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NEUROBEHAVIORAL GRAND ROUNDS—INTRODUCTION

Neuropsychological interventions for memory impairment and the role of single-case design methodologies

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INTRODUCTION

The Neurobehavioral Grand Rounds that follows by Svoboda and Richards (2009) describes a clinical intervention in a client with severe anterograde memory impairment. The study focuses on the training and use of emerging electronic technology, specifically a "smartphone," to reduce the impact of memory impairment on the client's everyday functioning. The authors use a single-case design to articulate a training approach to teach and support use of an external aid and the client's adoption of the aid for everyday activities. The training program itself is based on previous literature describing effective approaches to teaching new information, skills, or behaviors (Sohlberg et al., 2007; Wilson, 2003) and is potentially replicable in other individuals.

REHABILITATION FOR MEMORY DISORDERS

This case report provides an excellent example of "best practices" clinical intervention in that it describes a theoretically based, well-conceived, and carefully executed intervention that addressed important and relevant capacities in the patient's life. Indeed, the goal of neuropsychological rehabilitation should be to improve cognitive capacities or compensate for cognitive difficulties to support improved adaptive functioning of the individual in their everyday life and activities. Outcomes in neurorehabilitation are currently best conceptualized as a complex interaction of factors affecting performance in real-life contexts, rather than as specific gains in underlying cognitive processes, such as attention, memory, and executive function. This premise was formalized in the World Health Organization International Classification of Function, Disability and Health (www3.who.int/icf/icftemplate.cfm). Adherence to this model requires that interventions be tailored to the particular client. To be effective and meaningful, goals need to be identified for each individual and be customized to their particular cognitive profile and the requirements for memory function in the setting or settings to which they will return or in which they will otherwise need to function.

In most individuals who experience a significant anterograde memory impairment as a result of injury or insult, and for whom the memory impairment lasts well beyond a period of normal recovery, memory difficulty is likely to be persistent and to interfere with adaptive functioning across a range of functional domains (Wilson, 1991). While studies of such individuals have generally demonstrated that they have the capacity to learn some new information, new learning is much slower, and it often appears more reliant on relatively spared implicit or procedural memory (Evans et al., 2000). Considerable research has focused on identifying and developing techniques that can facilitate the learning of new information and skills in individuals with acquired memory impairment. Specialized teaching strategies, such as the facilitation of errorless learning, the method of vanishing cues, forward and backward chaining, and spaced retrieval, have been shown to enhance retrieval, learning, and exposure benefits in individuals with memory disorders (Sohlberg & Mateer, 2001; Wilson, in press). While these techniques can be effective in learning, the ability to learn large amounts of new declarative information, the capacity to carry out future intended actions (prospective memory), and the ability to retrieve personally experienced episodic memories are aspects of memory that have been difficult to remediate or restore. Many of these patients do, however, benefit from training in compensatory approaches, such as training in the use of external memory aids, and the principles and effectiveness of such training have been well described (Sohlberg et al., 2007; Wilson, 2003). This report adds further support to the effectiveness of compensatory memory aids and describes some of the added benefits of that approach that can be realized through the use of emerging electronic technologies.

The manuscript describes the training and use of a sophisticated but widely available newer technology, a smartphone.

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While the actual technology is impressive, the complex and novel ways in which the technology was used by an individual with significant memory impairment are even more impressive. Critical to making this possible was a very systematic approach to training the device, including acquisition of the basic information and skills needed to use different applications in the phone, extensive opportunities to practice the skills, and most importantly, purposeful adaptation to functional activities within the client's daily life. Equally impressive were the care taken to adapt use of the device to the individual's preferences, needs, and abilities and the application of the device to achieve meaningful goals.

The article adds to an emerging literature on the use of electronic devices in the management of memory impairment. Recently, DePompei et al. (2008) described the training and use of PDAs and smartphones in children and adolescents with developmental as well as acquired disorders. The authors describe that influencers of success include student motivation, audible beep of the device, support for programming and troubleshooting alterations of functions, and selection of features to motivate. DePompei et al. (2008) also stressed the importance of a clear and well-developed intervention plan.

