Donald T. Stuss: A Remembrance

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ORIGINS

Donald T. Stuss, PhD, OC, OOnt, FRSC, one of the giants of modern neuropsychology, died on September 3, 2019, of complications from pancreatic cancer after a short illness. He was 77 (Figure 1). Don did not follow a normal path to his eventual prominence. He was born in Sudbury, Northern Ontario, in 1941, but spent most of his early life in Kitchener-Waterloo. His father, Nicholas Stuss, had emigrated from Ukraine to Canada in 1921. He and his wife, Ann, owned a small restaurant in Kitchener called "Ann's Diner."

Don did well in school, and his parents encouraged him to study law or medicine. However, Don was rebellious. After he graduated from high school in 1959, he entered a monastery in Mundare, Alberta, run by the Order of St. Basil the Great, part of the Ukrainian Catholic Church. Figure 2 shows a photograph of the young seminarian with his mother in the early 1960s. At the monastery, Don studied and worshipped for 6 years, 3 years of which were under a vow of silence. Toward the end of his training, Don spent a brief time carrying out missionary work in Chad. He enjoyed the contemplative life but was restless. Being Don, he needed to act as well as meditate. Contemplation provided general principles, but these were of little use unless they served to guide behavior. One day just before Don was to become ordained as a priest, a colleague asked him whether he was happy, and he realized that he was not. He later remarked how truly disconcerting the question was.

Don left the monastery in 1965 and obtained bachelor's degrees in philosophy from both the University of Ottawa and St. Paul's University in 1967. A formative influence for him during this time was the work of Pierre Teilhard de Chardin, whose book *The Phenomenon of Man* (1959) considered evolution in theological terms. Teilhard de Chardin proposed that human evolution is part of the more general progress of the universe toward a state of maximum complexity and consciousness. Don found comfort in this combination of the mystical with the scientific.

Don subsequently taught high school and coached school football in Peterborough, Kitchener, and Ottawa. These were times of enjoyment and enthusiasm. Always innovative, he once had his football team punt on second down. The opposition was befuddled, and the kicker was able to collect his own kick and run in the winning touchdown. Don married Kaaren Kummer in 1969 and started a family. A son, David, was born in 1973, and a daughter, Leanne, in 1974. Don enjoyed teaching and counseling but realized he did not know enough about how brains and minds developed.

We can perhaps locate the beginning of Don's interest in the frontal lobes to this time. Child-centered learning was being advocated, and Don believed in the importance of fixing the attention of the class on what he was trying to teach them. In an attempt to find some intellectual mentor, he came across the Russian psychologist Lev Vygotsky and his book *Thinking and Speech* (published in 1934, translated 1962). Through him, Don also came to read his collaborator, Alexander Luria, whose

