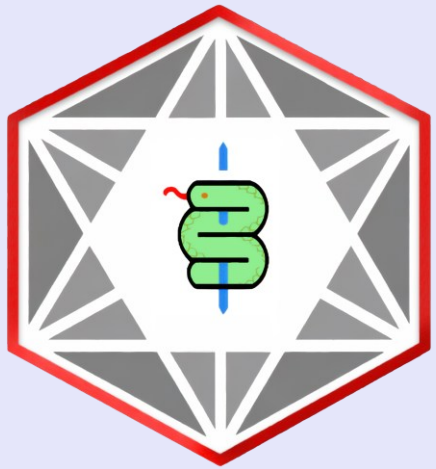
Ecological Assessment of Executive Dysfunction in Cerebrovascular Disorder



CLINICAL COGNITIVE SCIENCES LAB

Dr Graham Pluck

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International Conference on Neuroscience and Neurology (ICNN), 6th October 2025


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Science, 1994
NAZARBAYEV
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PASSAGE OF AN IRON BAR THROUGH THE HEAD.

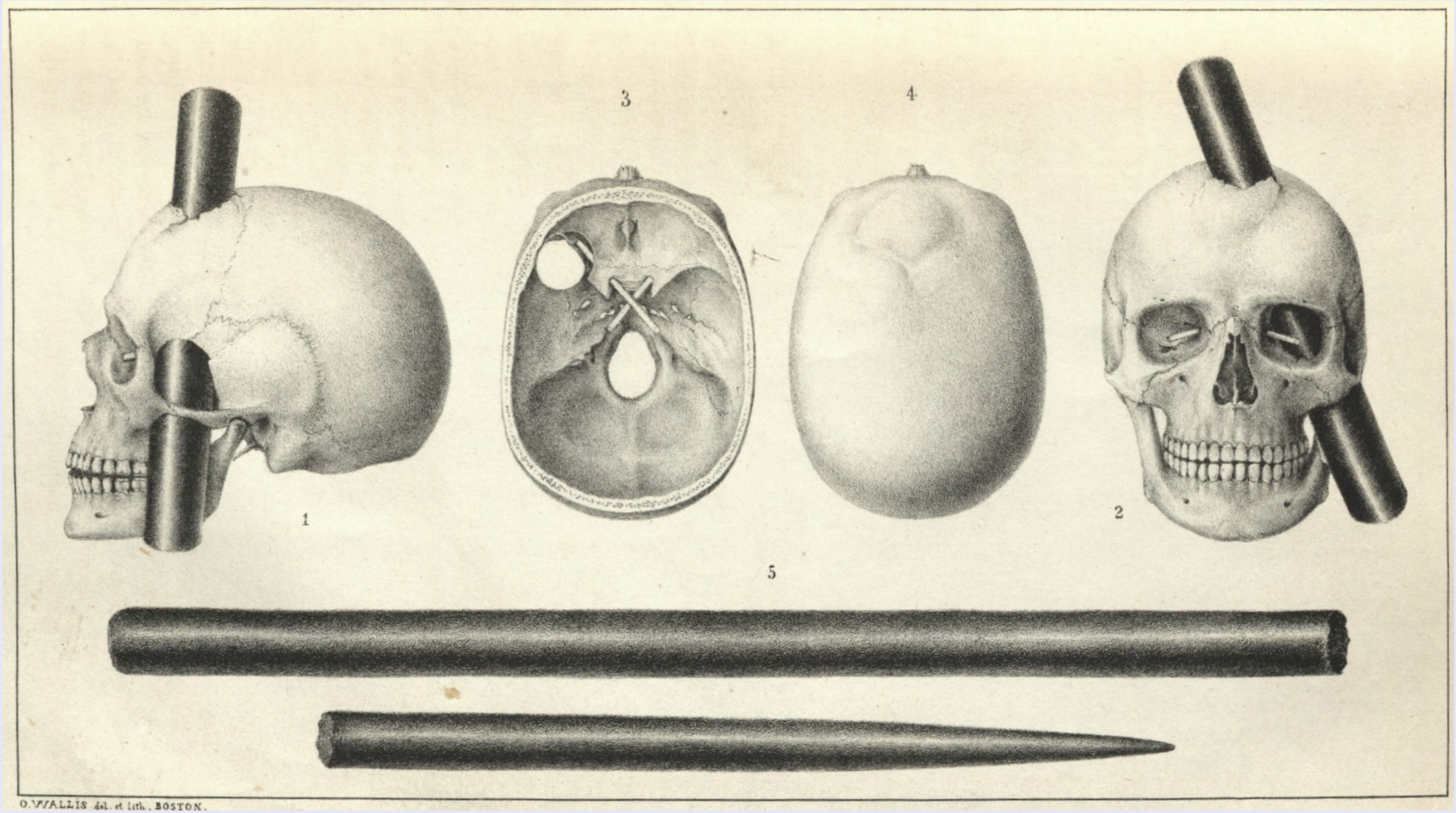
By JOHN M. HARLOW, M.D.,
OF WOBURN.

(With a Plate.)

Read before the Massachusetts Medical Society, June 3, 1868.

BOSTON:
DAVID CLAPP & SON.....334 WASHINGTON STREET.
MEDICAL AND SURGICAL JOURNAL OFFICE.
1869.

Phineas Gage

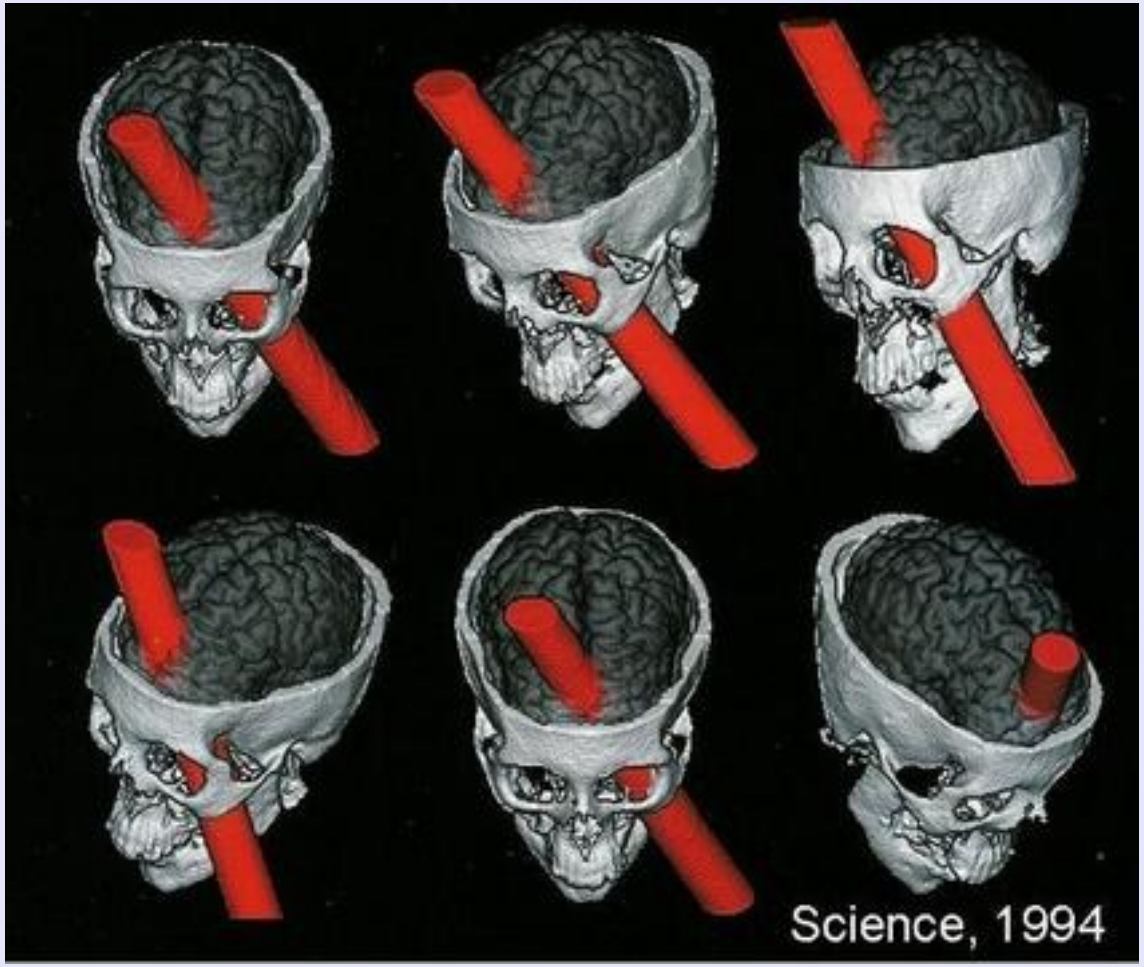


Bigalow, H.J. (1850). Dr. Harlow's case of recovery from the passage of an iron bar through the head. *American Journal of Medical Science*, *20*(39), 13-22.

Estimated damage

Left hemisphere: anterior half of the orbital frontal cortex, the polar and anterior mesial frontal cortices, and the anterior-most sector of the anterior cingulate gyrus.

