

<b>Institution:</b> University College London
<b>Unit of Assessment:</b> 4 - Psychology, Psychiatry and Neuroscience
<b>Title of case study:</b> Invention and commercial development of diagnostic tests of frontal lobe function
<p><b>1. Summary of the impact</b></p> <p>Based on his research at the UCL Institute of Cognitive Neuroscience, Professor Paul Burgess invented and co-invented several cognitive tests (known as the Hayling and Brixton Tests, and the BADS and BADS-C assessment batteries) which are used to detect dysfunction of the frontal lobes of the brain. These were developed for commercial production by Burgess and are now produced and marketed by the largest test publisher in the world (Pearson Assessment). There are versions in several different languages, and they are used in clinics worldwide to diagnose problems in a wide variety of patients with neurological, psychiatric and developmental problems. The tests are now administered around the world to around 55,000 patients per year.</p>
<p><b>2. Underpinning research</b></p> <p>In the mid-1990s, Burgess was investigating whether different sub-regions of a large brain region known as the prefrontal cortex support different mental abilities in humans, and if so, which regions support which ability. As part of these experimental and theoretical studies, a series of new psychometric measures were invented. There were two principal projects as part of this programme of research, which each led to new diagnostic instruments.</p> <p>The first, which led to the development of the Hayling and Brixton Tests, arose from work originally conducted in the Neuropsychology Department of the National Hospital for Neurology and Neurosurgery, where patients with acute neurological problems (principally brain tumours) were studied by Burgess. This work was conducted in collaboration with Professor Tim Shallice FRS (now Emeritus Professor at UCL.) The theoretical research emerging from this work was published in a series of studies between 1996 and 2006 [1-6] with the development of the tools for clinical rather than experimental use occurring during 1997. The experimental research showed that three of the most common symptoms of dysfunction of the frontal lobes of the brain which were hitherto thought to co-occur as part of a syndrome, were in fact quite distinct. This meant that they should therefore be examined separately, and that screening for frontal lobe dysfunction would be much more effective if this happened. The newly developed tools provided a way to do this, using normative data collected on the same set of individuals, allowing comparisons in performance across the tasks, which is particularly important for detecting deficit.</p> <p>The second research programme involved invention of psychometric instruments that would be aimed particularly at predicting everyday handicap in people who had suffered neurological problems. This was a collaboration with a research group at the MRC Cognition and Brain Sciences Unit, Cambridge (Professor Barbara Wilson OBE), Professor Jonathan Evans (Glasgow University) and Professor Nicholas Alderman FBPS (St. Andrew's Hospital, Northampton). Data was collected at St. Andrew's Hospital, The Oliver Zangwill Neurological Rehabilitation Unit (Ely) and the Rivermead Neurological Rehabilitation Centre (Oxford). These new experimental measures of frontal lobe function proved both more sensitive at detecting problems in the clinic than the existing diagnostic ones, and also better predicted handicap in everyday life. The new instruments were first commercially produced in 1996 (called the BADS battery), with new and updated versions produced from 1998-2013. Subsequently, these instruments proved to be of clinical utility for a wider variety of population groups than just neurological patients, and suitable for a greater range of uses than originally thought. Consequently, in 2003 a version of the BADS battery adapted for use with children was produced (called the BADS-C). Furthermore, specific subtasks invented by Burgess as part of the original BADS battery were also found to be predictive of real-world driving ability following neurological insult and so were developed for this purpose though a collaboration with Pat McKenna, Consultant Neuropsychologist, Rookwood Hospital,</p>

## Impact case study (REF3b)

Cardiff. This “Rookwood Driving Battery” was first marketed commercially in 2009.

