The Science and Engineering Behind

RC21X™

And

Roberto™

Powered By RC21X

The Science and Engineering Behind *RC21X* and *ROBERTO*

I. BACKGROUND

RC21X and *ROBERTO* are user-friendly computerized test batteries that provide an individual with his/her own unique human Brain Performance Profile (**BPP**). *RC21X* is a program designed to be taken on a desktop or laptop computer in about 12 minutes, while *ROBERTO* is an app designed to be taken on a mobile device in about 6 minutes.

By following the standardized instructions and rules for completing either an *RC21X* or *Roberto* test session, these fully automated tests ensure consistent test administration and an up-to-date assessment of a person's neurocognitive and neuromotor brain performance capacities. The modules incorporated in these unique applications were configured to screen many aspects of human brain functioning of the four lobes of the cerebrum, cerebellum, and midbrain within a relatively short timeframe.

The *RC21X* and *ROBERTO* tests each consist of a set of carefully developed modules, most of which are based directly on more than a 50-year history of human performance testing in psychology, neurology, bioengineering, kinesiology, and related fields. Tests of the types that provide the basis for many of the *RC21X* and *ROBERTO* modules have been extensively studied, and have been shown to be reliable and useful in many different applications. The *RC21X* and *ROBERTO* tests reflect lifelike components of neurocognitive and neuromotor human brain performance (*e.g.*, visual and auditory memory recall, working memory, information processing, attention, executive planning, spatial perception, vigilance, anticipation timing, simple, choice and discrimination reaction time, coordination, dynamic balance and manual dexterity).

A brief explanation of the 15 modules used with *RC21X* and the 7 modules used in *ROBERTO* are outlined below. Included are key references from the human performance literature to support the rationale for their usage in *RC21X* and/or *ROBERTO*.

II. RC21X and ROBERTO Test Modules

1. **VISUAL MEMORY DELAYED RECALL (VR)** – ***Module present in RC21X and ROBERTO***

Visual recognition memory (right hemisphere) and the ability to retrieve visual information that was previously learned.

The Benton Visual Retention Test (**BVRT**) is an individually administered untimed test for a participant that measures visual perception and visual memory. The participant is visually shown 10 designs, one at a time, and asked to reproduce each one as exactly as possible on plain paper from memory. This memory can also be tested by free recall, prompted recall, or recognition. It can also be used to help identify possible brain dysfunctions that might affect an individual's memory.

RC21X and *ROBERTO* use a visual recall short term memory paradigm by showing the participant eight easily identifiable visual images, one at a time. At the end of the test (*i.e.*, about 10 minutes later for *RC21X* and about 5 minutes later for *ROBERTO*), the participant is asked to recall these eight images using prompted recall from a list of 16 randomly assigned images (original eight images plus eight interfering images).

Betz, W. B. & Walsh, N.E. (1990). Tests and assessment (2nd ed.). Englewood Cliffs, N.J.: Prentice Hall.

Benton, A. L. (1945). A Visual Retention Test for Clinical Use. Archives of Neurology and Psychiatry, 54 (3): 212.

McCullough, V. E. (1992). Testing and your child: what you should know about 150 of the most common medical, educational, and psychological tests. New York: Plume.

2. **AUDITORY MEMORY DELAYED RECALL (AR)** – ***Module present in RC21X and ROBERTO***

Auditory recognition memory (left hemisphere) and the ability to retrieve auditory information that was previously learned.

Verbal learning is the learning of words. This learning can be tested by free recall, prompted recall, or recognition. Verbal learning has historically received considerable attention in psychology.

One of the most prominent verbal learning tests is the Auditory-Verbal Learning Test (**AVLT**). During this test, a 15-word list is read to the participant at the rate of one word per second. After each trial, the participant tries to recall as many of the words as possible. After this, an interfering list of 15 words is read followed by an immediate request for the participant to recall the original list. Another request to recall is made to the participant after a delay of 20 to 45 minutes.

RC21X and *ROBERTO* use an auditory recall, short-term memory paradigm by asking the participant to listen to eight easily identifiable words, one at a time. At the end of the test (*i.e.*, about 10 minutes later for *RC21X* and about 5 minutes later for *ROBERTO*), the participant is asked to recall these eight words using prompted recall from a list of 16 randomly assigned words (original eight words plus eight interfering words).

