Journal of the International Neuropsychological Society (2005), **11**, 488–493.

DOI: 10.1017/S1355617705050599

DIALOGUE

The clinical neuropsychologist's dilemma

BARBARA A. WILSON
MRC Cognition and Brain Sciences Unit, Cambridge, UK and The Oliver Zangwill Centre, Ely, UK

(Received December 20, 2004; Received March 16, 2005; Accepted March 17, 2005)

INTRODUCTION

Academic neuropsychologists are increasingly engaged in (and are part of) cognitive neuroscience. Neuroimaging is currently high on the agenda, neuroplasticity is a very topical field within neuroscience, and a number of neuropsychologists work on animal models of brain injury. Clinical neuropsychologists, particularly those involved in rehabilitation, will usually tell you that their work needs to be guided by theory or else they risk the accusation of being simply pragmatic. The fundamental question for clinical neuropsychologists is which theory or theories are most relevant and useful for the patients and families with whom they work? While it would seem that most clinical neuropsychologists consider cognitive neuroscience to be of direct or at least indirect benefit to clinical neuropsychological practice, it is part of the argument of this paper to suggest that the benefits are less substantial than is sometimes claimed. As I work with both academic and clinical neuropsychologists, I hold the conviction that theory should be relevant to clinical practice while, at the same time, wanting neuropsychological rehabilitation to be respectable in the eyes of the academic community. However, when treating a patient with brain injury it is sometimes a struggle to implement, or even see the relevance of findings from cognitive neuroscience.

At the mid-year meeting of the International Neuropsychological Society in Berlin 2003, Ian Robertson gave an elegant and influential paper entitled *Cognitive Neuroscience and Brain Injury Rehabilitation: A Promise Kept*. His main argument was that cognitive neuroscience has indeed been of benefit to brain injury rehabilitation, and he illustrated this by referring to some admirable research. In this paper I hope to show that, much as I admire Robertson's work in the field of cognitive neuroscience, when we are considering brain injury rehabilitation in its broadest sense and attending to the diverse problems and complex needs of brain injured people, then the value of cognitive neuroscience on its own may be severely limited.

A Summary of Robertson's 2003 Paper

Robertson holds the view that it is crucial to develop a theory combining behavior and physiology or behavior and biology. He argues that rehabilitation is in the realm of behavior whereas models of recovery are in the realm of physiology. Biological models on their own cannot tell us *how* to rehabilitate; they inform pharmacological not behavioral treatment. Thus rehabilitation has been, to a great extent, a theoretical orphan and it needs a home. This home, however, cannot lie solely in the realm of behavior. We need a way of making a theoretical link between behavioral and physiological levels of analysis. Conversely, biological treatments of brain damage must consider behavior: neither behavioral nor biological treatments on their own can maximize the effectiveness of rehabilitation.

Robertson goes on to point out that one of the important questions in rehabilitation is whether to try to "restore lost functioning or to try to compensate for deficits." Some people believe that restitution can only occur if there is a sparing of a minimum proportion of cells or connections (Robertson & Murre, 1999; Sabel, 1997). If more than the critical proportion of cells is destroyed then compensatory strategies are necessary. Robertson says it is critically important to know whether or not sufficient cells and connections remain otherwise we will not know whether to attempt to restore lost function or teach people to compensate. Thus, for a patient with aphasia we need to know whether to tackle the aphasia or teach alternative means of communication; for a person with hemiplegia do we treat the motor deficit directly or provide alternatives such as a wheelchair; for someone with executive deficits do we remediate these or structure the environment so that planning problems can be bypassed? If we cannot answer these questions we may

Reprint requests to: Professor Barbara A. Wilson, MRC Cognition and Brain Sciences Unit, Box 58 (Elsworth House), Addenbrooke's Hospital, Hills Road, Cambridge CB2 2QQ, UK. E-mail: barbara.wilson@mrc-cbu.cam.ac.uk

waste precious therapy on ineffective treatments, we may damage the patient through harmful therapy and we may allow atrophy of brain tissue by failing to give correct stimulation.