Right hemisphere: anterior and mesial orbital region, mesial and polar frontal cortices and the anterior segment of the anterior cingulate gyrus.



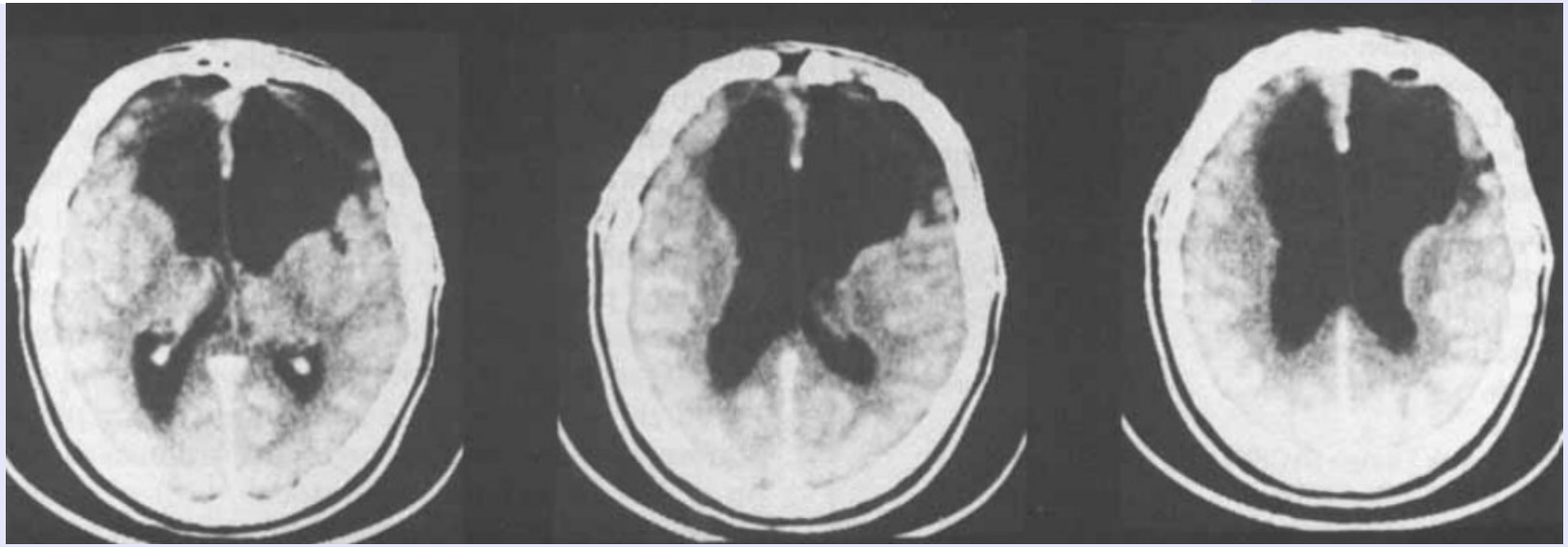
Damasio, H., et al. (1994). The return of Phineas Gage: clues about the brain from the skull of a famous patient. *Science, 264*(5162), 1102-1105.

- Acutely, he seemed to not lose consciousness.
  - He was able to talk, and to walk up a staircase to receive medical treatment.

- Chronically, no amnesia, aphasia, or other global or focal cognitive impairment reported.
  - Was able to continue paid employment.

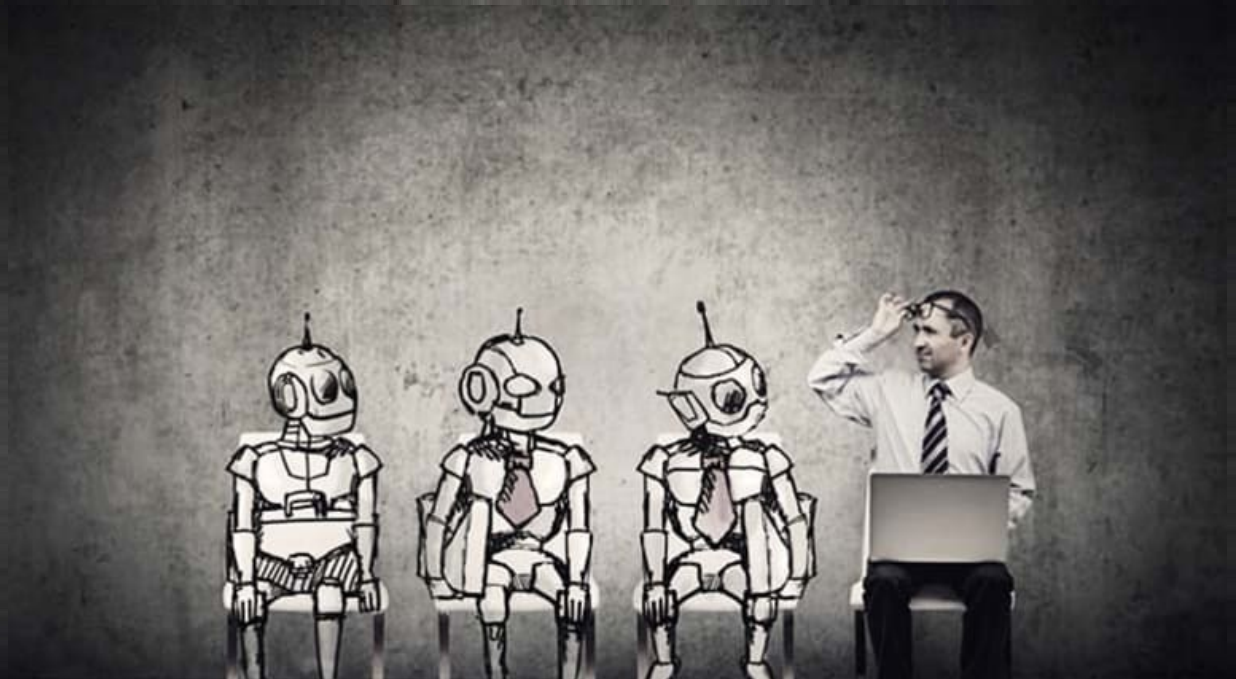
Many studies of patients with acquired brain injuries of the frontal lobes have reported average or above average IQ scores.

Intellect			
WAIS-R	Verbal IQ	129	(97th; superior)
	Performance IQ	135	(99th; very superior)



- Blair, R. J., & Cipolotti, L. (2000). Impaired social response reversal. A case of 'acquired sociopathy'. *Brain, 123*(6), 1122-1141.
- Cato, M. A., Delis, D. C., Abildskov, T. J., & Bigler, E. (2004). Assessing the elusive cognitive deficits associated with ventromedial prefrontal damage: a case of a modern-day Phineas Gage. *Journal of the International Neuropsychological Society, 10*(3), 453-465.
- Eslinger, P. J., & Damasio, A. R. (1985). Severe disturbance of higher cognition after bilateral frontal lobe ablation: patient EVR. *Neurology, 35*(12), 1731-1741.
- Shallice, T., & Burgess, P. W. (1991). Deficits in strategy application following frontal lobe damage in man. *Brain, 114*(2), 727-741.

Executive Function



The concept of ‘executive function’ originated in computer science. Programs that control other programs.

In 1956 a program called the *Automatic Supervisor* was developed for the IBM 702.

Shortly afterwards, *General Motors Executive System* was developed for the IBM 704

Moncreiff, B.: An automatic supervisor for the IBM 702. AIEE-IRE '56 Joint ACM-AIEE-IRE Western Computer Conference, pp. 21-25 (1956)

Several other top-down controllers, or operating systems were developed with similar ‘executive’ names.

Manufacturer	Computer	Year	Operating System
Honeywell	H800	1961	Executive Monitor
Univac	Univac 1107	1962	EXEC I
Burroughs	D825	1962	AOSP
Burroughs	B5000	1962	Master Control Program
Philco	Philco-2000	1962	SYS; BKS
GE	GE-215/225/235	1962	BRIDGE
IBM	IBM 7090/7094	1962	IBSYS
Bendix	G-20	1962	EXECUTIVE
CDC	CDC 1604	1962	CO-OP monitor system
CDC	CDC 3600	1963	SCOPE monitor system
Honeywell	Honeywell 1800	1963	ADMIRAL Master Monitor
GE	GE 625-635	1964	Comprehensive Operating Supervisor
RCA	RCA 3301	1964	Realcom system
SDS	SDS 9000	1964	MONARCH
DEC	PDP-6	1964	Supervisory Control Program

Table 1 An overview of the first operating systems offered by U.S. computer manufacturers 1960-1964

Bullynck, M.: What is an operating system? a historical investigation (1954–1964). In: De Mol, L., Primiero, G. (eds.) Reflections on Programming Systems: Historical and Philosophical Aspects. Springer, Cham (2018).

Minds, Brains & Computers

In 1973, drawing on computer science, Karl H. Pribram, working with cortical ablation of monkey brains, proposed that the frontal lobes may function like the ‘executive controllers’

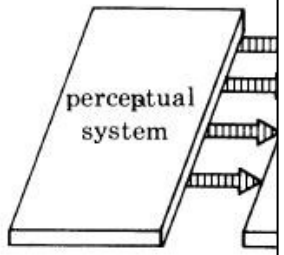


FIGURE 1. A simplified version of the
The lines with arrows represen
function of contention schedu
involved in schema operation
involves placing information i

Norman, D.A., Shallice, T.: Attenti
automatic control of behavior. Hu
Processing Technical Report no.

