐
Did the care provider *NOT* provide any prompts to complete exercises?	☐	☐
Did the care provider *NOT* provide any prompts to motivate the patient?	☐	☐
Did the patient complete exercise #1 with proper technique?	☐	☐
Did the patient complete exercise #2 with proper technique?	☐	☐
Did the patient complete exercise #3 with proper technique?	☐	☐
Did the patient complete exercise #4 with proper technique?	☐	☐
Did the patient complete exercise #5 with proper technique?	☐	☐
Did the patient complete exercise #6 with proper technique?	☐	☐

Total: _____ / _____

Comments:

APPENDIX B

EXAMPLE OF A TAP LOG FOR JONAS

(Session 12-2)

Date & Time	Activity	Screen
2008.04.10-13:15:00	Reminder is triggered	SnoozeScreen
2008.04.10-13:15:52	Remote Button Pressed 2 down	SnoozeScreen
2008.04.10-13:15:52	Pressed Snooze	SnoozeScreen
2008.04.10-13:16:19	Reminder is snoozed	SnoozeScreen
2008.04.10-13:31:27	Reminder is triggered	SnoozeScreen
2008.04.10-13:32:59	Remote Button Pressed 1 down	SnoozeScreen
2008.04.10-13:32:59	Pressed Play	SnoozeScreen
2008.04.10-13:33:01	Reminder is starting	ReminderApplication
2008.04.10-13:34:35	Remote Button Pressed 1 down	ReminderApplication
2008.04.10-13:34:35	Pressed to {blue}CONTINUE	Screen:_22g0
2008.04.10-13:35:15	Remote Button Pressed 2 down	ReminderApplication
2008.04.10-13:35:16	Pressed for {orange}moderate{black} effort	Screen:_22g2
2008.04.10-13:38:42	Remote Button Pressed 2 down	ReminderApplication
2008.04.10-13:38:42	Pressed to {orange}SKIP{black} to the next set of exercises	Screen:_22g3
2008.04.10-13:39:50	Remote Button Pressed 1 down	ReminderApplication
2008.04.10-13:39:50	Pressed for {blue}Not Working Hard	Screen:_22g7
2008.04.10-13:44:43	Remote Button Pressed 2 down	ReminderApplication
2008.04.10-13:44:43	Pressed to {orange}SKIP{black} to the next set of exercises	Screen:_22g8
2008.04.10-13:45:25	Remote Button Pressed 1 down	ReminderApplication
2008.04.10-13:45:26	Pressed for {blue}Not Working Hard	Screen:_22g12
2008.04.10-13:49:38	Remote Button Pressed 1 down	ReminderApplication
2008.04.10-13:49:38	Pressed to {blue}REPEAT{black} this set of exercises	Screen:_22g28
2008.04.10-13:53:31	Remote Button Pressed 4 down	ReminderApplication
2008.04.10-13:54:15	Remote Button Pressed 3 down	ReminderApplication
2008.04.10-13:54:16	Pressed to {green}EXIT{black} this program	Screen:_22g29
2008.04.10-13:54:44	Remote Button Pressed 3 down	ReminderApplication
2008.04.10-13:54:45	Pressed to {green}EXIT{black} this program	Screen:_22g33
2008.04.10-13:54:46	Reminder is over	ReminderApplication

APPENDIX C

TAP EXERCISE COMPLETION DATA FOR JONAS

Session	TAP Totals	Face Stretches	Tongue Stretches	Effortful	Mendelsohn
1-2	14	5	5	2	2
1-3	16	5	5	4	2
4-2	20	5	5	4	6
4-3	0	0	0	0	0
7-1	31	10	10	8	3
7-2	0	0	0	0	0
7-3	20	5	5	10	0
11-3	20	5	5	10	0
12-1	25	5	5	5	10
12-2	25	5	5	5	10
12-3	25	5	5	5	10
13-1	0	0	0	0	0
13-2	0	0	0	0	0
13-3	0	0	0	0	0
15-1	30	10	10	5	5
15-2	20	5	5	0	10
15-3	40	10	10	10	10
16-1	0	0	0	0	0
18-1	20	5	5	5	5
18-2	20	5	5	5	5
18-3	20	5	5	5	5
19-1	20	5	5	5	5
19-2	20	5	5	5	5
19-3	20	5	5	5	5
20-1	20	5	5	5	5
20-2	25	5	5	5	10
20-3	20	5	5	5	5
22-1	20	5	5	5	5
22-2	20	5	5	5	5
22-3	0	0	0	0	0