THE VALUE OF SINGLE-CASE DESIGNS IN NEUROPSYCHOLOGICAL REHABILITATION

Randomized controlled trials (RCTs) are often considered the "gold standard" for clinical intervention research. Yet there are many instances where intervention research cannot easily be conducted as an RCT. Indeed, RCT designs often pose significant challenges for researchers in the field of rehabilitation (Kennedy & Turkstra, 2006). Random assignment to interventions is not always possible within a clinical setting. In rehabilitation programs, every individual typically receives multiple rehabilitation services and ethically should be provided with best practice interventions. While the RCT framework has been adopted by researchers undertaking cognitive and behavioral interventions, its structure was designed for clinical drug trials, and as such, many features (e.g., consistency of the "treatment" in the form of a specific pharmacological agent, the notion of discrete dosing) are often not appropriate, practical, or relevant in behavioral intervention research.

Another difficulty posed by the conduct and interpretation of RCTs in the context of cognitive rehabilitation is the substantial heterogeneity in the patient population that might benefit from the intervention. In the case of memory rehabilitation, for example, memory difficulties can result from a wide range of neurological conditions with different neuroanatomical substrates. Functional memory difficulties can arise from injury to or disruption of different components of the memory system. Memory difficulties may be seen in relative isolation or may be part of a wider range of cognitive impairments, including attention, language, executive functions, and other domains. Given this heterogeneity, it is difficult to create homogenous groups either by cognitive profile or by neurological/neuroanatomical substrate. Other variables including age, preinjury status, time postinjury, and emotional adjustment, to name a few, also contribute to heterogeneity and can influence response to intervention (Sohlberg & Mateer, 2001).

The overall constellation of cognitive symptoms impacts on whether and to what degree particular interventions may be helpful and clinically plays a crucial role in what intervention techniques are selected and how long a period of training may be required. For example, the patient of Svoboda and Richards (2009) described in the following article demonstrated a severe anterograde memory impairment but relatively intact executive functioning; the errorless learning strategies employed proved to be effective and efficient. This patient also demonstrated spontaneous generalization of training and experience in her novel use of the device for untrained activities. Outcomes may be different, however, in individuals with a similar memory profile but who have comorbid difficulties with impulsivity, distractibility, judgment, reasoning, and/or awareness. For example, we described the implementation of a cuing system to prompt initiation of specific behaviors using an electronic pager in a densely amnestic individual (O'Connell et al., 2003). Although a consistent response to cuing was produced in a very short period of time, a much longer period of training was required for our patient to be able to learn how to enter messages into a computer for later distribution to the paging device. He also demonstrated quite a protracted learning curve when trained to use a memory notebook, in contrast to the relatively quick learning observed in this case. Though ultimately successful in undertaking specifically trained components of both memory devices, our client's substantial difficulties with executive function impairment, in addition to his severe anterograde amnesia, resulted in his being quite impulsive and easily distracted, which made it more difficult for him to acquire the necessary skills. Despite the adoption of an errorless learning approach, he demonstrated persistent difficulties, in the form of impulsive responding, when navigating a public Web site (to access the online calendar system that he was using to send messages to his pager). He also failed to demonstrate spontaneous generalization of notebook use for untrained or novel purposes, partly due to a more restricted sphere of activity and in part due, I believe, to his difficulties with initiation, insight, and awareness.

While both these clients were ultimately successful in using multiple external aids in ways that had a substantial positive impact on their everyday behavior, the outcome measures themselves, the selection and timing of particular training strategies, the patients' cognitive profiles, and their needs with respect to using the aids were very different. As such, I believe that the cases amply demonstrate the value and importance of single-case study designs as a research methodology. It would have been extremely difficult, if not impossible, to have applied a consistent treatment to both these individuals within a traditional RCT format. The unique outcomes would have been difficulty to capture and there would have been limited scope for exploring novel approaches to the training.

EVALUATING THE QUALITY OF SINGLE-CASE DESIGNS

Given the limitations and challenges of RCTs in neurorehabilitation research, there has been considerable reliance on the use of single-case studies. These studies provide a means of disseminating information about promising interventions that have had positive outcomes for particular individuals. A survey of research designs used in 1298 studies archived in the Psychological Database of Brain Impairment Treatment Efficacy (http://www.psychbite.com) (Tate et al., 2004) revealed that single-case designs constituted the largest proportion (39%), followed by case series (22%), RCTs (21%), other non-RCT group studies (11%), and systematic reviews (7%) (Perdices et al., 2006).

Single-case studies use experimental designs that provide "intensive and prospective study of the individual, using an a priori methodology, which includes systematic observation, manipulation of variables, repeated measurement and data analysis" (Tate et al., 2008). As such, these designs are particularly useful in their ability to individually tailor an intervention to the specific characteristics of the individual while still providing empirical evidence in support of the particular therapeutic interventions. Information gleaned in carefully described case studies can be applied to interventions designed for other individuals with similar difficulties.