"Cognitive neuroscience can help us with these questions," suggests Robertson. He gives several examples of how this has happened including neuroplasticity, reduction of unilateral neglect and remediation of executive disorders. As an example of neuroplasticity, Robertson describes a fascinating study by Molginer et al. (1993). In this study, the authors observed two adults with syndactyly (webbed fingers). These were studied before and after surgical separation of their webbed fingers. Magnetoencephalography was used to measure the representation in the brain of the hand. Before surgery the brain maps of the hand areas were shrunken and did not represent individual fingers. Within a few weeks of surgery cortical reorganization had occurred with an increase in the hand area of 3–9 mm together with representations for individual digits.

One of the examples Robertson gives of unilateral neglect is from his own work on limb activation. This work has established that people with neglect following right hemisphere stroke improve performance if they move their left arm or hand (Robertson et al., 1998). Later studies have shown that improvement only occurs if patients move the left limb in left space. Performance is not improved by moving the right hand in right space, the right hand in left space, the left hand in right space or *both* hands together. Thus, this is also an example of how general stimulation (moving both hands together) can lead to poorer performance. These findings are obviously important to people working with patients with neglect.

The third example I will give here from Robertson's paper, is the remediation of planning and organizational (executive) disorders. In one intriguing study (Manly et al., 2001), it was demonstrated that providing an external noise to patients with executive deficits following traumatic brain injury improved their performance on a planning task. Once again, this is an important finding and one we should be aware of in brain injury rehabilitation.

Cognitive rehabilitation according to Robertson is a structured, planned experience causing temporary or permanent changes in brain function; it must be embedded within a relevant theoretical framework and he argues that cognitive neuroscience provides that framework. His conclusions are that behavior changes the brain as much as it is determined by it and that we need all branches of neuroscience, particularly cognitive neuroscience, to understand how to harness this fact for rehabilitation.

The Limitations of Cognitive Neuroscience in Clinical Practice

Robertson's initially persuasive paper contains important findings and was very well received at the Berlin meeting so why was I uncomfortable with it and why did I feel that the promise had not been kept? My answer to this lies partly I think in the fact that Robertson's discussion of research findings and interpretations was directed solely at brain damage resulting from focal lesions rather than traumatic brain injury, and his examples were therefore based on cases resulting in specific sequelae that were more likely to be responsive to intervention by cognitive neuroscience. For me the promise has been kept only in such examples (and not in all cases of focal lesions) and certainly not across the whole spectrum of brain injury rehabilitation. In this paper, I wish to consider the current limitations of cognitive neuroscience when it is applied to brain injury rehabilitation in general. I use the word "current" here because it should be conceded that cognitive neuroscience is in its infancy and may in the future contribute more significantly to knowledge in the field of rehabilitation. For now, however, I would suggest that cognitive neuroscience remains in a state of possible future promise rather than widely applicable achievement in this field.

Most people receiving rehabilitation for the consequences of brain injury have both cognitive and non-cognitive problems. A typical patient in a rehabilitation center will have several cognitive problems such as poor attention, memory, planning, and organizational difficulties together with some emotional problems such as anxiety, depression or in some cases posttraumatic stress disorder. The patient may exhibit behavior problems such as poor self control or anger outbursts; there may be some subtle motor difficulties leading to reduced stamina and unsteady gait; there may well be problems connected with social skills and relationships; family members probably do not understand what has happened to the person they once felt they knew and understood and there will probably be issues connected with the continuation of work or education. All these important rehabilitation issues are hard or impossible to address with an approach derived solely from cognitive neuroscience. The same can be said both of the patient's pre-injury status which is also likely to impact on his or her post-injury status and the issue of cognitive reserve. People with the same amount of brain damage may have very different disabilities resulting from the damage. This is thought to be due to cognitive reserve; thus people with high reserve or more capacity can cope better with the limitations imposed by the brain damage than someone with less capacity or less cognitive reserve. Again, cognitive neuroscience on its own cannot be fully informative regarding these issues; nor can it provide insight into cognitive, social and behavioral problems faced by patients. The idea of treating the whole person which is imperative in brain injury rehabilitation is not new and has been espoused by Ben-Yishay (1978), Prigatano (1986, 1999) and Sohlberg and Mateer (1989, 2001).