APPENDIX D

TAP EXERCISE COMPLETION DATA FOR GERALD

Session	TAP Totals	Face Stretches	Tongue Stretches	Effortful	Tongue Strength	Masako
1-2	27	5	5	5	10	2
1-3	27	5	5	5	10	2
3-1	30	5	5	5	10	5
3-2	30	5	5	5	10	5
3-3	37	10	10	5	10	2
4-1	26	5	5	3	10	3
4-2	26	5	5	3	10	3
4-3	26	5	5	3	10	3
7-1	25	5	5	3	10	2
7-2	19	5	5	2	5	2
7-3	18	5	5	3	3	2
8-2	30	10	10	3	5	2
8-3	19	5	5	2	5	2
9-1	27	5	5	5	10	2
9-2	25	5	5	3	10	2
9-3	19	5	5	2	5	2
11-1	20	5	5	3	5	2
11-2	30	5	5	6	10	4
11-3	30	5	5	3	15	2
14-1	27	5	5	3	10	4
14-2	19	5	5	2	5	2
14-3	0	0	0	0	0	0
15-1	22	5	5	2	5	5
15-2	19	5	5	2	5	2
15-3	20	5	5	3	5	2
18-1	34	10	10	5	5	4
18-2	25	5	5	6	5	4
18-3	22	5	5	5	5	2

APPENDIX E

TAP EXERCISE COMPLETION DATA FOR TIMOTHY

Session	TAP Totals	Effortful	Mendelsohn
3-1	10	5	5
3-2	5	5	0
3-3	5	5	0
4-1	10	5	5
4-2	10	5	5
4-3	10	10	0
5-1	10	5	5
5-2	5	5	0
7-1	15	10	5
7-2	15	5	10
7-3	0	0	0
8-1	10	5	5
8-3	5	5	0
9-1	15	10	5
9-3	15	10	5
11-1	10	5	5
11-2	15	10	5
11-3	10	5	5
14-1	10	5	5
14-2	20	15	5
15-2	15	5	10
15-3	10	5	5
21-1	10	5	5
21-2	0	0	0
21-3	0	0	0

APPENDIX F

TYP SESSION EXERCISE LOG FOR TIMOTHY

On NON-TV DAYS: Please write down how many exercises you completed on your own

Day	Time	Number of Exercise Repetitions Completed	
		Effortful Swallows	Mendelsohn Swallows
EXAMPLE: Mon	*10:30*	*5*	*15*

APPENDIX G

TAP FEATURES SURVEY

Please place a checkmark in the appropriate box to indicate how effective or ineffective each TAP feature was *to encourage exercise completion.*

TAP Feature	Highly Ineffective	Ineffective	Neutral	Effective	Highly Effective
	1	**2**	**3**	**4**	**5**
Individualization					
Choice of Music					
Choice of Time of Day					
Video Features					
15-second Warning to Prepare					
Get Ready Instruction Video					
Exercise Demonstrations & Instructions					
On-Screen Cues for Instruction					
Use of Music to Motivate					
Exercise Counter to Motivate					
Verbal Encouragement to Motivate					
Variety of Content to Maintain Interest					
Cues for Break or Drink					
Questions for Self-Rating to Maintain Interest					
Pace of Videos					
Pace of Program					

APPENDIX H

SATISFACTION INTERVIEW & SURVEY: PATIENT VERSION

1. Please tell me your thoughts about using the TAP (TV) system for home therapy exercises. *Probes*: individualization (music, times of day); actor; video features (counter, motivators, modeling); feedback; self-pacing
    a. What did you **like** about using the TAP system?
    b. What did you **dislike** about using the TAP system?

2. Please describe any differences between using the TAP system versus non-TV days to complete your home therapy exercises. *[Probes: Remembering / Motivation]*

3. How much did you **enjoy or not enjoy** the TAP system that prompted your to complete swallowing exercises on your TV? __________
   Please comment on why you enjoyed (or not) the TAP system.

4. How much did you enjoy or not enjoy using the Typical Practice (non-TV day conditions) to complete your swallowing exercises? _________
   Please comment on why you enjoyed (or not) the Worksheet system.

