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Behavioural Science at Work for Canada: National Research Council Laboratories

Jennifer A. Veitch

NRC Institute for Research in Construction

Abstract

The National Research Council is Canada's principal research and development agency. Its 20 institutes are structured to address interdisciplinary problems for industrial sectors, and to provide the necessary scientific infrastructure, such as the national science library. Behavioural scientists are active in five institutes: Biological Sciences, Biodiagnostics, Aerospace, Information Technology, and Construction. Research topics include basic cellular neuroscience, brain function, human factors in the cockpit, human-computer interaction, emergency evacuation, and indoor environment effects on occupants. Working in collaboration with NRC colleagues and with researchers from universities and industry, NRC behavioural scientists develop knowledge, designs, and applications that put technology to work for people, designed with people in mind.

Résumé

Le Conseil national de recherches Canada (CNRC), qui compte 20 instituts et plus de 4 000 employés et 1 200 étudiants, travailleurs et chercheurs invités additionnels chaque année, est le principal organisme de recherche et de développement au Canada. Les instituts du CNRC sont structurés de manière à pouvoir se pencher sur des problèmes interdisciplinaires dans les secteurs industriels et à fournir l'infrastructure scientifique nécessaire comme celle de l'Institut canadien de l'information scientifique et technique (la bibliothèque scientifique nationale). Les scientifiques du comportement travaillent dans cinq instituts, soit l'Institut des sciences biologiques, l'Institut de

biodiagnostic, l'Institut de recherche aérospatiale, l'Institut de technologie de l'information et l'Institut de recherche en construction. La neuroscience cellulaire fondamentale, les fonctions du cerveau, les facteurs humains dans le poste de pilotage, l'interaction humain-ordinateur, les évacuations d'urgence et les effets du milieu ambiant intérieur sur les occupants sont au nombre des sujets de recherche. Par exemple, les chercheurs de l'Institut de biodiagnostic du CNRC ont réussi à identifier un marqueur neurophysiologique qui permet d'évaluer la fonction langagière chez les patients aphasiques en mettant au point une version informatisée d'un test de comportement standardisé et en le combinant avec l'électroencéphalographie (EEG). Les chercheurs de l'Institut de recherche aérospatiale étudient les effets des agents stressants sur les pilotes à l'aide d'un nouveau système embarqué qui permet d'effectuer des EEG et d'autres enregistrements physiologiques. À l'Institut de technologie de l'information du CNRC, des études de l'utilisation et la recherche sociale contribuent à veiller à ce que les besoins humains influencent le développement de la technologie. À l'Institut de recherche en construction du CNRC, les chercheurs orientent les codes et la conception du bâtiment de manière à assurer la sécurité, le confort et le rendement des occupants. Avec le concours de collègues du CNRC et de chercheurs universitaires et de l'industrie, les scientifiques du comportement développent des connaissances, des conceptions et des applications qui mettent la technologie au service de la personne.

Behavioural Science at Work for Canada: National Research Council Laboratories

Since 1916, the National Research Council of Canada (NRC) has been responsible for “undertaking, assisting or promoting scientific and industrial research in different fields of importance to Canada” (NRC Act, 1985). Many Canadians know NRC principally as the source of the official time signal. Some with longer memories recall the days when NRC was a source of research grants, prior to the establishment of the Natural Sciences and Engineering Research Council and the Social Sciences and Humanities Research Council in 1978. Few realize that the NRC of today is a widely-distributed institution with some 20 institutes and nearly 4000 employees across Canada, and an additional 1200 visiting scientists, guest workers, postdoctoral fellows, summer students and co-op students each year.

NRC research spans the range from fundamental through applied investigations, from astrophysics through fuel cells. Most NRC institutes are interdisciplinary centres formed to address broad industrial sectors (e.g., aerospace; manufacturing), although a few resemble more traditional academic disciplines (e.g., astrophysics, biological sciences). Historically, NRC scientists have been physicists, chemists, biologists, and engineers; more recently, computer scientists and psychologists have joined the ranks. Behavioural science of all types, from basic neuroscience to applied social psychology, has enjoyed a marked increase in activity and visibility at NRC over the past 10-15 years, and now appears in the research portfolios of five institutes. The purpose of this text is to describe briefly the current activities and recent achievements of these five institutes.