Baddeley, A., & Hitch, G. J. (1
Bower (Ed.), Recent Advances

supervisory

BRAIN AND COGNITION 7, 212–230 (1988)

Frontal Amnesia and the Dysexecutive Syndrome

ALAN BADDELEY

MRC Applied Psychology Unit, Cambridge

AND

BARBARA WILSON

Rivermead Rehabilitation Centre, Oxford

This study analyzes the memory deficits shown by an amnesic patient with bilateral frontal damage and a dysexecutive syndrome. He resembles a classic amnesic patient in showing grossly impaired episodic memory for both verbal and nonverbal material, together with normal digit span, and on occasion normal recency in free recall. He differs from the classic amnesic pattern however in showing an impairment in both the speed and accuracy of performance on tests of semantic memory, and in clear evidence for impaired performance on some though not all procedural learning tasks. Finally, his autobiographical memory was poor and subject to substantial confabulation. It is suggested that the pattern of deficits is consistent with a combination of a classic amnesic syndrome with the additional problems associated with the frontal dysexecutive syndrome, rather than exhibiting a qualitatively different form of amnesia.

Pluck, G., et al. (2023). Executive function
ntelligent goal-directed behavior:
pectives from psychology, neurology, and
puter science. In: Masci, P.,
ardeschi, C., Graziani, P., Koddenbrock,
almieri, M. (eds) Software Engineering
Formal Methods. SEFM 2022 Collocated
kshops. SEFM 2022. *Lecture Notes in*
puter Science, vol 13765. Springer,
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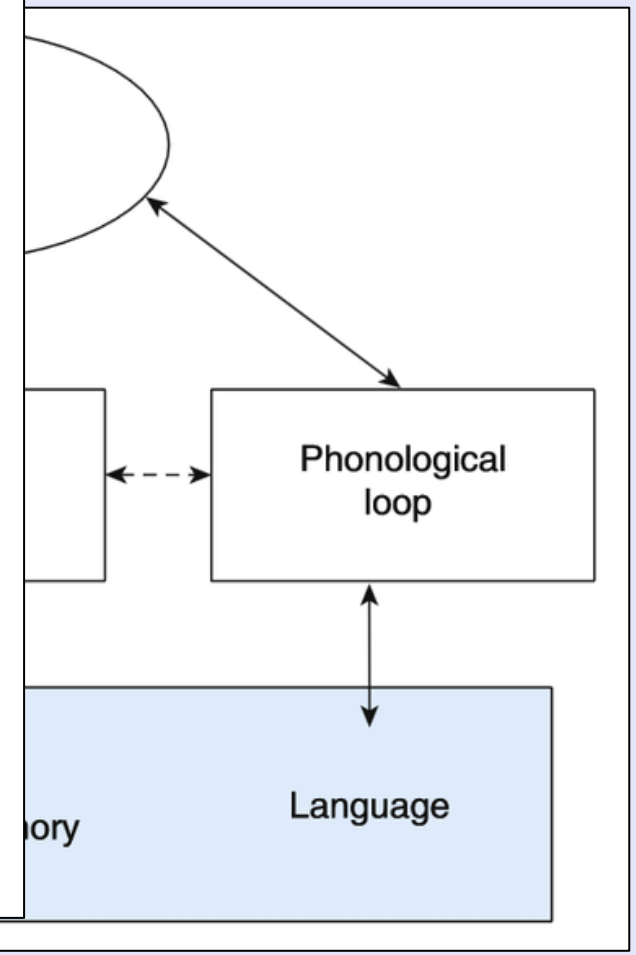
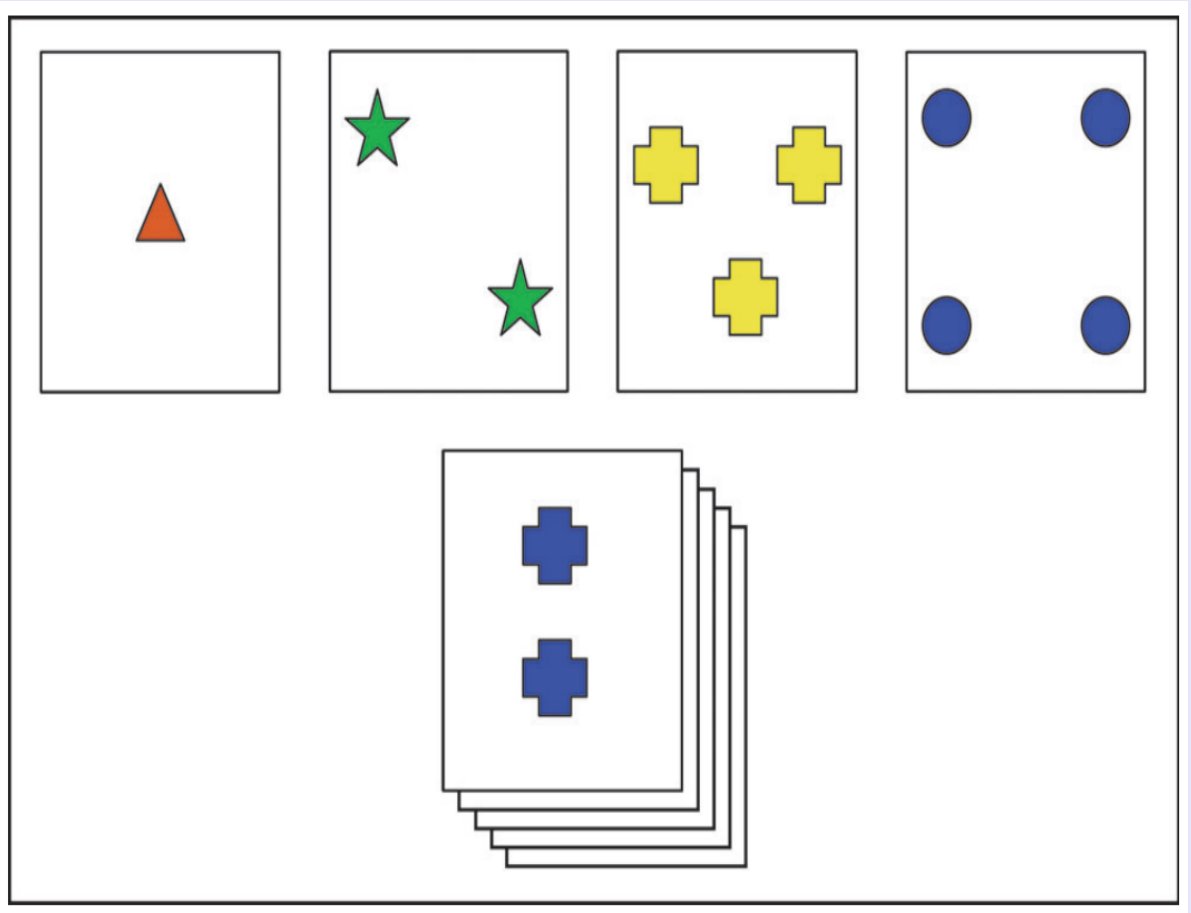
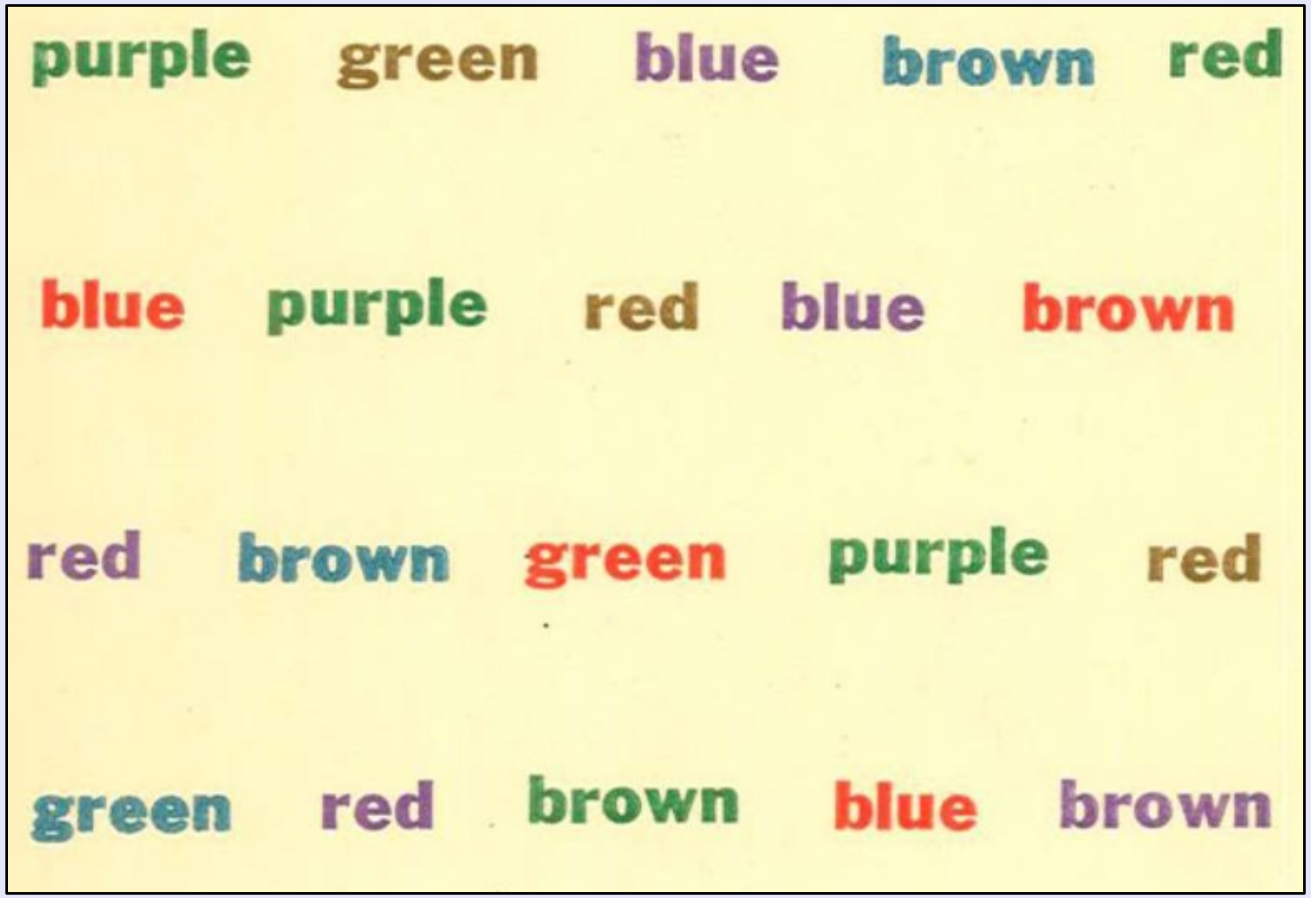