Lezak, M.D., Howieson, D. B., & Loring, D. W. (2004). Neuropsychological Assessment, (4th Ed.), Oxford: Oxford University Press.

3. **FINGER TAPPING (FT)** – ***Module present in RC21X and ROBERTO***

Bilateral finger motor speed and strength of the dominant hand.

Halstead (1947) designed the 10-second finger oscillation (or tapping) test in his pursuit to identify measures of biological intelligence. Provided the subject is motivated to tap as fast as possible, this test has proven useful in identifying severity of several brain diseases and injuries. Cross-validation studies have shown that the average speed of finger tapping can distinguish brain dysfunctional patients from medical controls.

RC21X and *ROBERTO* use a 10-second finger tapping task.

Dikmen, S., Machamer, J.E., Winn, H.R., et al. Neuropsychological outcome at 1-year post head injury. Neuropsychology 9:80-90, 1995

Geschwind, N. (1975). The apraxias: Neural mechanisms of disorders of learned movement. Am Sci 63:188-195.

Haaland KY, Temkin N, Randahl G, et al: Recovery of simple motor skills after head injury. J Clin Exp Neuropsychol, 16, 448-456, 1994.

Halstead WC: Brain and intelligence. Chicago: University of Chicago Press, 1947.

Heaton RK, Grant I, Matthews CG: Comprehensive Norms for an Expanded Halstead-Reitan Battery: Demographic Correlations, Research Findings, and Clinical Applications. Odessa, FL: Psychological Assessment Resources, 1991.

Klonoff PS, Costa LD, Snow WG: Predictors and indicators of quality of life in patients with closed-head injury. J Clin Exp Neuropsychol, 8, 469-485, 1986.

McKhann G, Drachman D, Folstein M, et al: Clinical diagnosis of Alzheimer's disease: Report of the NINCDS-ADRDA Work Group under the auspices of Department of Health and Human Services Task Force on Alzheimer's Disease.

Neurology, 34, 939-944, 1984.

Prigatano, G. P. & Hoffmann, B. (1997). Finger tapping and brain dysfunction: A qualitative and quantitative study. Barrow Quarterly, 13: no. 4.

Prigatano GP, Parsons OA: Relationship of age and education to Halstead test performance in different patient populations. J Consult Clin Psychol, 44, 527-533, 1976.

Prigatano GP, Wong JL: Speed of finger tapping and goal attainment after unilateral cerebral vascular accident. Arch Phys Med Rehabil, 78, :847-852, 1997.

Reitan RM: Manual for Administration of Neuropsychological Test Batteries for Adults and Children. Indianapolis: Indiana University Medical Center, 1955.

Vega A, Jr., Parsons OA: Cross-validation of the Halstead-Reitan tests for brain damage. J Consult Clin Psychol, 31, 619-623, 1967.

4. ONE CHOICE VISUAL INFORMATION PROCESSING (1C) – ***Module present in RC21X only.***

Visual motor coordination using right hand (left hemisphere)

Mental chronometry is the use of time in perceptual-motor tasks to infer the content, duration, and temporal sequencing of cognitive operations. Mental chronometry is studied using the measurements of reaction time (RT). Reaction time is the interval of time between the onset of a sensory stimulus that indicates the signal for the required movement and the initiation of the movement (*e.g.*, track sprinter beginning a race). The three most common types of reaction time are simple, choice, and discrimination. Simple RT involves one stimulus and one correct response to that stimulus. Choice RT involves two of more stimuli and one correct response for each stimulus. Discrimination RT involves two or more stimuli but only one correct overall response because the other stimuli require no response.

RC21X uses a one-choice simple reaction time task.

Donders, F.C. (1869). On the speed of mental processes. In W. G. Koster (Ed.), Attention and Performance II. Acta Psychologica, 30, 412-431. (Original work published in 1868.)

Sternberg, S. (1969). "The discovery of processing stages: Extensions of Donders' method". Acta Psychologica, 30: 276–315.

http://en.wikipedia.org/wiki/Jensen_box

Magill, R.A. (2011). Motor learning and control. New York: McGraw-Hill, 24-28.