5. How strongly do you agree or disagree with each of the following statements?
    a. I believe my swallowing improved because I completed exercises.
    b. I believe I completed exercises more often when the TV reminded me.
    c. I believe I completed exercises more often on non-TV days.
    d. I believe I practiced exercises more correctly with video instructions on the TV.
    e. I believe I practiced exercises more correctly on non-TV days.
    f. I think the TAP system was easy to use.
    g. After I learned to use the TAP system, I needed help to use it.
    h. I would rather use the TAP system to complete home exercises than follow a list of exercises on a Worksheet.
    i. I was more motivated to complete my exercises on TV days because of the TAP system.
    j. I feel better about my relationship with (care provider) because the TAP system did not require him/her to remind me to complete my exercises.

6. Would you recommend the TAP system to another person who needs to complete home therapy exercises? _________
   What information would you want them to know?

7. If you could continue to use the TAP system, what features would you want to change to improve how it works for you?

8. Do you have other exercises that you have been working on for the past month? How often do you complete those? Is there a difference with swallowing exercises from this study?

9. Compare TAP to other ATC for prompting…

10. Other types of reminders that would be useful over TV?

Additional Comments:

1	2	3	4	5
Did Not Enjoy At All		Neutral		Completely Enjoyed

1	2	3	4	5
Strongly Disagree		Neutral		Strongly Agree

1	2	3	4	5
Not Recommend At All		Neutral		Strongly Recommend

APPENDIX I

SATISFACTION INTERVIEW & SURVEY: CARE PROVIDER VERSION

1. Please tell me your thoughts about the TAP (TV) system for home therapy exercises. *Probes*: individualization (music, times of day); actor; video features (counter, motivators, modeling); feedback; self-pacing
    a. What did you **like** about the TAP system?
    b. What did you **dislike** about the TAP system?
    c. Which TAP **features** do you feel helped the patient **complete** the exercises?

2. Please describe any differences between exercise completion when the TAP system turned on or not. *[Probes: Remembering / Motivation]*

3. How much did you **enjoy** or not enjoy the TAP system that prompted (patient) to complete swallowing exercises on your TV? __________
   Please comment on why you enjoyed (or not) the TAP system.

4. How much did you enjoy or not enjoy when the TV system did *not* come on to complete swallowing exercises? _________
   Please comment on why you enjoyed (or not) the Worksheet system.

5. (a) How did you see your role when the TAP box turned on?
   (b) How about on days when the TAP Box did *not* come on?

6. How strongly do you agree or disagree with each of the following statements?
    a. I believe (patient's) swallowing improved because of the exercises.
    b. I believe (patient) completed exercises more often when the TV reminded (him/her).
    c. I believe (patient) completed exercises more often when I reminded (him/her).
    d. I believe (patient) practiced exercises more correctly with video instructions on the TV.
    e. I believe (patient) practiced exercises more correctly when the TV box did not come on.
    f. I think the TAP system was easy for (patient) to use.
    g. After (patient) learned to use the TAP system, s/he needed help to use it.
    h. I would rather have (patient) use the TAP system to complete home exercises than typical practice (no TV box).
    i. I believe (patient) was more motivated to complete exercises every day because of the TAP system.
    j. I feel better about my relationship with (patient) because the TAP system did not require me to remind him/her about completing exercises.

7. Would you recommend the TAP system to another family with a patient who needs to complete home therapy exercises? __________
   What information would you want them to know?

8. If you could continue to use the TAP system, what features would you want to change to improve how it works for you?

9. Did (patient) have other exercises to work on for the past month? How often did (patient) complete those? Is there a difference with swallowing exercises from this study?

10. Compare TAP to other ATC for prompting…

11. Other types of reminders that would be useful over TV?

Additional Comments:

1	2	3	4	5
Did Not Enjoy At All		Neutral		Completely Enjoyed

1	2	3	4	5
Strongly Disagree		Neutral		Strongly Agree

1	2	3	4	5
Not Recommend At All		Neutral		Strongly Recommend

APPENDIX J

SATISFACTION INTERVIEW: THERAPIST VERSION

1. Please tell me your thoughts about the TAP (TV) system for home therapy exercises. *Probes*: individualization (music, times of day); actor; video features (counter, motivators, modeling); feedback; self-pacing
   a. What did you **like** about the TAP system?
   b. What did you **dislike** about the TAP system?
   c. Which specific features of the TAP system do you feel were **most effective** to increase exercise adherence?
   d. Which specific features of the TAP system would you **change** in future iterations?