### 3. References to the research

- [1] Burgess PW, Shallice T. Bizarre responses, rule detection and frontal lobe lesions. *Cortex*. 1996 Jun;32(2):241-59. [http://dx.doi.org/10.1016/S0010-9452\(96\)80049-9](http://dx.doi.org/10.1016/S0010-9452(96)80049-9)
- [2] Burgess PW, Shallice T. Response suppression, initiation and strategy use following frontal lobe lesions. *Neuropsychologia*. 1996 Apr;34(4):263-72. [http://dx.doi.org/10.1016/0028-3932\(95\)00104-2](http://dx.doi.org/10.1016/0028-3932(95)00104-2)
- [3] Burgess PW, Alderman N, Evans J, Emslie H, Wilson BA. The ecological validity of tests of executive function. *J Int Neuropsychol Soc*. 1998 Nov;4(6):547-58. <http://dx.doi.org/10.1017/S1355617798466037>
- [4] Burgess PW, Veitch E, de Lacy Costello A, Shallice T. The cognitive and neuroanatomical correlates of multitasking. *Neuropsychologia*. 2000;38(6):848-63. [http://dx.doi.org/10.1016/S0028-3932\(99\)00134-7](http://dx.doi.org/10.1016/S0028-3932(99)00134-7)
- [5] Burgess PW, Alderman N, Forbes C, Costello A, Coates LM, Dawson DR, Anderson ND, Gilbert SJ, Dumontheil I, Channon S. The case for the development and use of "ecologically valid" measures of executive function in experimental and clinical neuropsychology. *J Int Neuropsychol Soc*. 2006 Mar;12(2):194-209. <http://dx.doi.org/10.1017/S1355617706060310>
- [6] Volle E, de Lacy Costello A, Coates LM, McGuire C, Towgood K, Gilbert S, Kinkingnehun S, McNeil JE, Greenwood R, Papps B, van den Broeck M, Burgess PW. Dissociation between verbal response initiation and suppression after prefrontal lesions. *Cereb Cortex*. 2012 Oct;22(10):2428-40. <http://dx.doi.org/10.1093/cercor/bhr322>

### 4. Details of the impact

Every year in Britain, many hundreds of thousands of individuals suffer from neurological problems, for example after strokes, head injuries or tumours. The measurement of cognitive deficits following frontal lobe damage (collectively known as “dysexecutive symptoms”) is a major issue for the treatment of these patients. It has long been known that patients can suffer a wide range of cognitive disabilities such as deficits in planning, multitasking, response suppression, etc. which present a severe handicap in everyday life. But although we have had good measures of intellectual and memory functioning, and also of visual perception, language, and motor skills, before our research it was not possible to quantify well dysexecutive problems in the clinic because the necessary psychometric tools to measure them did not exist.

Our diagnostic instruments have now been widely adopted by clinicians to determine if patients with neurological problems are suffering from dysexecutive symptoms. The results of the tests are used to guide treatment and make decisions relating to handicap – for instance, whether patients can return home to live independently, or are able to manage their own finances. They are also used to assess disability where there are issues relating to compensation (e.g. brain damage following car accidents).

The publisher of the four tests reports sales as follows (as at Feb 2012):

- The average sales of these products over the past three years would indicate that these tests are administered to approximately **55,000 patients per year**.
- The BADS has been translated into **six languages** (Brazilian Portuguese, Chinese, Dutch, German, Greek and Russian) and the BADS-C has been translated into Dutch. Over 15 research permissions have also been agreed for these tests over the past five years.
- The tests are **sold around the world** including in the UK, Australia/New Zealand, Denmark, France, Germany, Netherlands, Norway, Spain, Sweden, India, Canada, USA, as well as being distributed by local publishing partners in other countries across Europe,

Asia, Africa and South America [a].