5. **FOUR CHOICE VISUAL INFORMATION PROCESSING (4C)** – ***Module present in RC21X only.***

Enhanced visual motor tracking, visual motor discrimination and impulse control

Mental chronometry is the use of time in perceptual-motor tasks to infer the content, duration, and temporal sequencing of cognitive operations. Mental chronometry is studied using the measurements of reaction time (RT). Reaction time is the interval of time between the onset of a sensory stimulus that indicates the signal for the required movement and the initiation of the movement (*e.g.*, track sprinter beginning a race). The three most common types of reaction time are simple, choice, and discrimination. Simple RT involves one stimulus and one correct response to that stimulus. Choice RT involves two of more stimuli and one correct response for each stimulus. Discrimination RT involves two or more stimuli but only one correct overall response because the other stimuli require no response.

RC21X uses a four-choice reaction time task.

Donders, F.C. (1869). On the speed of mental processes. In W. G. Koster (Ed.), Attention and Performance II. Acta Psychologica, 30, 412-431. (Original work published in 1868.)

Sternberg, S. (1969). "The discovery of processing stages: Extensions of Donders' method". Acta Psychologica, 30: 276–315.

Magill, R.A. (2011). Motor learning and control. New York: McGraw-Hill, 24-28.

http://en.wikipedia.org/wiki/Jensen_box

6. **SHAPE MEMORY (SM)** – ***Module present in RC21X and ROBERTO***

Working memory and visual attention

Memory is the capacity to remember. Memory has two functional systems: working memory and long-term memory. Working memory operates in all situations requiring the temporary use and storage of information, while long-term memory is a more permanent storage of information.

Working memory is generally considered to have a limited capacity. The earliest quantification of the capacity limit associated with short-term memory was “seven”, plus or minus two, suggested by Miller in 1956. He noticed that the memory span of young adults was around seven elements, called chunks, regardless whether the elements were digits, letters, words, or other units. Later research revealed that span does depend on the category of chunks used (*e.g.*, span is around seven for digits, around six for letters, and around five for words).

RC21X and *ROBERTO* use a short-term memory test that utilizes common geometric shapes.

Pribram, Karl H.; Miller, George A.; Galanter, Eugene (1960). Plans and the structure of behavior. New York: Holt, Rinehart and Winston. p. 65.

Baddeley A (October 2003). "Working memory: looking back and looking forward". Nature Reviews Neuroscience, 4 (10): 829–39.

Miller, G.A. (1956). "The magical number seven plus or minus two: some limits on our capacity for processing information". Psychological Review, 63 (2): 81–97. Republished: Miller GA (April 1994). "The magical number seven, plus or minus two: some limits on our capacity for processing information”. 1956. Psychological Review, 101 (2): 343–52.

Magill, R.A. (2011). Motor learning and control. New York: McGraw-Hill, 222-227.

7. **NUMERICAL MEMORY (OR “DIGIT SPAN”) (NM)** – ***Module present in RC21X and ROBERTO***

Working memory (visual attention)

Memory is the capacity to remember. Memory has two functional systems: working memory and long-term memory. Working memory operates in all situations requiring the temporary use and storage of information, while long term memory is a more permanent storage of information.

Working memory is generally considered to have a limited capacity. The earliest quantification of the capacity limit associated with short-term memory was “seven”, plus or minus two, suggested by Miller in 1956. He noticed that the memory span of young adults was around seven elements, called chunks, regardless whether the elements were digits, letters, words, or other units. Later research revealed that span does depend on the category of chunks used (e.g., span is around seven for digits, around six for letters, and around five for words).

One of the most common kinds of tests of working memory is the digit span test. In digit span tests, the participant is presented with a list of numbers typically one at a time, and then asked to repeat them. Some versions require the digits to be recalled forwards (*i.e.*, “forward digit span”) and others require the digits to be recalled backwards (*i.e.*, “backward digit span”).

RC21X and *ROBERTO* use a forward digit span short-term memory test.

Groth-Marnat, G., & Baker, S. (2003). Digit Span as a measure of everyday attention: a study of ecological validity. Perceptual and Motor Skills, 97, 1209– 1218. Wechsler D. (1997). Manual for the Wechsler Adult Intelligence Scale— third edition. San Antonio, TX: Psychological Corp.

Pribram, Karl H.; Miller, George A.; Galanter, Eugene (1960). Plans and the structure of behavior. New York: Holt, Rinehart and Winston. p. 65.

Baddeley A (October 2003). "Working memory: looking back and looking forward". Nature Reviews Neuroscience, 4 (10): 829–39.