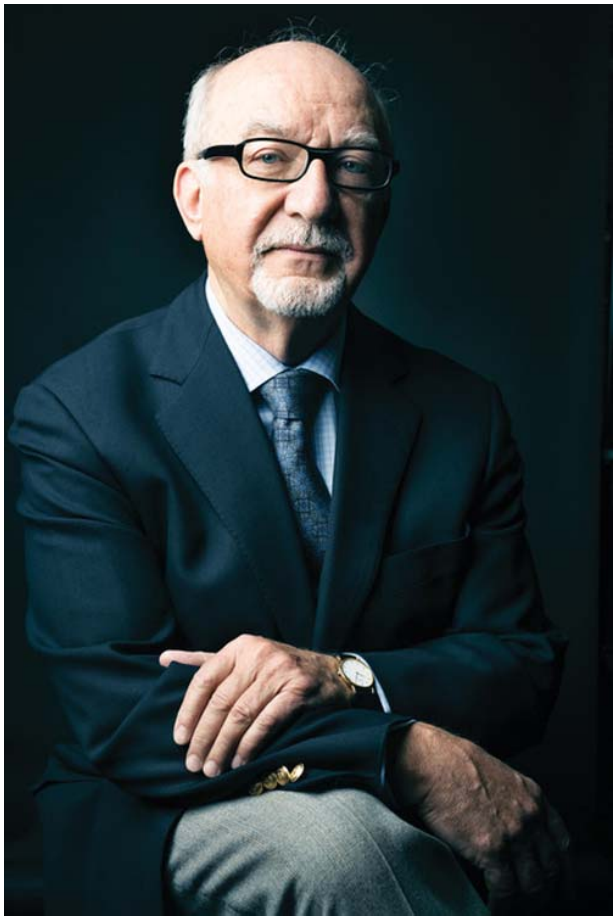

Figure 1. 2013, photo by Christopher Wahl.

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books *Higher Cortical Functions in Man* (1962) and *The Working Brain* (1973) described how human psychological processes could be localized to different regions of the brain and more specifically how the frontal lobes programmed and regulated these processes.

In 1972, he returned to university to study psychology at the University of Ottawa, receiving his MA in 1974 and his PhD in 1976. During this time, he was fascinated by the Human Neurophysiology and Neuroanatomy course that he took in the Medical School. He put together a map of all the anatomical connections of the frontal lobes and located possible psychological functions in each of the connections. Don's diagram was large (about 3 × 5 ft) and extremely intricate. This wondrous map was unfortunately lost, but many of its ideas survive in his later writings.

Don then completed a postdoctoral fellowship at the Aphasia Research Center at the Boston Veteran's Medical Center, where he carried out research with Harold Goodglass, Edith Kaplan, and Frank Benson. He returned to Ottawa in 1978, joining the Department of Medicine at the University of Ottawa. He taught and did research in both the School of Medicine and the School of Psychology, rising to Professor in 1989.

From this time on, Don's career took an additional new path, that of research leadership, initially at the Rotman Research Institute in Toronto and then, also in Toronto, at the Ontario Brain Institute. We return to these achievements later.

RESEARCH CONTRIBUTIONS

His personal research career, which had begun in Ottawa and Boston, really flourished in Toronto. There was one overriding strand in his research from the early 1970s onward—a fascination with the functions of the human prefrontal cortex. Indeed, it is our view that that he made the largest contribution to our understanding of prefrontal cortex of any neuropsychologist since the great pioneers Brenda Milner and Alexander Luria.

Don began research not in neuropsychology but in electroencephalography with Roger Broughton and Terry Picton in Ottawa. Don's early research efforts were not always successful. An early project was to study the psychology and physiology of "short-sleepers"—people who only need to sleep for brief periods. One of his subjects was an Indian Swami who claimed that he never had to sleep. Don set him up for an overnight recording to see how his brain waves changed during this prolonged wakefulness. During the night, there were multiple fire alarms, and ultimately, everyone had to evacuate the building. The Swami slept peacefully through all the alarms and was very disconcerted to be woken up for the evacuation.

Don's PhD work involved recording the event-related potentials during a task derived from the Weigl and Wisconsin Card Sorting tests of frontal lobe function. Then, during his postdoctoral fellowship in Boston, he studied a large cohort of people who had had frontal leucotomies years earlier. This work with Frank Benson and Edith Kaplan cemented his life-long interest in the impairment patterns, evaluation, and treatment of disorders of the frontal systems. In Ottawa, he continued active research in the psychophysiological measures of cognition and the neuropsychological assessments of patients with frontal lobe lesions but expanded his interests to brain injury and to rehabilitation.

One characteristic of patients with traumatic brain injury is that their real-life deficit is far greater than can be easily explained on the basis of the deficits found on neuropsychological tests. Despite their apparent competence, they have difficulty returning to employment and coping with normal life stresses. Don realized that a major factor is variability in performance: Patients do not behave consistently and cannot follow through on tasks. Much of this was likely related to frontal lobe damage. Their relatively normal performance on testing was perhaps due to the neuropsychologist taking on the role of the patient's frontal lobe, making sure that the patient stayed with the tests.