Wisconsin Card Sort Test



Stroop Test



Brain (1991), **114**, 727–741

DEFICITS IN STRATEGY APPLICATION FOLLOWING FRONTAL LOBE DAMAGE IN MAN

by TIM SHALLICE *and* PAUL W. BURGESS

(*From the National Hospital, Queen Square, London and the MRC Applied Psychology Unit, Cambridge*)

TABLE 5. ERRORS ON MULTIPLE ERRANDS

	Cases			
	1	*2*	*3*	*Control*
Inefficiencies	6*	9*	5*	1.4 (1.1)
Rule breaks	5*	8*	8*	1.6 (1.3)
Interpretation failures	1	1	1	0.4 (0.7)
Task failures	0	5*	4*	1.1 (1.4)
Total errors	12*	23*	17*	4.6 (2.1)

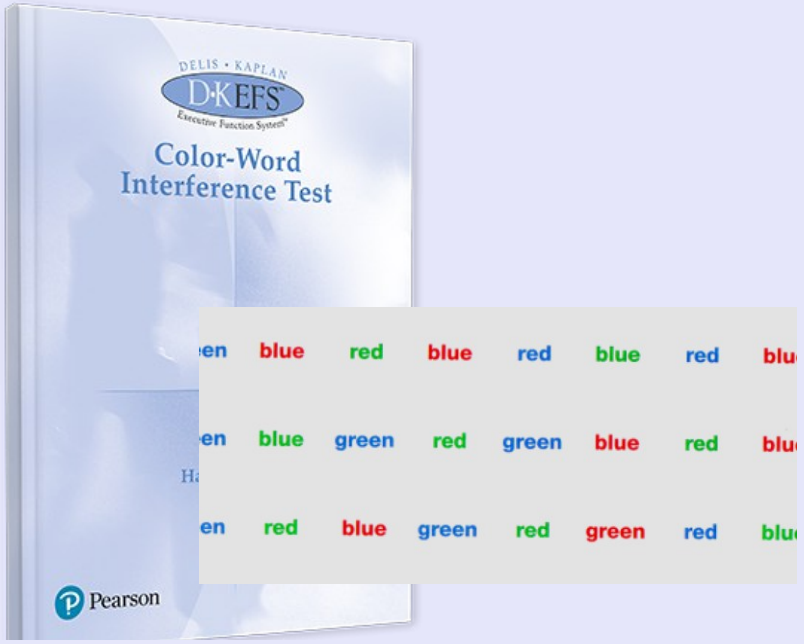
* More than 2 SD worse than the control subjects.

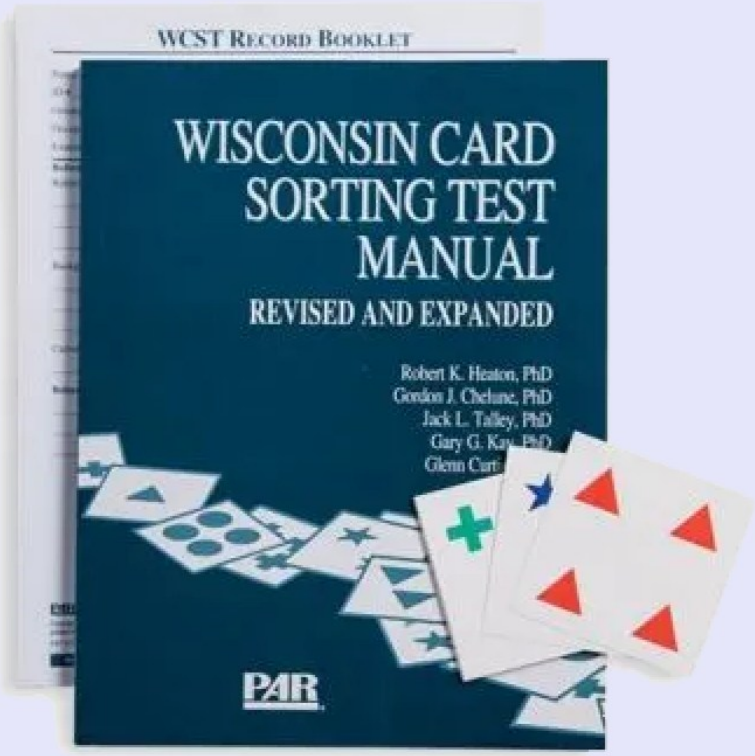
Shallice and Burgess gave three patients with extensive frontal lobe lesions the ‘Multiple Errands Test’. Sent to a shopping area in London with a list of tasks, such as:

- Buy a loaf of brown bread
- Be at a certain place 15 minutes after starting.
- Find the name of the shop likely to stock the most expense item.

Multiple Errands Test

- Notably, all three patients had current IQ scores > 120.
- Performed standard tests of executive function well, including Wisconsin Card Sorting and Stroop often better than control participants.





Multiple Errands Test (MET)

- Despite its complexity, MET has been applied in at least 32 subsequent research studies.
- Usually in hospital environments, but also, private homes, museums, shopping malls and therapeutic communities.
- Large effect sizes for distinguishing patients from controls.

Instructions

In this exercise you should complete the following three tasks:

1. *You should do the following 6 things:*
   - Collect something for the examiner* from the Main Information Desk (at the Khedive Entrance) and do what is necessary
   - Buy 4 local stamps (considered 1 item)
   - Buy a birthday card
   - Buy a can of Coca-Cola
   - Telephone Katherine at 416-785-2500 ext.2170 and say where you are, who you are, and what time it is
   - Mail something to Dr. Dawson** at the University of Toronto.
2. *You must meet me at the parrot cage 10 minutes after you have started the exercise and tell me the time*
3. *You should obtain the following information and write it down in the spaces below:*
   - What is the closing time of the resident's library on a Thursday?_____
   - What is the opening time of the gift shop on a Friday?_____
   - What is the price of a Mars Bar?_____
   - How many entrances/exits are there on the main floor of Baycrest?_____

Tell me when you have completed the exercise.

While carrying out this exercise you must obey the following rules:

Rules

- You should carry out all these tasks but may do so in any order
- You should spend no more than $7.50
- You should stay within the limits of the main floor of the hospital
- You should not enter any of the hospital treatment areas or "staff only" areas
- You should not go back into an area you have already been in
- You should buy no more than 2 items in the gift shop
- Take as little time to complete this exercise without rushing excessively
- Do not speak to us *unless* this is part of the exercise

*Your examiner is:

**Dr. Dawson
University of Toronto
500 University Ave., Suite 160
Toronto, Ont., M5G 1V7

Rotenberg, et al. (2020). Measurement properties of the Multiple Errands Test: A systematic review. *Archives of Physical Medicine and Rehabilitation*, *101*(9), 1628-1642.

Clinical staff who care for brain injured patients asked to describe the executive problems shown.

Patients with acquired brain injuries asked to role play working in an office environment.

Jansari, et al. (2014). Ecological assessment of executive functions: a new virtual reality paradigm. *Brain Impairment*, *15*(2), 71-87.