Miller, G.A. (1956). "The magical number seven plus or minus two: some limits on our capacity for processing information". Psychological Review ***63*** *(2): 81–97. Republished: Miller GA (April 1994). "The magical number seven, plus or minus two: some limits on our capacity for processing information”. 1956. Psychological Review, 101 (2): 343–52.*

Magill, R.A. (2011). Motor learning and control. New York: McGraw-Hill, 222-227.

8. **VISUAL SPATIAL MEMORY (VSM)** – ***Module present in RC21X only.***

Working memory and pattern sequencing ranging from 1 to 9 spatial positions

In addition to digit span tests, there are spatial span tests. Rather than presenting digits, these tests typically require participants to view and then reproduce an ordered spatial pattern.

Memory is the capacity to remember. Memory has two functional systems: working memory and long-term memory. Working memory operates in all situations requiring the temporary use and storage of information, while long term memory is a more permanent storage of information.

Working memory is generally considered to have a limited capacity. The earliest quantification of the capacity limit associated with short-term memory was “seven”, plus or minus two, suggested by Miller in 1956. He noticed that the memory span of young adults was around seven elements, called chunks, regardless whether the elements were digits, letters, words, or other units. Later research revealed that span does depend on the category of chunks used (*e.g.*, span is around seven for digits, around six for letters, and around five for words).

RC21X uses a spatial span short-term memory test.

Groth-Marnat, G., & Baker, S. (2003). Digit Span as a measure of everyday attention: a study of ecological validity. Perceptual and motor skills, 97(3 Pt 2), 1209–1218.

Wechsler D. Manual for the Wechsler Adult Intelligence Scale— third edition. San

Antonio, TX: Psychological Corp; 1997

Hill, B. D. (2008). The construct validity of the clinical assessment of working memory ability. A dissertation submitted to the Graduate Faculty of the Louisiana State University in the Department of Psychology.

Pribram, Karl H.; Miller, George A.; Galanter, Eugene (1960). Plans and the structure of behavior. New York: Holt, Rinehart and Winston. p. 65.

Baddeley A (October 2003). "Working memory: looking back and looking forward". Nature Reviews Neuroscience ***4*** *(10): 829–39.*

Miller, G.A. (1956). "The magical number seven plus or minus two: some limits on our capacity for processing information". Psychological Review ***63*** *(2): 81–97. Republished: Miller GA (April 1994). "The magical number seven, plus or minus two: some limits on our capacity for processing information. 1956". Psychological Review, 101 (2): 343–52.*

Magill, R.A. (2011). Motor learning and control. New York: McGraw-Hill, 222-227.

9. ***SPEED-ACCURACY RIGHT (CC1 RIGHT)* – *Module present in RC21X only.***

Visual motor coordination using right hand (left hemisphere)

Fitts' law is a model of human performance movement that predicts that the time required to rapidly move to a target area is a function of the distance to the target and the size of the target. Fitts' law predicts movement time when both speed and accuracy are required during movement. According to Fitts' law, if we know the spatial dimensions of these two variables, we can predict the movement time required to hit the target.

Limited capacity theories have an underlying theme that is similar: The amount of information that the human can process per unit time (*i.e.*, the rate of information processing measured in bits/s) is limited. It has been shown that humans compensate when performing more difficult coordinated movements by increasing movement time (Fitts, 1954) thus enabling the completion of necessary extra information processing time.

Related to this is channel capacity. Studies of aimed movement that consider the human motor system as a limited capacity channel have produced estimates of from 10 to 13 bits/s for normal human channel capacity (Hart & Wickens, 1990). By combining speed and accuracy, a measure of "coordination", or neuromotor channel capacity, can be studied (also measured in bits/s) which represents the capacity of the neurological communication channels involved in coordinated movement (Kondraske, 1992).

RC21X uses Fitts' law to test for speed and accuracy of right arm upper extremity neuromotor channel capacity.

Fitts, P.M. (1954). The information capacity of the human motor system in controlling the amplitude of movement. Journal of Experimental Psychology, volume 47, number 6, June 1954, pp. 381–391. (Reprinted in Journal of Experimental Psychology: General, 121(3):262–269, 1992).

Fitts, P.M. & Peterson, J.R. (1964). Information capacity of discrete motor responses. Journal of Experimental Psychology, 67(2):103–112.

Bainbridge, L. & Sanders, M. (1972). The Generality of Fitts's Law. Journal of Experimental Psychology, 96 (1), 130-133.