Once in Toronto, his research on the neuropsychology of frontal lobe function blossomed in a number of different ways. Initially, he was concerned that there was very little knowledge of the particular areas within frontal cortex where damage could lead to problems on standard clinical frontal lobe tasks such as the Wisconsin Card Sorting Test, Verbal Fluency, Trail-Making Test, and Stroop Test. So, in a series of studies, principally with Michael Alexander, he remedied the problem. The pair

Figure 2. Early 1960s, the young seminarian with his mother, Ann Stuss.

related accurate measurements of a variety of aspects of behavior to precise delineations of lesions in a large sample of neurological patients—methods that he continued to use throughout his research career.

He was aware, however, that such clinical tests were highly complex, involving many processing subcomponents, and therefore were not very suitable for basic science advances. For that, he believed a set of simpler tasks were needed—and ones that had as far as possible similar stimulus and response requirements. With this philosophy, for over 15 years, Don led an international group of scientists who evaluated an empirically derived model of attention in patients with precisely delineated frontal lesions (Figure 3). Each patient was tested with a battery of simple behavioral tests—the ROtman–Baycrest Battery to Investigate Attention (ROBBIA). The acronym alludes to the Florentine Andrea della Robbia, in whose ceramic sculptures subjects are distinguished from background by means of color and relief. Over the years, ROBBIA led to numerous important findings about how different regions of the frontal lobes contribute to simple attentional behaviors.

The first research paper from the test battery showed that the speed of response is controlled by more than one frontal system. The superior medial regions of the frontal lobe are essential for rapid reaction time, either generally or specifically following a warning stimulus. These regions "energize" other supervisory processes. Monitoring of stimulus occurrence and response behavior to enhance the speed of response to upcoming stimuli is, by contrast, sensitive to right lateral lesions of the frontal lobe.

His research on frontal functions was far from limited to these major projects. Some intriguing highlights of his research in this period were his description of how the human sense of humor depends upon the normally functioning right frontal lobe and how the frontal lobes are essential to the development of a theory of mind and a sense of self.

Much of what happens to cognition as we get older depends on how well frontal systems can maintain performance and even compensate for deteriorating abilities. His research supported the idea that aging is not simply a slowing of general processing. Rather different processes age differently. Some cognitive processes deteriorate quickly after middle age, and some persist well into old age. Cognitive aging is not an escarpment but follows multiple slopes.

Don was the quintessential collaborator. Getting people to work together was his forte. As well as the ROBBIA group, Don also collaborated extensively with Sandra Black at Sunnybrook Hospital. In addition, he was instrumental in getting an international group of experts together to set diagnostic criteria for frontotemporal lobar degeneration.

Don's research was published in over 200 articles. He also distilled his extraordinarily wide knowledge of the neuropsychology of patients with frontal lobe lesions in a considerable number of review articles and books.

Figure 3. ROBBIA Research Group in Trieste, Italy: Stuss, Alexander, Picton, and Shallice working on one of the early ROBBIA papers.

FUNCTIONS OF THE FRONTAL LOBE

Throughout his adult life, Don worked on a theory of how the prefrontal regions of the human brain operate. The following brief summary is based upon his chapter in the *Encyclopedia of Clinical Neuropsychology* (2017).

Don was very early in proposing that there is no single frontal executive or superior attentional system. Rather many different frontal systems interact among themselves and with other regions of the brain in shifting networks. Don was particularly intrigued by five different systems:

(i) Superior medial frontal regions are held to activate or "energize" other cognitive functions and in particular supervisory ones. Extensive damage to this region can result in abulia, apathy, or akinetic mutism. Less extensive damage makes patients slow to initiate and sustain mental processes. This slowness is observed in many tests, from reaction time tests to "fluency" generation ones.