PL = Planning

PR = Prioritization

ST = Selection

CT = Creative Thinking

AT = Adaptive Thinking

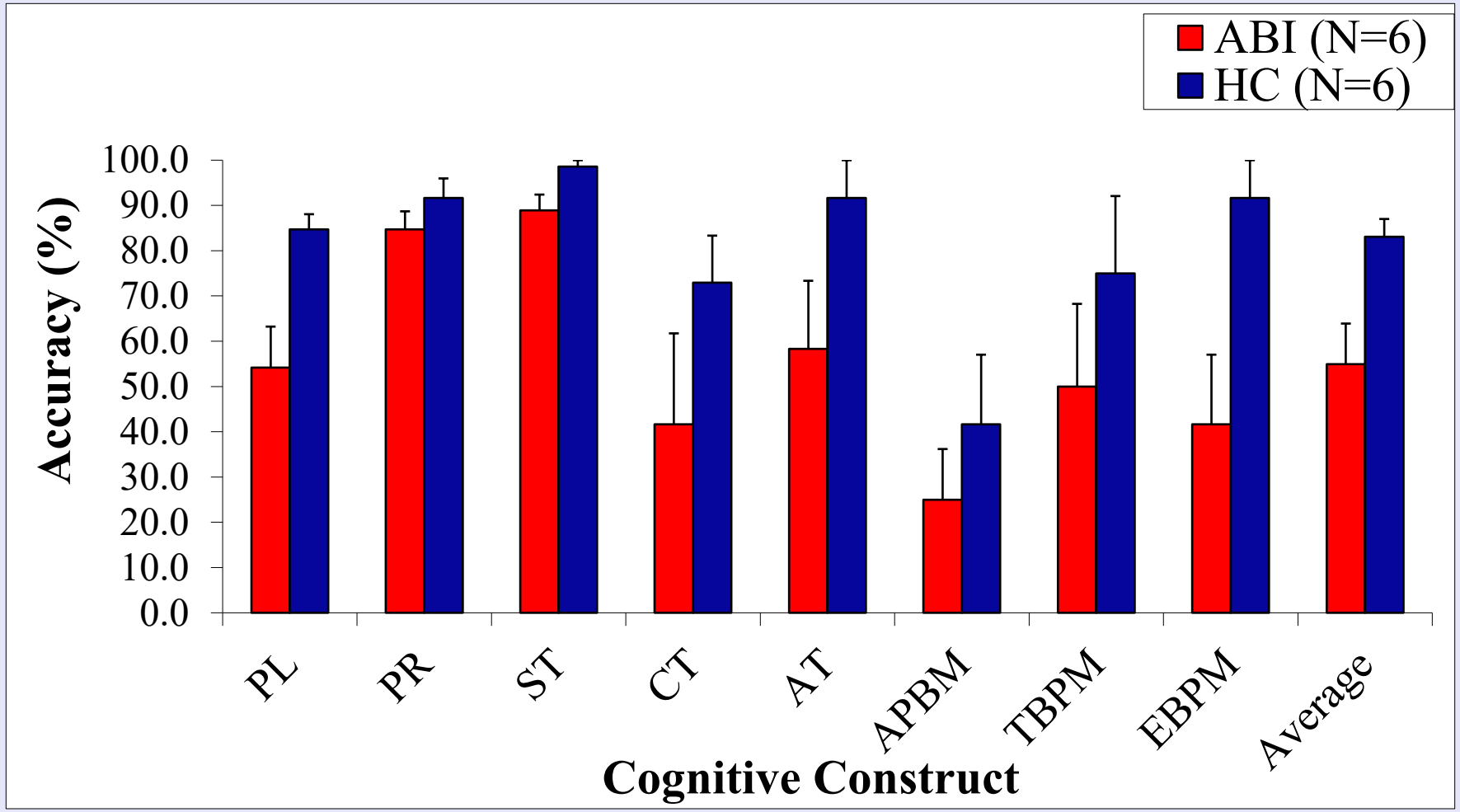
MT = Multitasking

APM = Action-based Prospective Memory

TBPM = Time-based Prospective Memory

EBPM = Event-based Prospective Memory

Actual office environment




In-tray
Completed
Post To Be Sent
Post Diary
My Notes For Manager


Student License. Commercial use is illegal

Non-immersive VR office environment

PL = Planning

PR = Prioritization

ST = Selection

CT = Creative Thinking

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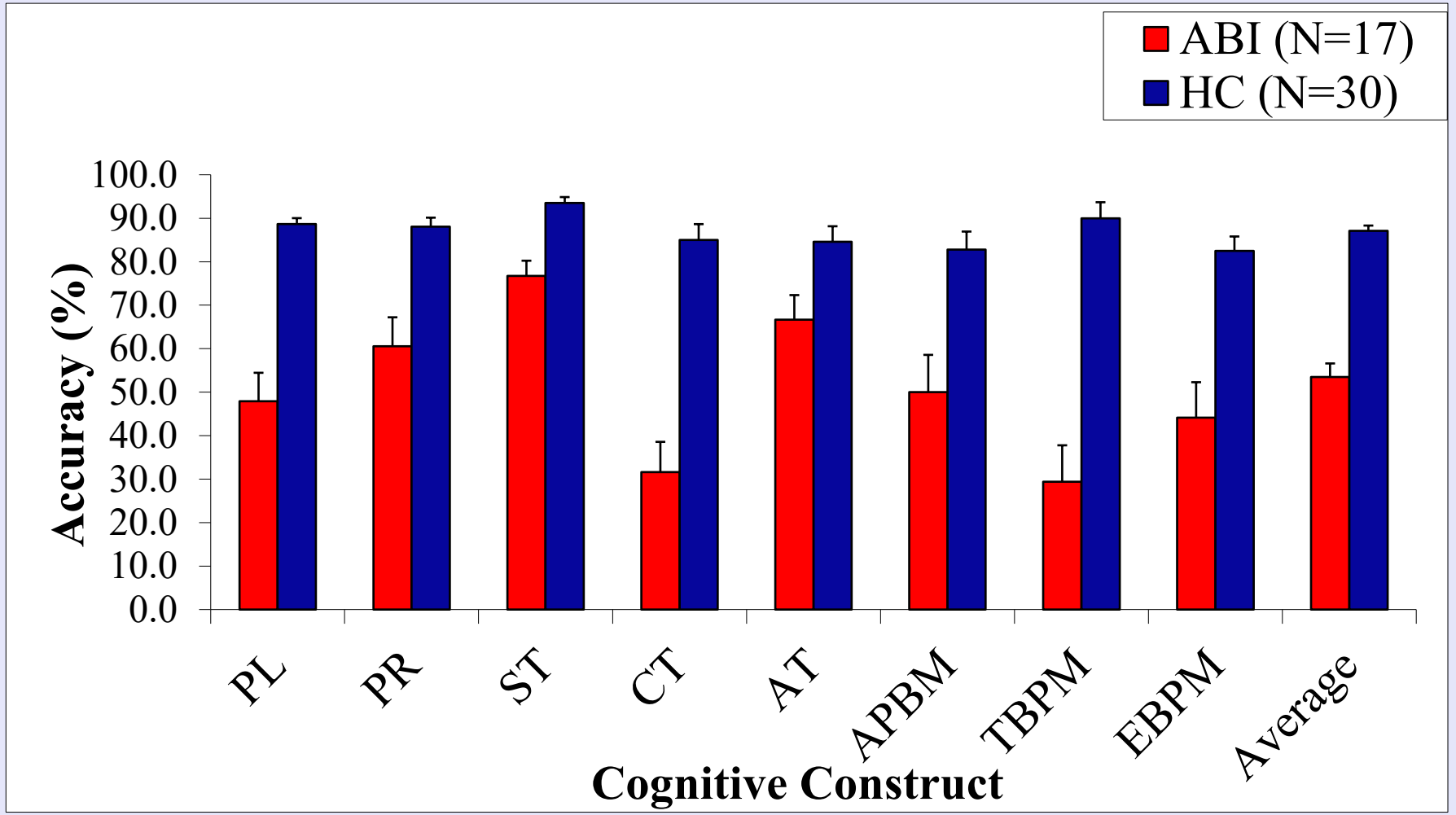


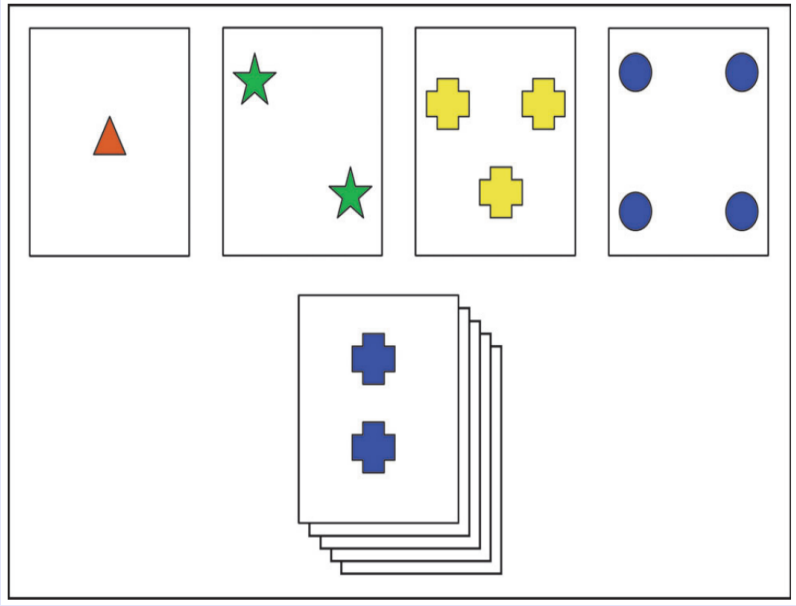
Jansari, A. S., Devlin, A., Agnew, R., Akesson, K., Murphy, L., & Leadbetter, T. (2014). Ecological assessment of executive functions: a new virtual reality paradigm. *Brain Impairment*, *15*(2), 71-87.