Hart, S. G., & Wickens, C. D. (1990). Workload assessment and prediction. In H. R. Booher (Ed.), MANPRINT: An approach to systems integration (pp. 257–296). New York: Van Nostrand Reinhold.

Magill, R.A. (2011). Motor learning and control. New York: McGraw-Hill, 136-140. 11

10. **SPEED-ACCURACY LEFT (CC1 LEFT)** – ***Module present in RC21X only.***

Visual motor coordination using left hand (right hemisphere)

Fitts' law is a model of human performance movement that predicts that the time required to rapidly move to a target area is a function of the distance to the target and the size of the target. Fitts' law predicts movement time when both speed and accuracy are required during movement. According to Fitts' law, if we know the spatial dimensions of these two variables, we can predict the movement time required to hit the target.

RC21X uses Fitts' law to test for speed and accuracy of left arm upper extremity neuromotor channel capacity.

Fitts, P.M. (1954). The information capacity of the human motor system in controlling the amplitude of movement. Journal of Experimental Psychology, volume 47, number 6, June 1954, pp. 381–391. (Reprinted in Journal of Experimental Psychology: General, 121(3):262–269, 1992).

Fitts, P.M. & Peterson, J.R. (1964). Information capacity of discrete motor responses. Journal of Experimental Psychology, 67(2):103–112.

Magill, R.A. (2011). Motor learning and control. New York: McGraw-Hill, 136-140.

11. **BASE-STEALING GAME OR "GO-NO-GO" (BSG)** – ***Module present in RC21X and ROBERTO***

Visual discrimination and impulse control

The Go-No-Go procedure involves a required response from the participant to one of the choices, but then the participant must withhold a response to the other alternatives. Go-No-Go represents a task in which stimuli are presented in a continuous fashion and participants perform a binary decision on each stimulus. One of the outcomes requires participants to make a motor response (Go), whereas the other requires participants to withhold a response (No-Go). Accuracy and reaction time are measured for each event. Go events typically occur with higher frequency than no-go events.

RC21X and ROBERTO use a "Go-No-Go" paradigm to visual stimuli.

Donders F.C. On the speed of mental processes. Acta Psychologica 1969; 30:412– 431. [PubMed:5811531] (Original work published 1868).

Gomez, P., Ratcliff, R., & Perea, M. (2007). A model of the Go/No-Go Task. J Exp Psychol Gen. 2007 August; 136(3): 389–413. doi:10.1037/0096-3445.136.3.389.

12. **SPACESHIP RACE GAME (SRG)** – ***Module present in RC21X only.***

Executive function, 2 dimension visual-spatial planning; UE dexterity & coordination.

Executive functioning is an umbrella term for the management of cognitive processes, including working memory, reasoning, task flexibility, and problem solving, as well as planning and execution.

RC21X uses an executive function paradigm in a race game format.

Elliott, R. (2003). Executive functions and their disorders. British Medical Bulletin.

(65); 49–59

Monsell, S. (2003). "Task switching". TRENDS in Cognitive Sciences, 7 (3): 134– 140.

Chan, R. C., Shum, D., Toulopoulou, T. & Chen, E.Y.H. (2008). "Assessment of executive functions: Review of instruments and identification of critical issues". Archives of Clinical Neuropsychology, 23 (2): 201–216.

13. **BASEBALL CATCH GAME (BCG)** – ***Module present in RC21X only.***

Modest information load, 1 dimension med-lat UE motion, anticipation and vigilance.

Executive functioning is an umbrella term for the management of cognitive processes, including working memory, reasoning, task flexibility, and problem solving, as well as planning and execution. Anticipation timing is the ability to time movement initiation with the movement of an external object such as catching or hitting a baseball.

RC21X uses an executive function paradigm in an anticipation timing game format.

Elliott, R. (2003). Executive functions and their disorders. British Medical Bulletin.

(65); 49–59

Monsell, S. (2003). "Task switching". TRENDS in Cognitive Sciences, 7 (3): 134–140.

Chan, R. C., Shum, D., Toulopoulou, T. & Chen, E.Y.H. (2008). "Assessment of executive functions: Review of instruments and identification of critical issues". Archives of Clinical Neuropsychology, 23 (2): 201–216.

Magill, R.A. (2011). Motor learning and control. New York: McGraw-Hill, 52.