(ii) Left lateral frontal regions are held to be essential to task setting and planning. This impairment is revealed in many tasks: impaired learning in the early trials of, for instance, serial reaction time or the Wisconsin Card Sorting Test; false positive errors indicating impaired criterion setting in a feature integration task; and false analogous errors in memory recognition in a word list learning task.

(iii) Right lateral frontal regions are held to be involved in monitoring performance. Damage here causes deficits on several tasks. There is the lack of the normal decrease in reaction time with longer interstimulus intervals in a so-called "variable foreperiod" task, variability in a timed tapping task, and inconsistency in recall over repeated word lists.

(iv) Ventromedial prefrontal (orbitofrontal) cortex is held to be involved in emotional processing and

behavioral regulation. Patients with lesions to this area have difficulty in understanding the emotional consequences of their behavior. Tasks sensitive to damage in this region are gambling tasks and the learning (and reversal) of stimulus–reward associations.

(v) Frontopolar regions (Brodmann's area 10) are held to be critical for metacognitive aspects of human behavior: autonoetic consciousness, theory of mind, empathy, self-awareness, humor appreciation, and personality. These behaviors require a representation of one's own mental states, beliefs, attitudes, and experiences.

Don focused on these five prefrontal systems. The frontal regions are, of course, the seat of many other cerebral processes such as memory access, language generation and more specifically syntax, and working memory. One day, Don hoped to bring them all together.

THE MASTER WEAVER

In 1989, Don began an equally important aspect of his career—research leadership. In that year, he accepted the challenge of building a human neuroscience research program at the Baycrest Centre in Toronto by becoming the Founding Director of the Rotman Research Institute (RRI). In this, Don worked closely with the entrepreneur/philanthropist Joseph Rotman, who had raised funds for an institute at the Baycrest Centre to evaluate the effects of aging and aging-related diseases on the human brain. Theirs was a very productive partnership. Joe convinced governments and institutions to support the research, and Don made sure that the research was significant.

Don began by recruiting Fergus Craik, Morris Freedman, Morris Moscovitch, and Endel Tulving as scientists. He quickly set up links to other Toronto institutions to allow research with magnetic resonance imaging (at Sunnybrook with Sandra Black) and positron emission tomography (at the Centre for Addiction and Mental Health with Sylvain Houle and Shitij Kapur). From this original nucleus and its linkages, Don was able to build one of the world's most prestigious centers for cognitive neuroscience. Don's leadership followed several guiding principles. The first was that the institute's endowment should be primarily used for people rather than for projects. The institute invested in good scientists and freed up their time so that they could devote themselves to research. Don's idea was that such scientists could then find their own research funds through peer-reviewed granting agencies. He made sure that scientists were chosen for both their scientific excellence and their collegiality. The latter quality would ensure collaboration both within the institute and with outside scientists. A second principle was that there was no tenure: A scientist's position was only guaranteed as long as he or she remained productive. A third principle was that the institute's research should be focused on clinical problems, particularly those related to aging. To ensure this, Don fostered the institute's clinical connections, promoted the transfer of new scientific findings to industry, and sponsored annual conferences to bring the results of research to public attention. A fourth principle was that the institute should be advised by a panel of independent international experts. Every 5 years, this panel reviewed the progress of the institute and its scientists and advised on its future. A final principle was that the director should remain active in research. Only then could he understand the needs and problems of other scientists.

Those who worked with him in the RRI found Don to be a congenial leader with an uncanny ability to bring people together. He had a great sensitivity to the needs of others and a depth of insight into ways to solve administrative problems. This was perhaps most evident in the way that he got the scientists at the institute to work together productively. In the words of Randy McIntosh, who took over after Don retired as director of the institute, Don was a "master weaver" of people and projects.