- N = 10 patients with cerebrovascular disorder
  - *n = 9 lacunar stroke*
  - *n = 1 multiple transient ischemic attacks*

- N = 19 age-matched controls, with no neurological history

JEF

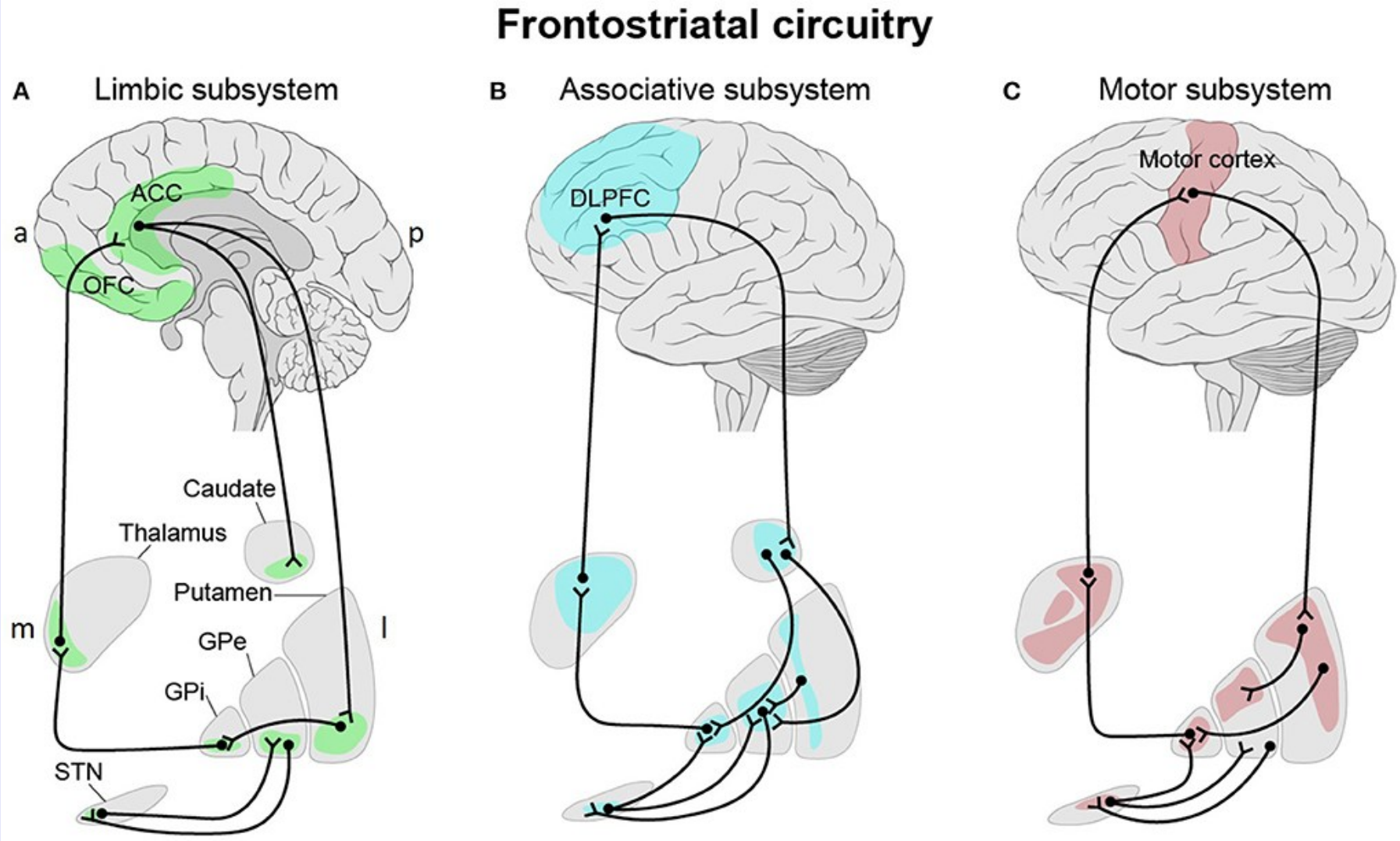
Wisconsin Card Sort



Lexical Decision

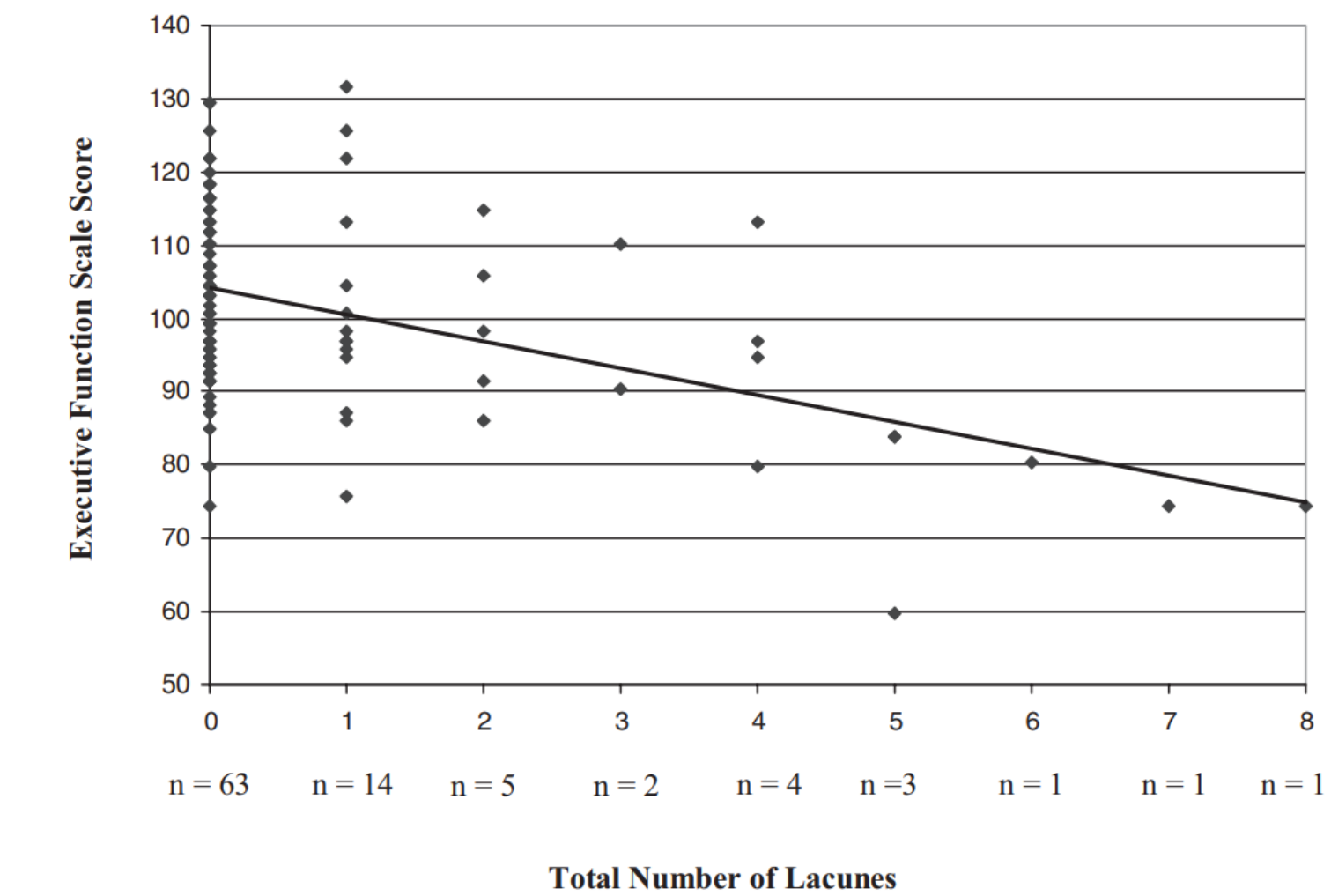
กบาล	—	เกือน
คเมช	—	จวัก
โอษฐ์	—	ทัศภาติ
ทรรษา	—	นาคา
ทิชากร	—	ถานร

Lucunes tend to disrupt the frontostriatal loops.



Zhu, et al. (2019). Basal ganglia-cortical circuit disruption in subcortical silent lacunar infarcts. *Frontiers in Neurology*, *10*, 660.

Lacunes are associated with low executive test scores even in otherwise cognitively healthy older people.