Brain Research

Two of the five institutes in which behavioural science may be found at NRC conduct brain research. These are the NRC Institute for Biological Sciences (NRC-IBS), in Ottawa, and the NRC Institute for Biodiagnostics (NRC-IBD) Atlantic laboratory in Halifax.

Cellular Neuroscience

Research at NRC-IBS¹ focuses on repairing the brain following an acute injury such as stroke or chronic neurodegenerative diseases such as Alzheimer’s and Parkinson’s. The adult brain has a limited capacity to compensate for the lost function by activating endogenous pathways of repair. These include neurogenesis (new neurons are born from resident stem cells), regeneration of the axons, growth of neurites and formation of new functional synapses. These pathways however, do not operate optimally because of free radicals that exist in the diseased brain. Regenerative and restorative strategies under investigation include combating such oxidative stress by modulating enzymes in the glutathione metabolism, which is the main antioxidant system of the cell. Without sufficient glutathione, neurons are unprotected from oxidative stress, and cell death accelerates (Byrd, Sikorska, Walker, & Sandhu, 2005). This research takes place collaboratively with university- and hospital-based collaborators, often focusing on cellular processes in patients with particular genetic variations or disease states (e.g., Sandhu et al., 2005).

¹ http://ibs.nrc-cnrc.gc.ca/neurobiology/neurogenesis_e.html and http://ibs.nrc-cnrc.gc.ca/neurobiology/neurogenesis_f.html (en français).

Brain Function

At NRC-IBD², researchers use electroencephalography (EEG) and functional magnetic resonance imaging (fMRI) to evaluate brain function. In particular, they seek methods for improved assessment of cognition for diagnostic and treatment purposes.

One line of research has been the adaptation of neuropsychological tests to evaluate neurocognitive function using neurophysiological outcomes in place of behavioural ones. For example, the assessment of language function following stroke can be problematic if the patient suffers from aphasia. The group developed a computerized version of the Peabody Picture Vocabulary Test – Revised (PPTV-R), and coupled it with EEG recordings of event-related potentials (ERPs), finding that the N400 component of the ERP correlated well with behavioural scores (Marchand, D’Arcy, & Connolly, 2002; D’Arcy et al., 2003). This provides a physiological means to evaluate the question “Does the patient understand language?” in patients who cannot speak. As the authors noted, the answer to this question has important consequences for subsequent treatment plans.

Neurosurgical planning requires the identification of healthy and abnormal patterns of brain activation. The NRC-IBD research team, with university collaborators, is studying fMRI during an object recognition task as a potential site-directed approach for the evaluation of functional status of the anterolateral temporal lobes, as is required for surgical approaches to treating temporal lobe epilepsy. In a recent study they used a picture-word matching

task, in which stimuli were either natural or artificial (e.g., duck or blouse; bird or clothing), and basic or superordinate (e.g., duck or bird; blouse or clothing). The categories were chosen because of evidence that the level of abstraction of a picture-word matching task influences the specific location of temporal lobe activation during the task. A preliminary study of 10 healthy adults has shown that the target regions can be evaluated using fMRI (D’Arcy et al., 2007), and that the specific regions of activation were different for the various object categories and levels of abstraction. Further work is planned to differentiate between lateral temporal activation and activation from tasks directed at the medial temporal structures.

Flight Research

The NRC Institute for Aerospace Research (NRC-IAR) Flight Research Laboratory in Ottawa integrates engineers and psychologists into a human factors team to address critical issues for aviation³. Their current focus is on the cognitive and perceptual problems facing pilots in conditions of high demand and low information.

Flying at night is a high-demand activity performed under conditions when visual perception is least sensitive. Night-vision goggles (NVGs) have been developed that can improve visual performance relative to flying without such aids (Ruffner, Antonio, Joralmon, & Martin, 2004); however, this technology brings its own risks. While amplifying available light, the electro-optical components of NVGs create scintillating noise in the display, which may influence depth motion, size, distance perception, and spatial navigation (Gauthier et al., 2005; Macuda, Allison, Thomas,

² http://ibd.nrc-cnrc.gc.ca/ibd_external/satellite_labs/ibd_atlantic_e.html and http://ibd.nrc-cnrc.gc.ca/ibd_external/satellite_labs/ibd_atlantic_f.html (en français)

³ http://iar-ira.nrc-cnrc.gc.ca/flight/flight_1_e.html and http://iar-ira.nrc-cnrc.gc.ca/flight/flight_1_f.html (en français).