The institute quickly gained international stature. The 2008 external review concluded: "In the course of less than two decades, the RRI has firmly established itself as the leading research institution in the field of memory and aging. It has developed a framework for investigating adult age changes in the organization of memory, working memory, and executive functioning that has been so immensely successful that many of the younger researchers around the world are not even aware that their research builds on theories and discoveries made at the RRI."

Figure 4 shows several of the RRI scientists at Don's cottage in September 2006. An intriguing aspect of the photograph is how everyone looks so unabashedly happy. It is highly unusual to have a photograph of nine people all smiling so naturally. We think that this indicates the "Stuss effect."

After 20 years of directing the RRI, Don retired briefly and then became the Founding President and Scientific Director of the Ontario Brain Institute (OBI) in 2011. This new institute was funded to promote brain research by the Government of Ontario, once again under the instigation of Joseph Rotman. Don led this institute until 2016. During his leadership, the institute set up a marvelously collaborative network of research in the province. Don followed several administrative principles. The first was that support should go toward research that could ultimately improve the care of patients. Through workshops and consultations, the institute identified five areas where clinical problems needed help and where scientists in the Province of Ontario had the expertise to provide this help: cerebral palsy, depression, epilepsy, neurodegenerative disorders, and neurodevelopmental disorders. In each of these areas, the institute then sponsored "integrative discovery programs" for collaborative research. The second principle was that the institute would not provide outright grants for research projects but would enter into partnerships with the research institutes of Ontario. This ensured

Figure 4. 2006, Rotman scientists at Stuss cottage: Lourenza Fourie, Donald Stuss, Cheryl Grady, Endel Tulving, Ruth Tulving, Randy McIntosh, Bernhard Ross, Gus Craik, and Steve Strother.

that the science would be supported by both the OBI and the specific institute wherein the research was being performed. A third principle was that the OBI would operate as a network of collaborating nodes. Each node was equal; there was no central node. This approach most likely came from Don's ideas about how the human brain works through interacting networks. A final principle was that all the data collected should be available for research use by other investigators. To this end, the OBI set up a central database to allow information to be shared by all the participating scientists. This database was carefully designed to ensure standardization of the information, to maintain the privacy of any personal data, and to allow access by specialized analytical programs.

Under Don's visionary leadership, the OBI became very productive. An external review described the collaboration and integration in the discovery programs as "unprecedented" and assessed the ongoing research as "transformational, scientifically excellent and internationally significant." Don's principles-based approach extended to his leadership and mentorship of the OBI staff. He taught an approach to management and education based on our knowledge of the frontal lobes. Everyone who worked with Don understood how this "executive of the brain" operated through energization, task setting, monitoring, emotional regulation, and metacognition. Don embodied these principles, and his vision for "science with impact" lives on in those who had the privilege of working with him. The staff of the OBI all affectionately recall his belief that kindness and humanity can often solve seemingly intractable situations.

TALKING AND TEACHING

After establishing the OBI, Don "retired" again in 2016 and settled into a few years of mentoring and advising as an Affiliate Scientist in the Evaluative Clinical Sciences at Sunnybrook Research Institute. Here, he worked with Sandra Black and helped teach her students, fellows, and residents. Don loved that role—for the first time in his life, he could concentrate on clinical teaching with no administrative responsibilities. He and his new partner, Lourenza Fourie, also operated a clinical practice wherein they used the principles that he had derived from research to help rehabilitate patients with brain damage.

Don was an enthusiastic lecturer and was frequently invited to speak at universities and at international meetings. Some idea of these presentations can be obtained from the title of a recent talk. In 2016, he gave a keynote lecture to the World Congress of Brain, Behavior and Emotions in Buenos Aires: "Social cognition and the frontal lobes: Amazing what patients can teach you if you just listen, observe, think and measure."

Don loved to teach. He mentored graduate students, neurology trainees, neuropsychologists, medical students, and anyone who asked him a question. It is hard to compute the number of neuroscientists, neuropsychologists, and neurologists who carry his notions of frontal functions and impairments forward.