### ***The Hayling and Brixton Tests***

The Hayling and Brixton Tests together measure three of the most common symptoms of the dysexecutive syndrome [b]. Firstly, the Hayling Test measures response suppression (the ability to withhold an inappropriate behaviour). The pre-existing measure of this ability (the “Stroop Test”) provides a false negative rate too high for most clinical purposes, and the Hayling Test has now largely supplanted it in the UK. Secondly, the Hayling Test measures response initiation. Despite being one of the most commonly reported dysexecutive problems (approximately 27% of all neurological rehabilitation patients show this problem) there was no pre-existing formal measure for it, so the Hayling Test filled this clinical need. Thirdly, the Brixton Test is a test of rule attainment. It has now supplanted the test previously in most common use (the Wisconsin Card Sort Test – WCST), having addressed a major concern with that test – that guessing could not be detected.

### ***The BADS test battery***

The BADS test battery is a suite of psychometric tasks which can be administered together to gain an overall diagnostic picture of the patient’s dysexecutive problems [c]. This was devised for wider clinical use than the Hayling and Brixton Tests, and can be administered by qualified occupational therapists and some other personnel who have specific training but who are not medical doctors or Chartered Psychologists. Like the Hayling and Brixton tests, it has also gained wide acceptance as a standard diagnostic instrument, and its use is presented in many standard texts [d].

### ***BADS-C***

Researchers and clinicians who work with children found the logic of the adult version of the BADS compelling, but wanted a version which was suitable for children. Accordingly, the BADS-C was created, and is used specifically to measure dysexecutive symptoms in children with neurological problems, as well as a range of psychiatric and developmental conditions where frontal lobe dysfunction is a feature [e].

### ***The Rookwood Driving Battery***

Damage to the frontal lobes can cause a range of cognitive disabilities and changes in behaviour, some of which can affect a person’s fitness to drive a vehicle. A 2007 study [f] found that three sub-tests from the BADS battery were useful in predicting on-road performance among people who had suffered some form of neuropathology, and these were incorporated (along with other tests from other authors) into a battery of tests specifically designed for driving assessment, which was named the Rookwood Driving Battery [g]. This is the only tool of its kind available in the world, and it is used in a wide range of conditions, including brain injury [h] and dementia [i].

### ***Use of the tests in clinical practice***

The tests described above have been widely adopted in clinical practice. A recent survey by the Division of Neuropsychology of the British Psychological Society (the principal representative body for neuropsychologists in the UK) asked members which of the many available tests they choose to use in their day-to-day practice for measuring frontal lobe cognitive deficits. The three most commonly used tests, out of the many invented over the last 100 years, were the BADS and the Brixton Tests (both 89% of respondents), and the Hayling Test (81%) [j].

Training on the diagnostic tests is now integrated into the professional training of e.g. clinical psychologists, occupational therapists, and psychiatrists. For instance a recent exam paper prepared by the Examinations Unit at the Royal College of Psychiatrists included a question on the correct use of the Hayling Test [k].

In 2010 Burgess received the “President’s Award for Distinguished Contributions to Psychological Knowledge” from the British Psychological Society, and the invention of these tests (as well as the resulting knowledge) was cited as a principal reason for the award [l].

### ***Use of the tests in legal proceedings***

**Impact case study (REF3b)**

The impact of these diagnostic procedures has also extended beyond the clinic. In New South Wales, Australia, for example, the Offender Assessment Unit recommends the Hayling and Brixton tests for measuring executive function in offenders [m]. In the case of *The Crown vs. David Waterhouse* (Bradford Crown Court, February 2008) evidence of diagnostic information provided by the Hayling Test was presented to the court in reference to a matter of responsibility in consideration of a charge of attempted murder. The defence argued that the defendant, following a frontal lobe injury, was incapable of stopping himself from stabbing his 14-year-old stepdaughter several times with a kitchen knife. But the result of the psychometric testing was accepted as evidence that this was not a safe interpretation of events, and the defendant was convicted [n].