2. Please describe any differences between using the TAP system or the typical practice condition for (patient) to complete home therapy exercises. *[Probes: Remembering / Motivation]*

3. Did this patient have other exercises or home programs to complete besides swallowing exercises for the past month? ________ If yes, please comment on differences between completion of home programs that were not cued by the TV system.

4. Would you recommend the TAP system to another patient who needed a home exercise program? _________
   What information would you want them to know?

5. Would you recommend the TAP system to another home care therapist? _______
   What information would you want them to know?

Additional Comments:

APPENDIX K

INTERVIEW NOTES FROM PATIENTS

Comments from Jonas:

Benefits/Advantages of TAP:

- "It came on early enough to allow us to arrange & prepare to sit down, get ready, and do the exercises."
- "After I got used to it, it kept my attention."
- "It features a rotation that you have to follow."
- "You can't forget it."
- "It's repetitive enough at the beginning."

Dislikes:

- Wanted greater variety with exercise videos.
- Wanted greater exercise frequency ("Have it come on every day.")

Compare TAP to TYP:

- "The reminder of how to do it needs to be there."

Recommendations:

- "Make sure you have a working TV!!"
- "I just had to make up my mind I was going to do it."

Completion of non-swallowing exercises?

- Did none of his PT exercises in past month ("nil").

Compare to other ATC:

- "It's good in the TV because it reminds us of what we have to do. Without the video, it's too easy to forget. You need to keep it fresh in your mind. You know how a tired mind can get!"
- Not sure how he would do with phone/pager reminders without trying. "Hard to say."

Want to Continue?

- Chose to continue exercises every day.

Comments from Gerald:

Benefits/Advantages of TAP:

- "It was easy to navigate through the program."
- "The music was fun and motivating."
- "It was not long and drawn-out."

Dislikes:

- "The Masako swallows are hard to do!"

Compare TAP to TYP:

- TYP: "I get lazy, and it's easy to forget to do exercises."
- TAP: Motivating factors included music, short & quick for a limited attention span, and liked ability to skip ahead/Fast Forward once knew program.

Recommendations:

- "Go Back button"

Completion of non-swallowing exercises?

- Does PT approx. 3x/week (on days that PT does not come to house).

Compare to other ATC:

- "I'm a TV guy. I like it on the TV." He felt that he would not do exercises if paged, not as motivating.

Want to Continue?

- Yes, would want to continue to use TAP system.

Other Potential TAP Content?

- PT exercises would be hard because of divided attention (hard to do exercises at same time while watching videos, especially in other rooms for exercises at counter)

Comments from Timothy:

Benefits/Advantages of TAP:

- "In case you get stuck with food [in your throat], you know how to get rid of it!"
- "It helped my swallow, so I don't choke any more. Sometimes I have a little cough now, but it's not from the food; it's just congestion."
- "I didn't know anything about [swallowing] before. It's a good thing to know."
- "It's useful."
- "I liked the way it explained everything. It's something you need to know."
- "I didn't know how to swallow before. This gave me a lesson of what to do in case I choke".

Did you enjoy the TV system? "I guess."
Was it ever annoying? "No."
Helpful to have reminders? "I can remember if it tells me the date."
Dislikes: "Nothing."
Compare TAP to TYP:

- "Once I learned [to do the exercises], it was easy."
- "It didn't make any difference. I knew what to do because I had seen it several times."
- "It didn't matter one way or the other. If there was no TV, then [my care provider] would remind me. It's easy to forget."
- "It's better to have it on. It was a benefit for me."
- "It's good that it reminds you. Sometimes you just forget."
- "The videos were helpful to do the exercises correctly. I want to do it correctly, not incorrectly. A lot of people just don't know about swallowing!"
- "It's better to review the videos when the TV is on in case you missed or forgot. You need to do it correctly."

Recommendations:

- "If you have problems with your swallowing, it's good to learn about it because you might choke. It will benefit you. Choking is very dangerous."
- "Nothing. [The videos] teach you. It's taught correctly. It's better to have the lesson. It didn't bug me at all."

Completion of non-swallowing exercises?

- (PT leg exercises) "I do them twice every day." (& he demonstrated)

Compare to other ATC:

- "It's good to have a reminder. Both ways [phone or TV] are helpful as a reminder. It would be good to get a review and reminder of any exercises."