Craig, & Jennings, 2004; Macuda, Craig, et al., 2005). Halo around light sources in the field of view is problematic because its visual size is invariant with distance, creating confusing cues that could adversely affect pilot performance (Craig, Macuda, Thomas, Allison, & Jennings, 2005) (see Figure 1). There are several variations on NVG design, each with different optical properties; NRC-IAR research suggests that psychophysical measures such as the NRC Grating Acuity Task may be more sensitive indices of the effectiveness of specific NVG optics than physical measures alone (Macuda, Allison, et al., 2005).

Figure 1. Halo around light sources, seen through night vision goggles.

Advanced cockpits challenge pilots' cognitive capacities by increasing information quantity and complexity. Although simulations and ground-based experiments have led to a fair understanding of performance under high-demand conditions using both behavioural and neurophysiological outcomes (e.g., EEG, electrocardiography, skin conductance, neurochemistry), generalizations to in-flight behaviour have been limited because only gross behavioural measures were available under ecologically valid conditions. NRC-IAR and the University of Iowa are collaborating to develop a system for portable EEG during flight (Schnell et al., 2006), and have begun to use this technology to explore influences on pilot mental state during flight, in both fixed and rotary-wing aircraft.

Human-Computer Interaction

Several research programs at the NRC Institute for Information Technology (NRC-IIT)⁴ include a behavioural science component, varying from investigations of cognitive function in virtual environments (at NRC-IIT Ottawa), to social communication over the Internet (at NRC-IIT Fredericton and Moncton). Research projects not discussed here (because of space limitations) include technologies for learning (e-learning); privacy protection and security; research ethics in software engineering; and, speech-based interfaces.

Navigation in Virtual Environments

Large-scale virtual environments differ from real environments in that they lack the frequent spatial and locomotive cues that people use in navigation; in addition, users may not spend sufficient time in any given virtual environment to acquire familiarity. Vinson (1999) developed a set of design guidelines for virtual environments based on guidelines for navigation in real environments. He subsequently developed a testing platform in which users navigate a virtual environment to find and collect targets; the time to collect each target is recorded (see Figure 2). He and Avi Parush of Carleton University are currently completing an investigation that used a think-aloud protocol to obtain users' navigational strategies as they completed the task. Other recent work includes a study of desktop-induced cybersickness, analogous to motion sickness (Vinson, Roberts, & Parush, 2006).

⁴ http://iit-iti.nrc-cnrc.gc.ca/r-d/prog-index_e.html and http://iit-iti.nrc-cnrc.gc.ca/r-d/prog-index_e.html (en français), and in particular http://iit-iti.nrc-cnrc.gc.ca/r-d/hci-ipm_e.html and http://iit-iti.nrc-cnrc.gc.ca/r-d/hci-ipm_f.html (en français).

Figure 2. Virtual environment from subject's perspective. This figure shows a screen shot of the virtual environment from the subject's perspective. Target #1 is displayed on the right side, close to the viewpoint. Targets remained invisible until subjects moved to within 45 virtual meters of them. The targets were collected by passing beneath them. In this trial, the subject is supposed to find and collect target 7, as indicated on the bottom left of the screen. Subjects could only collect the target indicated on the screen. The time remaining to collect the target is shown on the bottom right of the screen. To avoid cases of exhaustive search or aimless wandering we imposed a 5-minute time limit to find and collect each of 9 targets (from Vinson, Roberts, & Parush, 2006).

Applied Social Communication

Collaboration the wiki way. A wiki is "...a type of Web site that allows the visitors themselves to easily add, remove, and otherwise edit and change some available content, sometimes without the need for registration. This ease of interaction and operation makes a wiki an effective tool for collaborative authoring" (www.wikipedia.org, retrieved 22 November 2006).