**5. Sources to corroborate the impact**

- [a] Commercial sales: letter from Pearson Assessment (Feb 2012) to corroborate the figures and commercial details quoted here. Copy available on request.
- [b] <http://www.pearsonclinical.co.uk/Psychology/AdultCognitionNeuropsychologyandLanguage/AdultAttentionExecutiveFunction/HaylingandBrixtonTests/HaylingandBrixtonTests.aspx>
- [c] <http://www.pearsonclinical.co.uk/Psychology/AdultCognitionNeuropsychologyandLanguage/AdultAttentionExecutiveFunction/BehaviouralAssessmentoftheDysexecutiveSyndrome%28BADS%29/BehaviouralAssessmentoftheDysexecutiveSyndrome%28BADS%29.aspx>
- [d] e.g. Armstrong, C. L. (2010) *Handbook of Medical Neuropsychology: Applications of Cognitive Neuroscience*. New York: Springer; Strauss, E., Sherman, E. & Spreen, O. (2006) *A Compendium of Neuropsychological Tests: Administration, Norms, And Commentary*. New York: Oxford University Press.
- [e] <http://www.pearsonclinical.co.uk/Psychology/ChildCognitionNeuropsychologyandLanguage/ChildAttentionExecutiveFunction/BehaviouralAssessmentoftheDysexecutiveSyndromeinChildren%28BADS-C%29/BehaviouralAssessmentoftheDysexecutiveSyndromeinChildren%28BADS-C%29.aspx>
- [f] McKenna P, Bell V. Fitness to drive following cerebral pathology: the Rookwood Driving Battery as a tool for predicting on-road driving performance. *J Neuropsychol.* 2007 Mar;1(Pt 1):85-100. <http://dx.doi.org/10.1348/174866407X180837>
- [g] Rookwood Driving Battery:  
[http://www.pearsonclinical.co.uk/Psychology/AdultCognitionNeuropsychologyandLanguage/AdultGeneralAbilities/RookwoodDrivingBattery\(RDB\)/RookwoodDrivingBattery\(RDB\).aspx](http://www.pearsonclinical.co.uk/Psychology/AdultCognitionNeuropsychologyandLanguage/AdultGeneralAbilities/RookwoodDrivingBattery(RDB)/RookwoodDrivingBattery(RDB).aspx)  
See PDF overview: "Five tests are included to assess executive functioning, three of which were chosen from the Behavioural Assessment of the Dysexecutive Syndrome Battery (BADS) Wilson, Alderman et al (1996)."
- [h] [www.wales.nhs.uk/sites3/docopen.cfm?orgid=737&id=119559](http://www.wales.nhs.uk/sites3/docopen.cfm?orgid=737&id=119559)
- [i] <http://www.rcpsych.ac.uk/pdf/Driving%20and%20Dementia%20final.pdf>
- [j] Source: Lenherr & Gerhand, BPS Division of Neuropsychology Newsletter August 2012. <http://www.bpsshop.org.uk/Division-of-Neuropsychology-Newsletter-Vol-11-No-2-Autumn-2012-P2299.aspx> Copy available on request.
- [k] The following example is taken from a paper prepared by the Examinations Unit at the Royal College of Psychiatrists (see first question on page 3; Hayling Test). <http://www.rcpsych.ac.uk/pdf/Paper%202%20sample%20questions.pdf>
- [l] <http://hopc.bps.org.uk/hopc/histres/bpshistory/awards/pres.cfm>
- [m] [http://www.correctiveservices.nsw.gov.au/\\_data/assets/pdf\\_file/0009/436761/compendium-of-assessments-2nd-edition-7-march-final.pdf](http://www.correctiveservices.nsw.gov.au/_data/assets/pdf_file/0009/436761/compendium-of-assessments-2nd-edition-7-march-final.pdf) (see page 89)
- [n] [http://www.thetelegraphandargus.co.uk/news/local/bradford/2293796.man\\_locked\\_up\\_for\\_stabbing\\_girl/](http://www.thetelegraphandargus.co.uk/news/local/bradford/2293796.man_locked_up_for_stabbing_girl/)