Similarly regarding the question of compensation *versus* restitution (posed, incidentally, by Zangwill in 1947 and still not answered satisfactorily), decisions about which approach to take are made primarily through behavioral observations of patients' responses to treatment. It is possible that this will always prove to be the most economical and sensible way to decide between restoration or compensatory approaches. Furthermore, even though Robertson believes one's choice of strategy depends on the number of cells and connections remaining, I think that it also depends on the function concerned. For a person with organic amnesia there is no evidence that restoration of function can occur, while for a person with language or attention deficits the proportion of remaining cells and connections may be important.

Like Robertson, I am of the opinion that no single model or theory is sufficient in itself to inform the practice of cognitive rehabilitation. As we cannot therefore be constrained by any one theoretical approach (Wilson, 2002), I am left questioning the suggestion that cognitive neuroscience can be a complete answer. Even though biological and behavioral models are important, we need a whole range of other theories, models and frameworks to inform our rehabilitation practices (Wilson, 1997, 2002). It is not that the findings and models from cognitive neuroscience are wrong; it is rather that they are limited in terms of description. At one level everything we do is mediated by the brain and must have correlates in brain function, thus one could argue that all models and theories of behavior, learning, emotion and so forth can be understood within a neuroscience framework but the point I am trying to make here is that in terms of intervention, cognitive neuroscience does not always provide useful levels of description. To use an analogy provided by my colleague, Tom Manly, one can describe the making of a cake in terms of how the molecules interact or as a recipe. While both descriptions may be accurate the second description is more useful when one wants to cook a cake. Thus, some theories inform our rehabilitation strategies more than other theories and, I suggest, cognitive neuroscience has informed intervention to a lesser degree than theories of behavior, learning and emotion. At present, cognitive neuroscience has not kept its promise to brain injury rehabilitation. This is not true of other models as I hope to illustrate with an example.

CLINICAL EXAMPLE

One patient seen at the Oliver Zangwill Centre for Neuropsychological Rehabilitation illustrates a number of these points. At the age of 30, Mark fell 1000 feet while on a mountain biking holiday in Switzerland. It is thought that he stopped to take some photographs and when his friends moved on he stepped back and fell. He was airlifted to a specialist hospital where he received very good treatment. He sustained a very severe head injury, he was in coma for 1 week and in post traumatic amnesia for a further week. A CT scan showed a diffuse axonal injury, edema, small deep mid-line hemorrhages and a subdural hematoma. The hematoma was evacuated *via* a burr hole. Mark had a tracheostomy tube in for 10 days; he contracted meningitis, pneumonia and septicemia. Thus it can be seen that he had a stormy post injury course on the road to his final level of recovery.

Once stable, Mark was transferred to London and admitted to hospital there. He was said to be agitated and ataxic at this time. He received early rehabilitation and 9 months later was transferred to The Oliver Zangwill Centre for help with memory, attention and planning problems. He was described as lacking initiative and although he had some realization that all was not right in his everyday life, he did not appreciate the nature and extent of his problems nor the potential impact of these on his work.

Neuropsychological assessment showed that his general level of intellectual functioning was above average; he had particular problems with memory tasks, being at the first percentile on delayed memory on the Wechsler Memory Scale–Revised; and he experienced some problems with executive tasks (for example he was at the 10th percentile on Trails B).

Like all clients at the center, rehabilitation was focussed around goals. For a description of goal setting see Wilson et al. (2002). The goals were negotiated between the rehabilitation staff, Mark and his family, and were those that Mark wanted to achieve and expected to achieve by the end of his 6-month program.

Goals Agreed for Mark:

1. Develop an awareness of his strengths and weaknesses in a written form
2. Describe how these would impact on his domestic, social and work situations
3. Identify whether he can return to former employment (underwriter for an insurance firm)
4. Manage his own financial affairs independently
5. Demonstrate competence in negotiating skills as rated by a work colleague
6. Develop a range of leisure interests.