Despite the optimistic definition, there exists limited formal investigation of the utility of wiki software for collaboration. Researchers at NRC-IIT focused on schoolchildren to identify major usability problems with a particular wiki implementation. These investigations are case studies; the team held extracurricular sessions with groups of students who chose to participate in collaborative story-writing. The team noted questions and problems that arose during the sessions, and also inspected the students' work after each session to

identify problems. Observations of groups of grade 4 students showed that most groups were able to use the software after minimal instruction, although there were elements that were difficult to use (Désilets, Paquet, & Vinson, 2005). Further observations, involving students in grades 4, 5, and 6, have led to guidelines for using wiki in the classroom (Désilets & Paquet, 2005). Usability guidelines developed during this project may facilitate wiki use among non-technical adult groups.

Information and communication technologies. The Internet makes it possible to disseminate widely information and services that formerly required print and face-to-face communication. Governments have seized this opportunity to reach out to citizens; however, not all citizens have equal access to these new tools. The Community Intermediaries in the Knowledge Society (CIRP) project⁵ investigated how community organizations use information and communication technologies to deliver government services to citizens. Interviews, focus groups, and document analysis were the principal research tools. The community groups involved in the project used various media to communicate with their clients and with the public; however, limitations in resources, knowledge, and skills created tensions that reduced the use or effectiveness of digital media (e.g., e-mail, web pages) (O'Donnell, McIver, & Rideout, 2006). Overall, the project identified financial, technical, and social barriers to the use of communications technologies by community-based groups, and provided

⁵ The CIRP project page is: http://iit-iti.nrc-cnrc.gc.ca/projects-projets/cirp-pric_e.html [http://iit-iti.nrc-cnrc.gc.ca/projects-projets/cirp-pric_f.html]. The project was conducted from the e-Citizen Studio (a research lab): http://iit-iti.nrc-cnrc.gc.ca/about-sujet/e-citizen-studio-citoyen-electronique_e.html [http://iit-iti.nrc-cnrc.gc.ca/about-sujet/e-citizen-studio-citoyen-electronique_f.html].

policy and program recommendations to improve service delivery (Rideout, Reddick, O'Donnell, McIver, Kitchen, & Milliken, 2006).

People in Buildings

The NRC Institute for Research in Construction (NRC-IRC) is the largest building science research body in Canada. Two of its four research programs, Fire Research and Indoor Environment (both located in Ottawa), include behavioural science components.

*Evacuation*⁶

In 2001, 338 Canadians died as a result of building fires, and a further 2310 were injured (Council of Canadian Fire Marshals and Fire Commissioners, 2004). Human behaviour plays a large role in the prevention of fire-related injuries and fatalities: What influences whether or not occupants hear the fire alarm? How promptly do they evacuate? What building design features help or hinder the evacuation? Staff in the Fire Research program study these questions primarily using field experiments and surveys.

A study of the effectiveness of photoluminescent marking (PLM) materials and other wayfinding systems took place in a building with four stairwells, each of which had a different guidance system installed along with video cameras for data collection (Proulx, Kyle, & Creak, 2000). An unannounced evacuation drill took place, following which researchers calculated speed of movement through the stairwells. Occupants were able to move effectively through a stairwell marked by PLM guidance systems without electric lighting, although an exit survey identified ways in which the experimental system could be

improved. Further investigations to develop specific installation guidance are currently under way.

Interviews and surveys of fire survivors are another important source of information. NRC-IRC staff investigated the experiences of survivors of the World Trade Center disaster (Averill et al., 2005) and the Cook County Administration Building fire in Chicago (Proulx & Reid, 2006). Such research is the only ethical approach to learn how buildings perform in an emergency, and contributes directly to changes in building and fire codes.

*Acoustics*⁷

Research in this area seeks primarily to predict occupant response to sounds in buildings by identifying criteria based on the physical properties of sound fields. In studying speech intelligibility and privacy the goal is to identify objective sound measurements that predict the fraction of words understood, or the threshold of intelligibility (below which speech cannot be understood), or the threshold of audibility (below which speech cannot be heard) (Gover & Bradley, 2004). In studying distraction and annoyance, researchers seek to identify objective criteria that predict how people respond in a given setting, such as open-plan offices (Bradley & Gover, 2003). Such criteria are the basis for recommendations and standards, providing guidance to the building industry.