While single-subject designs can provide very useful information about the conduct and outcome of rehabilitative interventions, they have a number of difficulties associated with them that have been well described and discussed (Anderson & Kim, 2003; Barlow & Herson, 1984; Chambless & Hollon, 1998; Hersen & Barlow, 1976; Kazdin, 2003; Robey et al., 1999). As summarized in Tate et al. (2008), such difficulties include being able to operationally define target behaviors, creating control conditions in the design (e.g., reversal/withdrawal, multiple baseline across behaviors), adequately demonstrating and accounting for variability in behavior, reducing potential observer bias, problems with statistical analysis and/or establishing effect sizes to verify treatment efficacy, and providing evidence of generalization beyond specific target behaviors. Nevertheless, the information gleaned from case studies is often difficult to develop when using other experimental designs, and researchers in rehabilitation (e.g., Guyatt et al., 1990; Moher et al., 2001) have urged both more carefully controlled studies and more comprehensive and transparent reporting of single-case design studies.

Recently, Tate et al. (2008) developed the Single-Case Experimental Design (SCED) Scale, an instrument designed to help quantify the methodological quality of single-subject designs. The SCED is practical to use in terms of length and complexity. It was created to assess the features of single-subject designs that are widely regarded as important for results to be meaningful and to make distinctions between single-case studies of varying quality. The SCED Scale uses a dichotomous scoring system with a maximum score of 10 points. In order to obtain a point on a particular item on the scale, there must be an explicit statement in the written report that addresses and satisfies that particular criterion. The SCED Scale was subject to careful item development, and content validity was assessed by empirical testing using 85 published single-case studies, which had demonstrated effectiveness of various interventions for persons with acquired brain impairment. The SCED Scale has a high level of interrater reliability for both individual raters (intra-class correlation, ICC = .83) and between pairs of raters on consensus ratings (ICC = .88). The authors also demonstrated its reliability with raters who received a relatively short period of training. The average score given by experienced raters for 20 randomly selected single case reports was 4.65 out of 10 (*SD* = 2.35, range 0–8). Specification of clinical history was identified in 85% of the reports (though this item is not included in the total score of 10). Specification of target behavior was also reported in most of the studies (85%); independence of the assessor and the therapist was only evident in 15% of the reports.

The SCED scale provides a means to facilitate critical appraisal and evaluation of the methodological quality of n-of-1 trials, SCEDs, and other single-subject designs submitted for publication and/or reported in the literature. Tate et al. (2008) suggested that the SCED items could also be used as a checklist when designing and reporting single-case designs along the same lines that the Consolidated Standards of Reporting Trials (CONSORT) statement (Moher et al., 2001) is used as a checklist for RCTs. By improving the methodological caliber and the consistency of reporting, it will be possible to undertake meta-analyses of such studies, such as has occurred with RCTs (Schulz et al., 1995).

For illustrative purposes, I have applied the published SCED criteria to the study reported by Svoboda and Richards (2009) that follows this introduction. Table 1 provides the criteria and definitions from the SCED and then identifies aspects of this single-case study that meet or address those criteria. Although this study incorporates many of the criteria necessary for a well-designed single-case study, it achieves an SCED score of just 4. As identified in Table 1, the authors reported very detailed information about the client's performance during the training regime and substantial information about ways in which the client spontaneously used the smartphone for novel untrained activities. Unfortunately, this information did not achieve a score on the SCED. Other information that might have generated a score was either not reported or could not be gleaned sufficiently from the report.

In conclusion, the case report by Svoboda and Richards (2009) provides a very compelling description of the ways in which an electronic aid can be used to mitigate the impact of severe memory impairment on everyday activities. The aid clearly provided the client with tools to manage a broad range of information, both for planning her future activities and for reconstructing her past. As promising approaches develop in the field of neurorehabilitation, there remains a valuable role for carefully controlled and well-described case study reports. Such studies allow clinicians and researchers to use emerging techniques and increasingly

Table 1. Criterion items from the SCED Scale (Tate et al., 2008): Application to study described by Svoboda and Richards (2009)