HONORS

Don received many honors in recognition of his clinical work and research leadership. He became an Officer in the Order of Ontario in 2001 and in the Order of Canada in 2017. As an officer of the Order of Canada, Don was able to preside at citizenship ceremonies for new Canadians. As a child of an immigrant from Ukraine, Don thoroughly enjoyed this responsibility.

He was elected as a Fellow in the Royal Society of Canada in 2004 and the Canadian Academy of Health Science in 2005. In 2004, he was elected University Professor at the University of Toronto (awarded to only 2% of the academic staff). He was elected as a fellow in

multiple national and international societies: the American Association for the Advancement of Science, the American Psychological Association, the American Psychological Society, the American Heart and Stroke Association, and the Canadian Psychological Association. Don received lifetime achievement awards from the International Neuropsychological Society, where he had also been President, and from the National Academy of Neuropsychology. In 2014, he was given the Gold Key Award of the American Congress of Rehabilitation Medicine. In 2016, the Canadian Society for Brain, Behaviour and Cognitive Science honored him with their highest recognition: the Donald O. Hebb Distinguished Contribution Award.

Figure 5. 1990, on the Nahanni River.

PERSON

Always generous and never too serious or full of his own achievements, Don enjoyed his life outside the academy and the hospital. He loved being Canadian and he loved all things Canadian. Proud of his Ukrainian background, he was happy discovering a small restaurant that made excellent perogies on the route to his cottage in the north. He loved food and drink. He was an excellent dancer and was the last to drop at many a party. He relished long canoe trips in the north. Figure 5 shows his white-water prowess on the Nahanni River in 1990. On this trip, he joined a group of neurosurgeons led by John Girvin. Don was Mike Schwartz's "trusty bowman." He loved music and maintained an insanely huge CD collection that ranged from Bach to country western. He went to Stratford every year for back-to-back plays.

Don believed that his unusual path to his career was an essential element to his success. In the monastery, he learned contemplation and the importance of reflection before action. No longer traditionally religious, he maintained a respect for and interest in spirituality of any type. He was always sympathetic and forgiving of the foibles of others. As a coach of high school football, he learned to identify and utilize the strengths of his team and the abilities of individuals and then work together to a goal that no one on the team could achieve on his or her own. Monastic contemplation and high school football made good guides for a lifetime of achievement.

WHAT MAKES US HUMAN

Throughout his career, Don tried to understand, as much as possible, the cerebral bases of those activities we consider characteristically "human": remembering, planning, judging, attending, laughing, and imagining. We shall leave the last words to Don and quote from the final summary in his 1986 book *The Frontal Lobes*.

> The human prefrontal cortex attends, integrates, formulates, executes, monitors, modifies, and judges all nervous system activities. Most individual mental functions, those carried out by the posterior systems, can be maintained without prefrontal participation, but the responses are automatic and the qualities that make a well-rounded human are clearly deficient. In this mechanical functioning, the posterior functional systems and even some parts of the frontal functional systems, resemble the activities postulated for advanced generations of computers by the more ardent advocates of artificial intelligence…. The mental abilities attributed to the higher levels of prefrontal activity, however, are clearly beyond current computer potentials.
>
> Although not the seat of "intelligence" demonstrated by formal IQ tests, the prefrontal lobes are essential for the highest of mental activities, those demanding control of intelligence. Moreover, in the role of "I," the consciousness of self, the prefrontal structures bridge the gap between the complex, multi-integrated response mechanisms that make up the brain and the free-willed, independently thinking entity called the mind. The mind–brain dichotomy is more clearly expressed and loses sharp differentiation with study of prefrontal functioning. Investigation of these functions are difficult and easily lead to erroneous simplifications. Nevertheless, it is through understanding the influence of prefrontal brain structures on mental activity that the true essence of humanness will be approached. The frontal lobes are the key to the highest human functions.