Mark attended both group and individual therapy during his 6-month program. Groups included the Understanding Brain Injury (UBI) Group, the Memory Group and The Problem Solving Group. Individual sessions included Psychological Support, Individual Memory Rehabilitation, Computer work and liaison with Mark's employers. Mark was an underwriter for a large insurance company and his company was keeping his job open for him in the hope he could return after rehabilitation. In the UBI group Mark learned about the effects of a brain injury and how cognitive, emotional, motor, social and behavioral problems might arise. The main purpose of this group was to increase patients' awareness and understanding of what had happened to them. In the memory group he was encouraged to keep a record of his memory failures and prompted in this if he failed to observe an error. Again this was to help improve his insight. He was also introduced to various memory aids and strategies. In the problem-solving group he was provided with strategies to cope with problem-solving difficulties (see

https://doi.org/10.1017/S1355617705050599 Published online by Cambridge University Press

Evans 2001 for a further description of the problem-solving group and strategies employed). Individual psychological support sessions addressed Mark's emotional well being and helped him to come to terms with his increasing awareness of the effects of his brain injury, including the fact that he would not find return to work as effortless as he once believed. In his individual memory therapy sessions, Mark learned to use an organizer to remember his daily schedule and mnemonics for remembering people's names. The computer work was largely centered around tasks he would need to do for a successful return to work. He was encouraged to consider what skills and tasks he would need to accomplish in order to function adequately at work. Liaison with the company began early to find out exactly what was required of Mark and to plan a gradual return to his former job.

Mark soon began to use the organizer effectively and continues to do so to this day. He set up a computer "contacts" card for recording relevant information such as names of customers and their birthdays, and other information to ensure they felt the company cared about them. He used the mnemonics taught to him for learning names of new people and other information and continues to use these. He also developed a data-base for high-risk areas such as the location of a major oil spill or earthquake as this could affect the decision to insure or not insure a company. Finally, return to work was carefully planned by Jonathan Evans, Mark's program co-ordinator. Mark began by going into work one day a week and shadowing a colleague. He gradually took on more responsibilities such as taking decisions in minimal risk situations with a senior colleague checking these decisions. He increased the number of days at work and gradually took on more responsibility. At first Mark's manager checked everything but as his confidence in Mark's capability grew he let Mark make the decisions.

Seven months after starting the program Mark returned to full-time work in his previous role and on the same salary. The program had allowed Mark's manager time to develop confidence in Mark's abilities in a high-risk business. It allowed Mark time to develop his self-confidence and time to learn to apply the strategies. Four years later Mark remains employed, a considerable feat for someone with his history. He has paid for the cost of his rehabilitation through the tax he pays and the tax paid by his employer.

There is little doubt that in this case rehabilitation was clinically and economically effective. However, it seems very remote from the cognitive neuroscience examples described earlier. It is possible that in Mark's case more areas of the brain were functioning, or functioning at a superior level, but we do not know this as Mark was not scanned before and after treatment. He may have had greater cognitive reserve and almost certainly had good pre-morbid functioning. Apart from the CT scan in hospital no other scans were administered. This is usually the case for rehabilitation patients. One wonders, if he had been scanned, would the findings have enabled us to improve on the rehabilitation program? Probably not. In keeping with most people with severe head injury, Mark did not have unilateral neglect so the elegant limb activation studies were not appropriate here. He did have attention and executive deficits so the alerting tones may well have improved his performance in certain situations. Findings from cognitive neuroscience may have been of limited use in planning Mark's program. As for teaching the use of memory aids and helping Mark to understand the effects of brain injury, I would suggest that learning theory is more relevant than cognitive neuroscience. In regard to the program that led to Mark's successful return to intellectually demanding work, as far as I am aware there are no studies from cognitive neuroscience that would have informed us how to do this.