14. **METEOR DODGE GAME (MDG)** – ***Module present in RC21X only.***

Executive function (decision-making), high information load; 2 dimension UE motion and vigilance

Executive functioning is an umbrella term for the management of cognitive processes, including working memory, reasoning, task flexibility, and problem solving, as well as planning and execution.

RC21X uses an executive function paradigm in a dodge game format.

Elliott, R. (2003). Executive functions and their disorders. British Medical Bulletin.

(65); 49–59

Monsell, S. (2003). "Task switching". TRENDS in Cognitive Sciences, 7 (3): 134–140.

Chan, R. C., Shum, D., Toulopoulou, T. & Chen, E.Y.H. (2008). "Assessment of executive functions: Review of instruments and identification of critical issues". Archives of Clinical Neuropsychology, 23 (2): 201–216.

15. **SIT-STAND-TAP (SST)** – ***Module present in RC21X and ROBERTO***

Dynamic balance and coordination

Static balance involves maintaining equilibrium while stationary (*e.g.*, sitting or standing), while dynamic balance involves maintaining equilibrium while in motion (*e.g.*, sitting and standing, walking, or running).

RC21X and *ROBERTO* use a dynamic balance postural stability paradigm.

Magill, R.A. (2011). Motor learning and control. New York: McGraw-Hill, 50-53.

Drowatzky, J.N. & Zuccato, F.C. (1967). Interrelationships between selected measures of static and dynamic balance. Research Quarterly for Exercise and Sport, 38, 509-510.

Guralnik, J. M., Ferrucci, L., et al. (2000). "Lower extremity function and subsequent disability: consistency across studies, predictive models, and value of gait speed alone compared with the short physical performance battery." J Gerontol A Biol Sci Med Sci 55(4): M221-31.

Buatois, S., Miljkovic, D., Manckoundia, P., Gueguen, R., Miget, P., Vancon, G. et al. (2008). Five times sit to stand test is a predictor of recurrent falls in healthy community-living subjects aged 65 and older. J Am Geriatr Soc; 56(8):1575-1577.

Bohannon, R.W. (2006). Reference values for the five-repetition sit-to-stand test: a descriptive meta-analysis of data from elders. Percept Mot Skills; 103(1):215222.

III. Why Web-Based Testing?

Methods traditionally used for neurologic screening are largely based on subjective observations that require direct face-to-face interaction between patients and clinicians—a costly and time consuming endeavor. This has motivated the use of more objective and quantitative brain performance tests. Such set-ups are "lab-based", generally requiring a separate lab room, and the instruments are considered of the highest fidelity but not portable. An alternative may be characterized as "clinic-based", in which a major portion of the functionality of a lab-based performance capacity measurement system is incorporated into a smaller, more portable package. Others have developed and evaluated cognitive web-based instruments in clinical contexts and have reported encouraging results.

However, to access the broadest population, the use of web-based brain performance screenings in which only the hardware associated with standard home or office computer configurations would be required is the next breakthrough in monitoring brain performance in a cost effective manner.

Given these perspectives, *RC21X* and *ROBERTO* were conceived as a measurement and evaluation system consisting of a set of objective Web-based Brain Performance Capacity (**BPC**) Tests and subjective questionnaire-type elements covering important issues such as subject history (*e.g.*, current health, education, important environmental issues, etc.). This vision includes the self-administration of all components of *RC21X* and *ROBERTO* using nothing but the standard hardware typically associated with a home or office computer set-up or a "smart" mobile device.

E. B. Montgomery, Jr., W. C. Koller, T. J. K. LaMantia, N. C. Newman, E. Hyland, A. W. Kaszniak, K. Lyons K, "Early detection of probable idiopathic Parkinson's disease:. I. Development of a diagnostic test battery," Mov Disorders, vol. 15, pp. 467-473, 2000.

A. M. Johnson, P. A. Vernon, Q. J. Almeida, L.L. Grantier, R. Singarayer and M. S. Jog, "Screening for Parkinson's disease with response time batteries: A pilot study," BMC Medical Informatics and Decision Making, vol. 4, pp. 14, 2004.

G. V. Kondraske, "A PC-based performance measurement laboratory system," J of Clinical Engineering, vol. 15, no. 6, pp. 467-478, 1990.