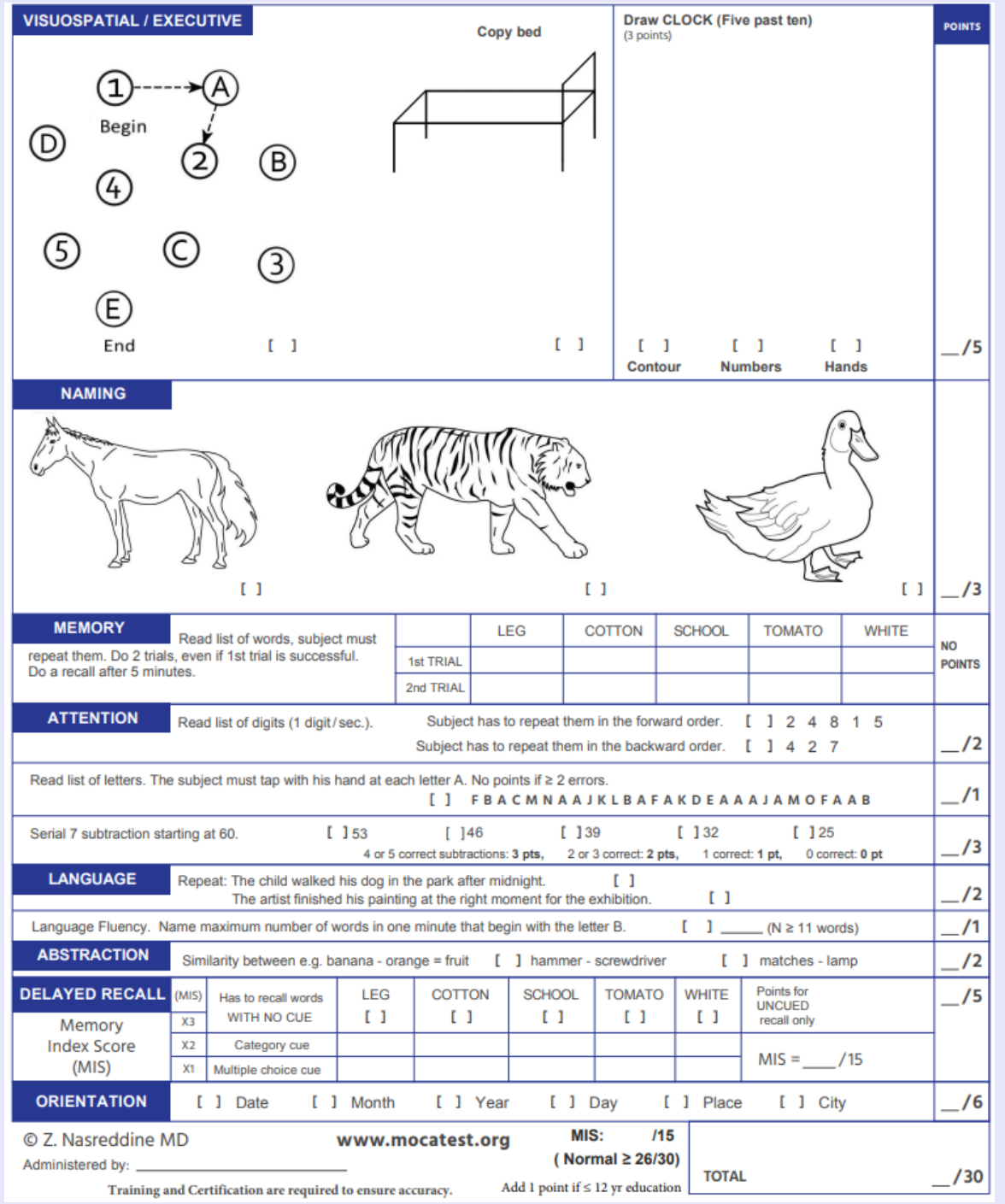
Carey, et al. (2008). Subcortical lacunes are associated with executive dysfunction in cognitively normal elderly. *Stroke*, *39*(2), 397-402.

Montreal Cognitive Assessment (MoCA)

MoCA scores of patients

Mean = 26.7, SD = 1.8, range 20 – 30

All above the cut-off for mild-cognitive impairment



VISUOSPATIAL / EXECUTIVE

Copy bed

Draw CLOCK (Five past ten)
(3 points)

POINTS

Begin

End

[ ] Contour [ ] Numbers [ ] Hands

__/5

NAMING

[ ] [ ] [ ]

__/3

MEMORY

Read list of words, subject must repeat them. Do 2 trials, even if 1st trial is successful. Do a recall after 5 minutes.

	LEG	COTTON	SCHOOL	TOMATO	WHITE
1st TRIAL					
2nd TRIAL					

NO POINTS

ATTENTION

Read list of digits (1 digit/sec.).

Subject has to repeat them in the forward order. [ ] 2 4 8 1 5

Subject has to repeat them in the backward order. [ ] 4 2 7

__/2

Read list of letters. The subject must tap with his hand at each letter A. No points if ≥ 2 errors.

[ ] F B A C M N A A J K L B A F A K D E A A A J A M O F A A B

__/1

Serial 7 subtraction starting at 60. [ ] 53 [ ] 46 [ ] 39 [ ] 32 [ ] 25

4 or 5 correct subtractions: **3 pts**, 2 or 3 correct: **2 pts**, 1 correct: **1 pt**, 0 correct: **0 pt**

__/3

LANGUAGE

Repeat: The child walked his dog in the park after midnight. [ ]

The artist finished his painting at the right moment for the exhibition. [ ]

__/2

Language Fluency. Name maximum number of words in one minute that begin with the letter B. [ ] _____ (N ≥ 11 words)

__/1

ABSTRACTION

Similarity between e.g. banana - orange = fruit [ ] hammer - screwdriver [ ] matches - lamp

__/2

DELAYED RECALL

Memory Index Score (MIS)

	Has to recall words WITH NO CUE	LEG	COTTON	SCHOOL	TOMATO	WHITE
(MIS) X3		[ ]	[ ]	[ ]	[ ]	[ ]
X2	Category cue					
X1	Multiple choice cue					

Points for UNCUED recall only

MIS = ____/15

__/5

ORIENTATION

[ ] Date [ ] Month [ ] Year [ ] Day [ ] Place [ ] City

__/6

© Z. Nasreddine MD

www.mocatest.org

MIS: /15

(Normal ≥ 26/30)

Administered by: _____

Training and Certification are required to ensure accuracy.

Add 1 point if ≤ 12 yr education

TOTAL __/30

Manjavong, M., Limpawattana, P., & Sawanyawisuth, K. (2021). Can RUDAS be an alternate test for detecting Mild Cognitive Impairment in older adults, Thailand?. *Geriatrics*, *6*(4), 117.

PL = Planning

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APM = Action-based Prospective Memory