It is also possible to find examples of successful rehabilitation that are not driven by theory. With Hazel Emslie, Jonathan Evans and other colleagues I have published several papers evaluating a paging system for people with memory and/or planning problems. This system, NeuroPage, was developed by a father for his head injured son. The father was an engineer with no knowledge of psychology, neuroscience or learning theory who simply wanted to help his son remember what to do and where to go when he went back to college after his head injury. It has been one of the most rewarding areas of research I have ever worked in. We have established that NeuroPage can increase independence and save money for health and social services (Evans et al., 1998; Wilson et al., 1997, 1999, 2001, 2002, 2003; Wilson & Evans, 2003). As a result of our research, the local National Health Service Trust has set up a NeuroPage service for people throughout the United Kingdom. This is a good example of how research that has not been informed by cognitive neuroscience has influenced clinical practice.

OTHER USEFUL MODELS AND THEORIES IN BRAIN INJURY REHABILITATION

Apart from behavioral, physiological or biological models considered by Robertson (2002) to be important in rehabilitation, what other models might be available to us? Theories and models of emotion are becoming increasingly important in cognitive rehabilitation and may make all the difference between a successful and unsuccessful outcome. Gainotti (1993) suggests there are three main categories of emotional disorder: first, such disorders may arise as a direct result of neurological damage, thus someone with a specific lesion in the limbic system may be unable to regulate emotional and social behavior. Gainotti points out that this is typically seen in people with closed head injury. Another example would be a patient with a right hemisphere stroke who is unable to judge and express emotion accurately. The second category includes emotional disorders that arise from psychological or psychodynamic factors; for example, loss of cognitive ability may cause poor self-esteem and depression. The third category includes emotional problems that result from psychosocial causes, the effect that the consequences of brain injury have on the patient's social activities and social network, for example; thus social isolation, common after traumatic head injury, may give rise to depression.

Although some cognitive neuroscientists may be interested in emotion and the areas of the brain involved in emotion, their work has to date had little influence on treatment of emotional problems in survivors of brain injury even though sometimes such treatment may override cognitive needs. One of the Oliver Zangwill Centre patients was stabbed through the head in the right temporoparietal area with a hunting knife while traveling on a train. She was 19 years old at the time and did not lose consciousness, probably because the knife did not enter her brain stem. She described feeling a pain in her head and a weight as if the carriage had fallen on top of her. She stood up and realized that something terrible had happened. She went into the next carriage where another man told her to sit down and stay still and he would get help. She put her hand up and felt the knife and asked if she was going to die. The man said "No" and that he would get help. At the next stop an ambulance arrived and took her to hospital.

After a few months she came to our rehabilitation center. She had a number of cognitive problems including visuospatial and memory deficits but the emotional difficulties almost certainly took priority in treatment. She was anxious and avoided many social situations, she would not look at people, feared for her family, had classic symptoms of posttraumatic stress disorder including flashbacks and nightmares and refused to go on public transport. Like Mark, she had both group and individual therapy including a considerable amount of psychological support and treatment for the emotional problems identified (Williams et al., 2003). This involved cognitive behavior therapy including stress inoculation and graded exposure to situations she avoided. She also had treatment for her cognitive difficulties but if these had been the only ones treated, it is doubtful that she would have made such a good recovery and returned to a full and meaningful life.

Models and theories of behavior have also played a large part in brain injury rehabilitation for many years (Wilson, 1991). They are particularly useful because they provide structure, ways of analyzing problems, a means of assessing everyday manifestations of problems, and methods for analyzing treatment effectiveness. Alongside behavioral models and theories are models and theories of learning. In 1993 Baddeley said, "A theory of rehabilitation without a model of learning is a vehicle without an engine" (Baddeley, 1993, p. 235). An important aspect of neuropsychological rehabilitation in the past 10 years is Errorless Learning—a teaching technique whereby people with organic memory deficits are prevented from making mistakes while learning (Baddeley & Wilson, 1994; Clare et al., 2000; Wilson et al., 1994). Errorless learning is now a widely used strategy in memory rehabilitation and is a good example of how two different types of theoretical models have come together. Errorless discrimination learning from behavioral psychology (Terrace, 1963, 1966) and implicit learning from cognitive psychology (e.g., Schacter, 1985) were the two theoretical strands that led Baddeley and Wilson to start evaluating errorless learning for people with memory difficulties. This work provides evidence of how clinical practice develops from theoretical underpinnings. In our first study we asked the question, "Do amnesic people learn better if prevented from making mistakes while learning?" and followed an experimental design that required people to learn lists of words. Once we had an answer to the question (Yes), we wanted to know if the principle could be applied to real life problems and again the answer was positive.