G. V. Kondraske, R. Mulukutla, and R.M. Stewart. "Investigation of a portable performance measurement system for neurologic screening in clinics," CD-ROM Proceedings of the 28th Int. Conf. of the IEEE Engineering in Medicine and Biology Society, New York, Aug 30 – Sept 3, 2006, pp. 3962-3965.

D. M. Erlanger, T. Kaushik, D. Broshek, J. Freeman, D. Feldman, J. Festa, "Development and validation of a web-based screening tool for monitoring cognitive status," J. Head Trauma Rehab., 17(5):458-476, 2002.

R. L. Kane, T. Roebuck-Spencer, P. Short, M. Kabat and J. Wilken, "Identifying and monitoring cognitive deficits in clinical populations using Automated Neuropsychological Assessment Metrics (ANAM) tests," Arch of Clin Neuropsych, 22, Suppl1: 115-126, 2007.

G. V. Kondraske, "The elemental resource model for human performance," in The Biomedical Engineering Handbook 3rd Ed.: Biomedical Engineering Fundamentals. J. Bronzino, Ed. Boca Raton: CRC Press, Taylor & Francis, 2006, pp. 75.1-75.19.

G. V. Kondraske and P. J. Vasta, "Neuromotor channel capacity, coordination, and motion quality," in CD-ROM Proceedings of the World Congress on Medical Physics and Biomedical Engineering, Chicago, July 23-28, 2000, 4 pgs.

G. V. Kondraske and R. M. Stewart, "Neuromotor channel capacity as an outcome and tracking measure in Parkinson's Disease," in CDROM Proceedings of the 24th Int. Conf. IEEE Eng. in Med. Biol. Soc., Houston, October 23-26, 2002, pp. 24712472. 17

IV. Summary

RC21X and *ROBERTO* are web-based systems for measuring a person's Brain Performance Profile (**BPP**) using a game-like approach, maximally challenging selected cognitive and neuromotor Brain Performance Capacities (**BPCs**), and monitoring changes over time.

Our goal is to provide a simple and fun way for everyone to better understand brain performance and to promote not taking brain performance for granted.

Features of *RC21X* and *ROBERTO*:

- Quick (12 minutes per session for *RC21X* and 6 minutes per session for *ROBERTO*).
- Standardized, simple procedures, "do-able" by children and adults.
- Objective measures, data-based records, and reports for all sessions.

- Repeated sessions used to establish an initial baseline range of your brain performance capacities.
- Informative reports: Current session performance, current session performance compared to baseline range, current session compared to best performance – and others.
- As a measurement tool, brain performance capacities incorporated are the same as those used by researchers, vocational experts, sport science professionals, and clinicians – but *RC21X* and *ROBERTO* are designed to be self-administered.
- Components based on more than 50 years of human performance research and clinical testing.
- A systems approach incorporating the science of General Systems Performance Theory (**GSPT**) and based on the structure of the human cognitive and neuromotor systems. Performance capacities measured are drawn upon and affect every-day and sport task performance and may be affected by a wide range of factors such as sleep, drugs, nutritional supplements, injury, *etc*.

One can choose to use *RC21X* and *ROBERTO* in many different ways depending on interests, activities, life circumstances, and imagination:

- Measure your BPP and see how it changes at different times of day or before or after special events.
- Monitor progress as you attempt to improve your BPP.
- Develop a record of your BPP and use it as a reference to see if an event (such as a fall or injury) has resulted in a change in performance.
- See if new medications have an effect on your BPP.

Neither *RC21X* nor *ROBERTO* is a test that provides a medical diagnosis. However, given their easy accessibility and that brain performance capacities included in *RC21X* and *ROBERTO* have been shown in many scientific studies to be affected by different types of injuries and diseases, it is very likely that many individuals (parents, athletes, clinicians, researchers, *etc*.) will consider using these tests, not as a diagnostic tool, but rather to monitor brain performance quantitatively. Such uses are within the scope of the *RC21X* and *ROBERTO* vision.

For self-administered sessions, the quality of the results obtained depends on the ability and willingness of users to follow simple instructions and put forth their best effort. For some purposes, it may be desirable to conduct an *RC21X* or *ROBERTO* session in a setting where a professional can observe and supervise the session. Web-based accessibility makes this easy to combine self-administered and professionally supervised session results for assessments by experts.

The RC21X team has established collaborations with several researchers with interests in specific applications. We encourage other researchers to contact us to discuss how we might be able to support their investigations and interests.

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