Want to Continue?

- "Now that I know how to do [the exercises], I don't need it. I took these lessons to learn how to do it correctly, and now I can."

Will you continue to exercise without the TAP system?

- "Maybe. Every once in a while, only if I have a problem."

Other Potential TAP Content?

- "I don't need that [for PT exercises]. I already know how to do them - they send me a diagram."

APPENDIX L

INTERVIEW NOTES FROM CARE PROVIDERS

Comments from Jonas' Care Provider:

Benefits/Advantages of TAP:

- "The speech was all very clear and easy to understand."
- "Its presence was helpful - otherwise, he would not have done the exercises at all."
- "It definitely works. The program helps the swallowing."

Dislikes:

- "It was too loud."
- "It went too fast. The whole thing moved too fast for him."
- "The music was sort of distracting, especially toward the end. He's not able to do more than one thing at a time."

How did you see your role as CP on TAP or TYP days?

- TAP: "Prompter" (but went too fast & had to prompt to press buttons).
- TYP: "I tried to remind him on occasion, but I didn't push him too hard. The more I push, the more backwards he goes."

Compare TAP to TYP:

- "It was definitely more motivating when the box came on."
- "He did not enjoy doing exercises [on non-TAP days], except that he didn't have to do them!"

Recommendations:

- "I should think someone would have to use it every day to get maximum benefits."
- More spacing between instructions, between printed lines.
- Slow it down. "He does not process rapidly."
- Don't use colored text -- too hard to read.

Completion of non-swallowing exercises?

- "He so rarely did them on his own. Never."

Compare to other ATC:

- You can blow off a phone call or forget it 30 sec later. With this, you need to do something specific to turn it off.
- "It depends on whether people are visual or auditory."

Want to Continue?

- Yes, wanted to continue to use TAP 5 days/week.
- "It has definitely been helpful for him."

Other Potential TAP Content?

- It would be useful for any of the PT exercises, like the ones they have posted down the hall. It's so easy to just walk right past them!"
- "Would be useful for anything that you want someone to seriously do."
- "He always does better with a live person here to supervise or assist him. Hard to say how he would do with just a video."

<u>Comments from Gerald's Care Provider:</u>

Benefits/Advantages of TAP:

- Liked 15-sec warning to get ready.
- "Easy to use - it was good. It didn't take a big effort to use."
- "The length of time was effective; anything longer would have been harder."
- "Good variety of exercises."
- "It was quick and straight-forward."
- Liked that it was customized to selected times of day.
- Most motivating features: "The number of exercises in each set. It was quick and do-able."

Dislikes:

- No comments on features not liked.

How did you see your role as CP on TAP or TYP days?

- Enjoyed having TAP system come on because "it was all right there."
- Saw her role decreased on TAP days.

Compare TAP to TYP:

- TAP: "It's right there, coming on the TV. The TV does it all, right in front of you. You can't not do it.:
- TYP: "I had to prod him to do exercises. Sometimes he just didn't want to do them, or we'd both forget."

Recommendations:

- Have it come on 5 days/week to get maximum effects.

Completion of non-swallowing exercises?

- Stated that Pt actually completed PT exercises only 1-2 x/week.

Compare to other ATC:

- TAP is more effective… "the fewer phone calls to me, the better" (juggling lots of appointments, insurance claims, etc.)

Want to Continue?

- Would want to continue to use TAP system… but chose not to keep it due to transition to outpatient and unsure of schedule. Asked them to call me if they want to try it again…

<u>Comments from Timothy's Care Provider:</u>

Benefits/Advantages of TAP:

- "It was good for him."
- "We work as a team to benefit him. I always follow the doctor's orders, and I never miss anything - exercises, medications, anything that's important."

Dislikes:

- "No. It doesn't bother me."
- "It was occasionally stressful when it didn't work. I worried because I had to figure out when it wasn't working."
- "It didn't always click with him if he was sleepy. He did best when he was awake."

Compare TAP to TYP:

- "It was not as motivating without the TV system."

How did you see your role as CP on TAP or TYP days?

- "It was helpful to free my time, a little."