The work cited above provides evidence that models from many sources can be drawn upon in the treatment of brain injured people. Models of assessment, recovery and compensation as well as models of cognitive functioning and models from cognitive neuroscience are all important in trying to understand and reduce the complex problems of people with brain injury.

CONCLUSIONS

There is much evidence to support the fact that many successful rehabilitation programs have *not* relied upon cognitive neuroscience for their theoretical input. Findings from cognitive neuroscience are indeed important, and some exciting research is coming from workers in this field, but we should not forget that there are other fields and other approaches. We need to draw on a number of fields in our clinical practice. If we are too wedded to one approach or one style, this is likely to lead to poor clinical practice. Brain injury rehabilitation makes clinical and economic sense but we must not lose sight of the needs of the individual patients, their families, their many different problems and their need to return to their own most appropriate environments.

ACKNOWLEDGMENTS

I would like to thank Tom Manly, Fergus Gracey, Huw Williams and Jon Evans for their helpful comments on earlier drafts of this paper; and to three reviewers who allowed me to improve the paper; also Mark for permission to use details of his rehabilitation program and Julia Darling for typing several versions of the paper.

REFERENCES

Baddeley, A.D. (1993). A theory of rehabilitation without a model of learning is a vehicle without an engine: A comment on Caramazza and Hillis. *Neuropsychological Rehabilitation*, *3*, 235–244.

Baddeley, A.D. & Wilson, B.A. (1994). When implicit learning fails: Amnesia and the problem of error elimination. *Neuropsychologia*, *32*, 53–68.

Ben-Yishay, Y. (Ed.) (1978). *Working approaches to remediation of cognitive deficits in brain damaged persons* (*Rehabilitation Monograph*). New York: New York University Medical Center.

Clare, L., Wilson, B.A., Carter, G., Breen, E.K., Gosses, A., & Hodges, J.R. (2000). Intervening with everyday memory problems in Dementia of Alzheimer Type: An errorless learning approach. *Journal of Clinical and Experimental Neuropsychology*, *22*, 132–146.

Evans, J.J. (2001) Rehabilitation of the dysexecutive syndrome. In R.L. Wood & T.M. McMillan (Eds.), *Neurobehavioural disability and social handicap following Traumatic Brain Injury* (pp. 209–227). Hove, UK: Psychology Press.

Evans, J.J., Emslie, H., & Wilson, B.A. (1998). External cueing systems in the rehabilitation of executive impairments of action. *Journal of the International Neuropsychological Society*, *4*, 399–408.

Gainotti, G. (1993). Emotional and psychosocial problems after brain injury. *Neuropsychological Rehabilitation*, *3*, 259–277.

Manly, T., Hawkins, K., Evans, J.J., Woldt, K., & Robertson, I.H. (2001). Rehabilitation of executive function: Facilitation of effective goal management on complex tasks using periodic auditory alerts. *Neuropsychologia*, *40*, 271–281.

Molginer, A., Grossman, J.A.I., Ribary, U., Joliot, M., Volkmann, J., Rapaport, D., Beasley, R.W., & Llinas, R.R. (1993). Somatosensory cortical plasticity in adult humans revealed by magnetoencephalography. *Proceedings of the National Academy of Sciences*, *90*, 3593–3597.

Prigatano, G.P. (1986). Personality and psychosocial consequences of brain injury. In G.P. Prigatano, D.J. Fordyce, H.K. Zeiner, J.R. Roueche, M. Pepping & B.C. Wood (Eds.), *Neuropsychological rehabilitation after brain injury* (pp. 29–50). Baltimore: The Johns Hopkins University Press.

Prigatano, G.P. (1999). *Principles of neuropsychological rehabilitation*. New York: Oxford University Press.