KEY PUBLICATIONS

Books

Stuss, D. T., & Benson, D. F. (1986). *The frontal lobes*. New York: Raven Press.

Stuss, D. T., Winocur, G., & Robertson, I. H. (Eds.). (2008). *Cognitive neurorehabilitation: Evidence and application* (2nd ed.). Cambridge, UK: Cambridge University Press.

Stuss, D. T., & Knight, R. T. (Eds.). (2013). *Principles of frontal lobe function* (2nd ed.). New York: Oxford University Press.

Reviews

Stuss, D. T., & Alexander, M. P. (2000). Executive functions and the frontal lobes: A conceptual view. *Psychological Research*, *63*, 289–298.

Stuss, D. T., & Binns, M. A. (2001). Aging: Not an escarpment, but multiple slopes. In M. Naveh-Benjamin, M. Moscovitch, & H. L. Roediger, III (Eds.), *Perspectives on human memory and cognitive aging: Essays in honour of Fergus Craik* (pp. 334–347). East Sussex, United Kingdom: Psychology Press.

Stuss, D. T., & Levine, B. (2002). Adult clinical neuropsychology: Lessons from studies of the frontal lobes. *Annual Review of Psychology*, *53*, 401–433.

Stuss, D. T. (2017). Frontal lobes. In J. S. Kreutzer, J. DeLuca, & B. Caplan (Eds.), *Encyclopedia of clinical neuropsychology* (2nd ed.). Cham, Switzerland: Springer.

Research Papers

Alexander, M. P., Stuss, D. T., & Benson, D. F. (1979). Capgras syndrome: A reduplicative phenomenon. *Neurology*, *29*, 334–339.

Stuss, D. T., Shallice, T., Alexander, M. P., & Picton, T. W. (1995). A multidisciplinary approach to anterior attentional functions. *Annals of the New York Academy of Sciences*, *769*, 191–211.

Wheeler, M. A., Stuss, D. T., & Tulving, E. (1997). Toward a theory of episodic memory: The frontal lobes and autonoetic consciousness. *Psychological Bulletin*, *121*, 331–354.

Neary, D., Snowden, J. S., Gustafson, L., Passant, U., Stuss, D. T., Black, S., et al. (1998). Frontotemporal lobar degeneration. A consensus on clinical diagnostic criteria. *Neurology*, *51*, 1546–1554.

Levine, B., Black, S. E., Cabeza, R., Sinden, M., McIntosh, A. R., Toth, J. P., et al. (1998). Episodic memory and the self in a case of isolated retrograde amnesia. *Brain*, *121*, 1951–1973.

Craik, F. I. M., Moroz, T. M., Moscovitch, M., Stuss, D. T., Winocur, G., Tulving, E., et al. (1999). In search of the self: A positron emission tomography study. *Psychological Science*, *10*, 26–34.

Shammi, P., & Stuss, D. T. (1999). Humour appreciation: A role of the right frontal lobe. *Brain*, *122*, 657–666.

Stuss, D. T., Gallup, G. G., & Alexander, M. P. (2001). The frontal lobes are necessary for "theory of mind." *Brain*, *124*, 279–286.

Stuss, D. T., Murphy, K. J., Binns, M. A., & Alexander, M. P. (2003). Staying on the job: The frontal lobes control individual performance variability. *Brain*, *126*, 2363–2380.

Stuss, D. T., Alexander, M. P., Shallice, T., Picton, T. W., Binns, M. A., MacDonald, R., et al. (2005). Multiple frontal systems controlling response speed. *Neuropsychologia*, *43*, 396–417.

Rosenbaum, R. S., Stuss, D. T., Levine, B., & Tulving, E. (2007). Theory of mind is independent of episodic memory. *Science*, *318*, 1257.

Stuss, D. T., & Alexander, M. P. (2007). Is there a dysexecutive syndrome? *Philosophical Transactions of the Royal Society of London, Series B: Biological Sciences*, *362*, 901–915.