Speech intelligibility research uses listening tests in which participants sit in a sound-isolated room, listening to stimuli presented over several loudspeakers (Bradley & Gover, 2003; Gover & Bradley, 2004). The stimuli, usually a standard set of nonsense sentences (IEEE, 1969), may be modified to simulate relevant building

⁶ http://irc.nrc-cnrc.gc.ca/fr/frhb/HBprojects_e.html and http://irc.nrc-cnrc.gc.ca/fr/frhb/HBprojects_f.html (en français).

⁷ Lighting and acoustic research information are at: http://irc.nrc-cnrc.gc.ca/ie/index_e.html and http://irc.nrc-cnrc.gc.ca/ie/index_f.html (en français).

conditions (e.g., to simulate the effects of a given wall construction through which the speech is heard). The dependent measure is the fraction of the words in the sentence that the participant correctly repeats. Analyses commonly compare the predictive power of various ways to specify the stimulus conditions, such as signal-to-noise ratios and various mathematical models of frequency analyses.

Recent noise annoyance research at NRC-IRC has concerned open-plan office design. When a high degree of experimental realism is needed, investigations take place in the Indoor Environment Research Facility, a dedicated 12.2 m x 7.3 m space designed to permit a wide variation in lighting, ventilating, thermal, and acoustic conditions and instrumented for precise measurement of those conditions. The furnishings at present are typical modular systems, so that the space looks like an unexceptional small open-plan office. Veitch, Bradley, Legault, Norcross, and Svec (2002) used the space to study the effect of adding simulated ventilation system noise (varying in both sound pressure level and spectral content) to mask speech sounds. This work revealed that when the speech intelligibility index (SII, a frequency-weighted speech-to-noise ratio) is less than 0.20, acoustic satisfaction is acceptable. Bradley and Gover (2003) used a different method to expose participants to a wider range of SII values and found generally good agreement with this result.

Lighting

Historically, most lighting researchers have had backgrounds in vision or perception, or have begun in engineering. Vision research at NRC-IRC has resulted in a model of visual performance (Rea & Ouellette, 1991) that has influenced lighting recommendations in North America (Illuminating Engineering Society of North

America, 2000). The model predicts relative visual performance in relation to retinal illuminance, task size and task contrast. Its plateau-and-escarpment shape means that for most common tasks and over the broad range of common interior light levels, relative visual performance is invariant (Figure 3).

Figure 3. Relative visual performance model (Rea & Ouellette, 1991).

The Lighting sub-program today focuses on identifying ways to deliver energy-efficient lighting that achieves high satisfaction, comfort, and task performance. Laboratory simulations of office lighting conditions are the most common method (e.g., Newsham, Arseneault, Veitch, Tosco, & Duval, 2005; Veitch & Newsham, 2000). In these experiments, facilities are set up to resemble real offices, with a variety of commercially-available lighting systems; in some cases, individuals have partial or total control over the lighting at their workstations. Participants spend up to a working day in the facility, completing a wide variety of cognitive, clerical, and psychomotor tasks and questionnaires concerning satisfaction, comfort, and mood. Investigations in which personal control was

provided have shown that there are broad individual differences in preferred lighting conditions, such that the only way to provide suitable lighting for most people is to provide individually-controllable lighting systems (Newsham & Veitch, 2001). Individual control over lighting appears to buffer the drop in motivation noted over the workday among people who lack such control (Boyce et al., 2006), a finding that is the focus of ongoing work.

Concluding Remarks

NRC's behavioural scientists are, clearly, a diverse group. However, we share common characteristics, beginning with strong foundations in basic science to underpin our applied research. We also share an openness to interdisciplinary investigations. As a result, many of us collaborate widely with academic, medical, and industry researchers as well as with professionals in other government departments and other countries. Working with our NRC colleagues in collaborative interdisciplinary teams means that the knowledge we build about technology users is an integral part of technology research and development. Across varied subject matter, we develop knowledge, designs, and applications that put technology to work for people, designed with people in mind. Although behavioural science is a small component of NRC's research portfolio, it is an important dimension, through which NRC can reach its goals to contribute through science and technology to Canada's social and economic well-being (NRC, 2006).

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