Robertson, I.H. (2002). Cognitive neuroscience and brain rehabilitation: A promise kept. *Journal of Neurology, Neurosurgery and Psychiatry*, *73*, 357.

Robertson, I.H., Hogg, K., & McMillan, T.M. (1998). Rehabilitation of unilateral neglect: Improving function by contralesional limb activation. *Neuropsychological Rehabilitation*, *8*, 19–29.

Robertson, I.H. & Murre, J.M.J. (1999). Rehabilitation of brain damage: Brain plasticity and principles of guided recovery. *Psychological Bulletin*, *125*, 544–575.

Sabel, B.A. (1997). Unrecognized potential of surviving neurons: Within-systems plasticity, recovery of function and the hypothesis of minimal residual structure. *Neuroscientist*, *3*, 366–370.

Schacter, D.L., Rich, S.A., & Stampp, M.S. (1985). Remediation of memory disorders: Experimental evaluation of the spaced-retrieval technique. *Journal of Clinical and Experimental Neuropsychology*, *7*, 79–96.

Sohlberg, M.M. & Mateer, C.A. (1989). *Introduction to cognitive rehabilitation: Theory and practice*. New York: Guilford Press.

Sohlberg, M.M. & Mateer, C.A. (2001). *Cognitive rehabilitation: An Integrative Neuropsychological Approach*. New York: Guilford Press.

Terrace, H.S. (1963). Discrimination learning with and without "errors." *Journal of Experimental Analysis of Behavior*, *6*, 1–27.

Terrace, H.S. (1966). Stimulus control. In W.K. Honig (Ed.), *Operant behavior: Areas of research and application* (pp. 271–344). New York: Appleton-Century-Crofts.

Williams, W.H., Evans, J.J., & Wilson, B.A. (2003). Neurorehabilitation for two cases of post-traumatic stress disorder following traumatic brain injury. *Cognitive Neuropsychiatry*, *8*, 1–18.

Wilson, B.A. (1991). Behaviour therapy in the treatment of neurologically impaired adults. In P.R. Martin (Ed.), *Handbook of behavior therapy and psychological science: An integrative approach* (pp. 227–252). New York: Pergamon Press.

Wilson, B.A. (1997) Cognitive rehabilitation: How it is and how it might be. *Journal of the International Neuropsychological Society*, *3*, 487–496.

Wilson, B.A. (2002). Towards a comprehensive model of cognitive rehabilitation. *Neuropsychological Rehabilitation*, *12*, 97–110.

Wilson, B.A., Baddeley, A.D., Evans, J.J., & Shiel, A. (1994). Errorless learning in the rehabilitation of memory impaired people. *Neuropsychological Rehabilitation*, *4*, 307–326.

Wilson, B.A., Emslie, H., Quirk, K., & Evans, J. (1999). George: Learning to live independently with NeuroPage®. *Rehabilitation Psychology*, *44*, 284–296.

Wilson, B.A., Emslie, H.C., Quirk, K., & Evans, J.J. (2001). Reducing everyday memory and planning problems by means of a paging system: A randomised control crossover study. *Journal of Neurology, Neurosurgery and Psychiatry*, *70*, 477–482.

Wilson, B.A. & Evans, J.J. (2003). Does cognitive rehabilitation work? Clinical and economic considerations and outcomes. In G. Prigatano (Ed.), *Clinical neuropsychology and cost-outcome research: An introduction* (pp. 329–349). Hove, UK: Psychology Press.

Wilson, B.A., Evans, J.J., Emslie, H., & Malinek, V. (1997). Evaluation of NeuroPage: A new memory aid. *Journal of Neurology, Neurosurgery and Psychiatry*, *63*, 113–115.

Wilson, B.A., Evans, J.J., & Keohane, C. (2002). Cognitive rehabilitation: A goal-planning approach. *Journal of Head Trauma Rehabilitation*, *17*, 542–555.

Zangwill, O.L. (1947). Psychological aspects of rehabilitation in cases of brain injury. *British Journal of Psychology*, *37*, 60–69.