Recommendations:

- "It would have been better to have the TV system come on every day, on a regular schedule - every day at the same time, to make it more motivating. When it did come on, there was no option. He had to do them."
- "It's good for people like [him] who have a good brain. In foster homes, it's harder. The other people have dementia and no brains. They can't even use a spoon, so they couldn't use this [remote]. For him, it was good to help him. The others don't need it."

Compare to other ATC:

- "He couldn't use a pager. A phone is too hard for him. I have to dial the numbers. He can't use his fingers, and he doesn't hear too good. [The TV Box] is okay. The phone would just make extra work for me."

Want to Continue?

- "Yes. But just make it work properly! Only would use it if there were no problems!"

APPENDIX M

INTERVIEW NOTES FROM THERAPISTS

Comments from Therapist for Jonas and Timothy:

Impressions of benefits from discussions with patients:

- Both patients thought the TAP exercise system helped them, and improved their swallowing.
- Both patients are swallowing better. For Jonas, he had an asthma attack, which usually put him in the hospital, but this time he stayed out of the hospital – "that's huge progress for him!" For Timothy, "he is able to demonstrate the exercises, is more aware of his swallowing challenges, and is better able to handle solid textures."
- "They both did the program and were interested… the fact that they independently reported problems with the system also tells me that they were interested in the program. If they just didn't want to do it or weren't interested, they would just let it slide."
- "Neither of them commented on the mundane-ness."
- "Both patients reported they were doing well. They got a smile on their face whenever I asked about the system! They were really excited to use it, and they really felt they were helping themselves."
- Both participants reported that "sometimes the machine didn't work, but they had no ongoing frustrations, and seemed to enjoy the system."
- "The care providers also liked it, mostly because it gave the patients something to do. I think they liked it more than the patients. It helped to regiment their lives. It gave them something to do."
- "They liked the flexibility to say 'no' if they didn't want to do the exercises."
- Overall, "99% was positive, good feedback. Only 1% was negative feedback when the machine didn't work."
- Both patients initiated to comment on enjoying the TV exercise program "before I even asked them. They reported, 'I do this all the time.' Now, I'm sure they weren't doing the exercises perfectly, but we got them doing it as good as we can, and it's better than without the instructions."

What do you see as some of the advantages of the TAP system over Typical Practice?

- "It keeps them honest."
- "It keeps them motivated."
- "It reminds them to do their exercises."
- "I think the visual of someone doing exercises with them is helpful. It's not as good as a live one-on-one therapist, but it helped both of these patients because of their cognitive impairments and fluctuating performance."
- "In my typical experience, it is rare to get even 50% success with home exercise programs."
- "With the TV system, I see much better improvements in getting their exercises done."
- Jonas: "He would not have completed exercises at all, and would have been full of excuses."

- Timothy: "He would have been prompted by his caregiver, but I would question his accuracy in completing the exercises without the visual feedback from a therapist or the videos. Without the system there on certain days, I don't think the caregiver would have reminded him as much."

Would you recommend the TAP system to other patients?

- The first thing this therapist said to me, before I even asked any questions about the TAP system, was that he had 3 more referrals to use the program…
- "Yes, no doubt! I would do it even without getting paid!"
- "It's right to the point. It gets the patients doing the exercises as close to how we want them to do it as possible."

Would you recommend the TAP system to other therapists?

- "Yes… once it's up and running."
- "Both of these participants were tough because of co-occurring physical and cognitive impairments [in addition to swallowing], but both had good outcomes!"
- "I see the most benefit to patients with mild cognitive impairments who need reminders and the external framework."
- "The next challenge would be to see if it can also work for patients who are non-compliant. It would be interesting to see what would motivate them or how we could get them to follow-through."

What improvements or changes would you recommend to the current TAP system?

- "#1: Improve the reliability of the machine."
- "Expand on the types of exercises it can do."
- "Keep it to the point. I think the main reason we saw success with it was because it was quick and to the point."

Summary of Comments from Therapist for Gerald:

- He never observed the TAP system in action, so could not comment on specific features. Instead, impressions were based on what he heard from the Pt and CP
- The system was positive. It definitely peaked the therapist's interest, especially because it was novel.
- The Pt and CP reported compliance with using the system, but functionally the therapist observed no changes.
- The therapist was *not surprised* by the discrepancy between TAP and TYP conditions for typical home practice. He stated that low compliance is "common" and "expected."
- He saw potential for using a TAP system with more patients, and was also interested in learning more about telerehabilitation models for working with patients in rural/remote areas across the state.

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