SCED criterion	Aim and description of the item	Examples from Svoboda and Richards' (2009) study, which meet the criterion	Score
Clinical history	The study provides critical information regarding demographic and injury characteristics of the research subject that allow the reader to determine the applicability of the treatment to another individual	Subject RR Age, 55 years; education, 14 years; occupational history, office management Medical history described Relevant medical condition: excision of colloid cyst, with substantial postsurgical complications (well described) Severe anterograde memory impairment with otherwise relatively spared abilities The subject's functional status was well described	n/a
1. Target behaviors	The article provides precise, repeatable, and operationally defined target behavior that can be used to measure treatment success	Correct responses to a phone call schedule (five calls per week) were used to quantify prospective memory Different phone call schedules were used for each condition of the study to reduce practice effects	1
2. Design	The study design allows for the examination of cause-and-effect relationships to demonstrate treatment efficacy	Within-subject $A^1B^1A^2B^2$ SCED: baseline (A^1), immediate posttraining (B^1), return to baseline (A^2), 4-month postintervention follow-up (B^2)	1
3. Baseline	To establish that sufficient sampling of behavior had occurred during the pretreatment period to provide an adequate baseline measure	Baseline responses to the phone call schedule were recorded during 2 weeks prior to training. However, the baseline data are reported as a total score. This is not normally considered sufficient to establish the variability (or the stability) of the baseline. Ideally, at least three separate occasions on which the target behavior is measured (e.g., three different weeks during which the client was asked to make phone calls) and three scores reflecting that or a single score with an indication of variability—for example, mean, range, or *SD* across the three occasions	0
4. Sampling behavior during treatment	To establish that sufficient sampling of behavior during the treatment phase has occurred to differentiate a treatment response from fluctuations in behavior that may have occurred at baseline	Data were collapsed over the $A^1B^1A^2B^2$ phases of the study (figure 4 in the study) such that fluctuations in behavior could not be easily determined from the study	0
5. Raw data record	To provide an accurate representation of the variability of the target behavior	Detailed data on the percentage of correct trials were provided over training sessions (figure 3 in the study) for the three stages of skill acquisition. Unfortunately, this was not the target behavior (which was collapsed), so it does not yield an SCED point. Nevertheless, the data provided valuable information about the training regimen itself	0
6. Interrater reliability	To determine if that target behavior measure is reliable and collected in a consistent manner	There was no indication of interrater reliability, but the outcome measure used (completing a phone call at a prescribed time) was well defined, with measurable criteria. This reduced the need for interrater reliability (essential for more judgmental ratings). According to the SCED Scale, the phone calls would be considered reasonably objective and therefore would be awarded a point	1
7. Independence of assessors	To reduce assessment bias by employing a person who is otherwise uninvolved in the study, to provide an evaluation of the patients	While other individuals were not involved in the evaluation, the inspection of the record in the smartphone itself was used to document use of the device for training and untrained purposes. Registration of the target behavior on a computer device (the phone) constitutes an independent assessment	1
8. Statistical analysis	To determine the effectiveness of the treatment of interest by statistically comparing the results over the study phases	There was no indication of the use of statistical analysis (although visual inspection of the data was impressive)	0

(*continued*)

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Table 1. Continued

SCED criterion	Aim and description of the item	Examples from Svoboda and Richards' (2009) study, which meet the criterion	Score
9. Replication	To demonstrate that the application and results of the therapy are not limited to a specific individual, therapist, or setting	The article describes in detail a systematic approach to training the use of a smartphone as a memory aid and identifies outcomes across multiple domains of functioning for one individual. The article references success with other clients and notes that replication with a larger group of patients is underway	0
10. Generalization	To demonstrate the functional utility of the treatment in extending beyond the target behaviors or therapy environment into other areas of the patient's life	The client was described as using the "smartphone" extensively and in novel untrained ways (e.g., she was noted to attach extra notes to appointments to remind her of associated details resulting in a retrospective memory log for each event; she used the device to take photos of family members, which she shared with friends; and she used the memo function to create a large store of information, such as a medication log, lists of Christmas gifts, log, and directions to favorite locations and Web sites) However, to receive this point, it is necessary to specify *a priori* what the measure of generalization will be and to measure this pre- and posttraining. The measure of generalization should demonstrate treatment effects on a behavior that was not actually subject to training	0

Note. n/a - not applicable.

sophisticated technologies in individuals with varying cognitive profiles for the purpose of improving their everyday functioning. Results of such studies can provide valuable information about the effectiveness of such interventions, which can be applied and adapted for use with other cases. Far from serving as one-off and therefore irrelevant or unreliable, such studies, when well designed, can be characterized by rigorous experimental control and can yield important insights and findings.

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