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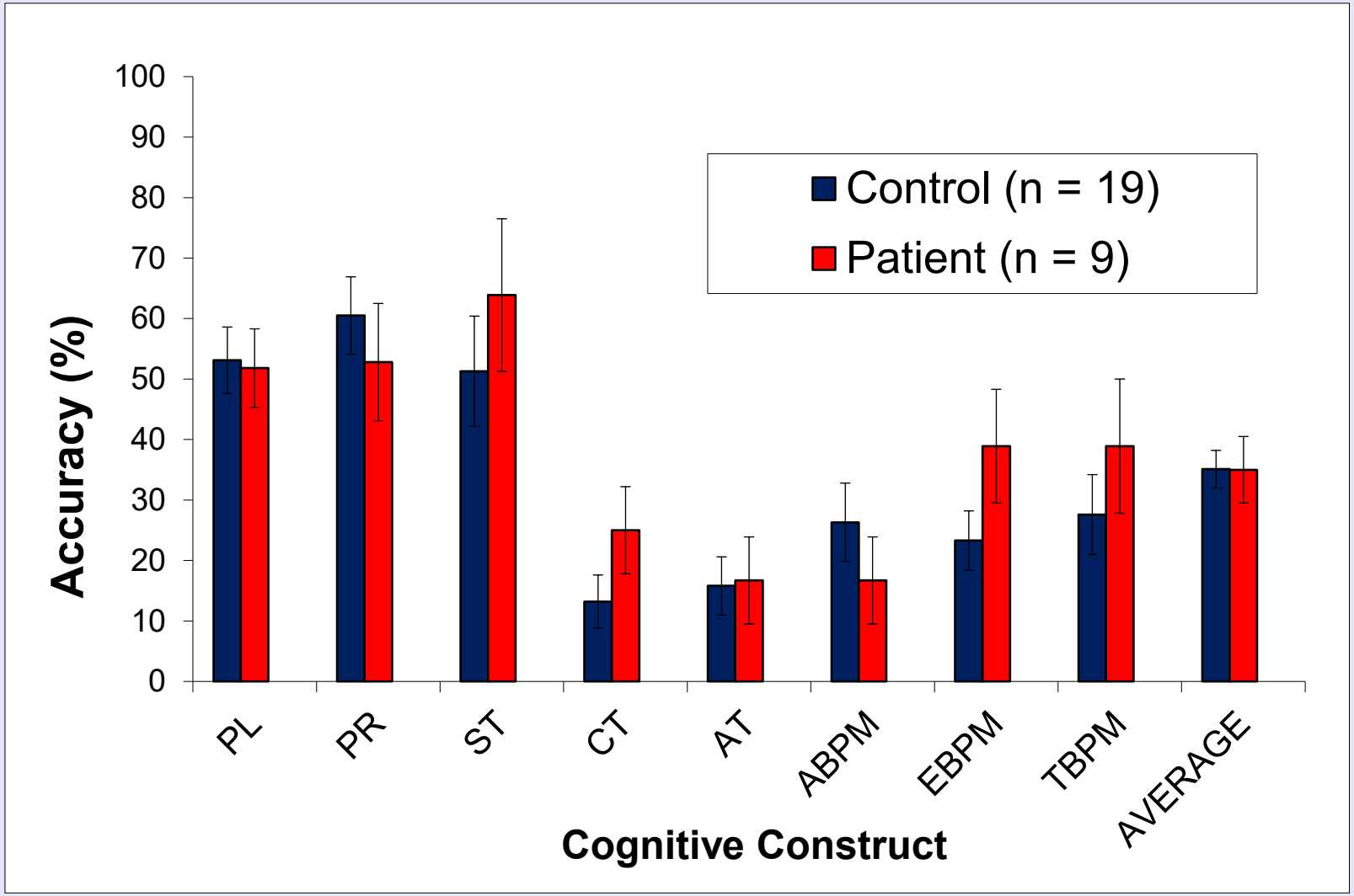
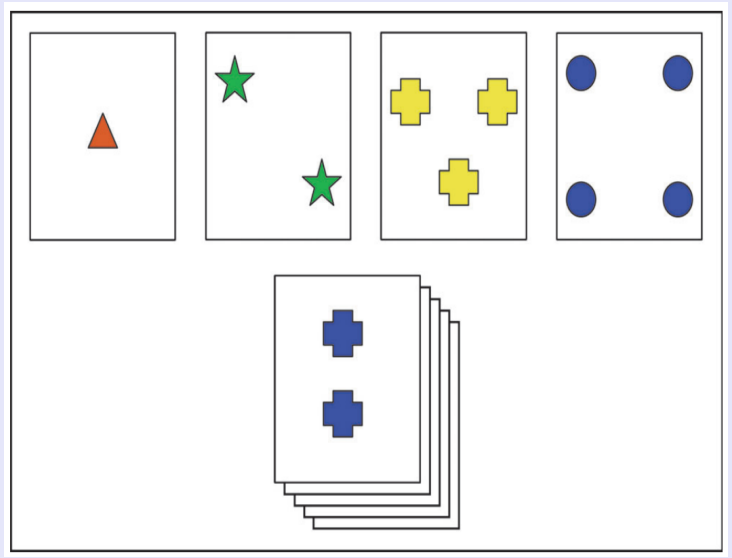
JEF Scores: cerebrovascular disorder / elderly controls



Within – patient comparisons

Wisconsin Card Sort



n = 4
impaired

n = 6
unimpaired

JEF = 7.5

p = .03

JEF = 14.8

Lexical = 35.8

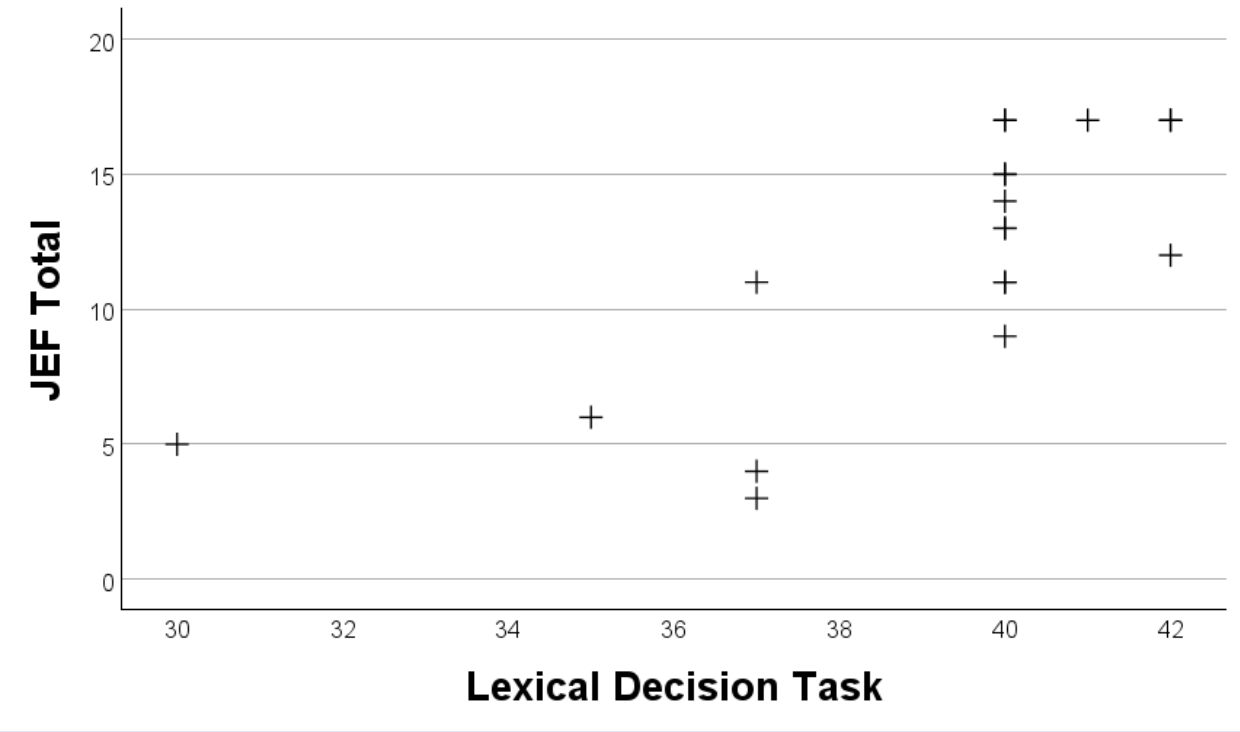
p = .34

Lexical = 37.0

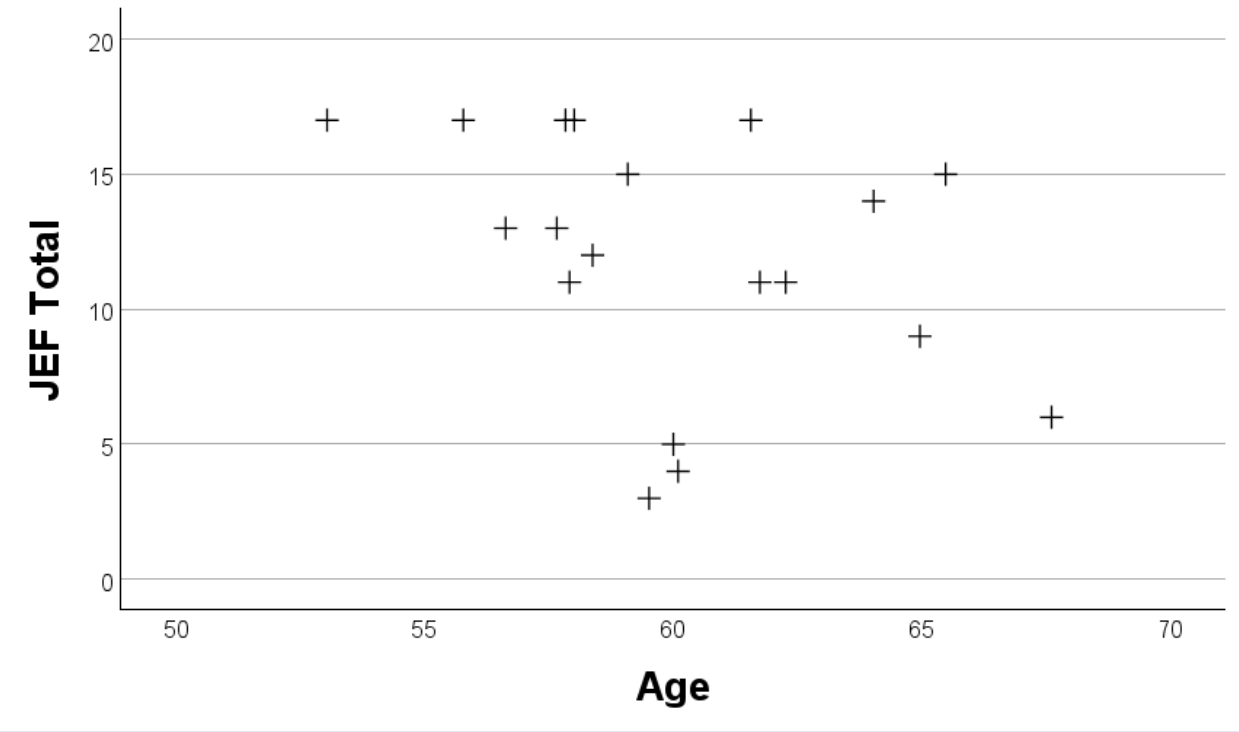
Within – control comparisons

- Lexical decision is predictive of executive function measured by JEF
- Executive function measured by JEF shows a large age-related decline

r = .74

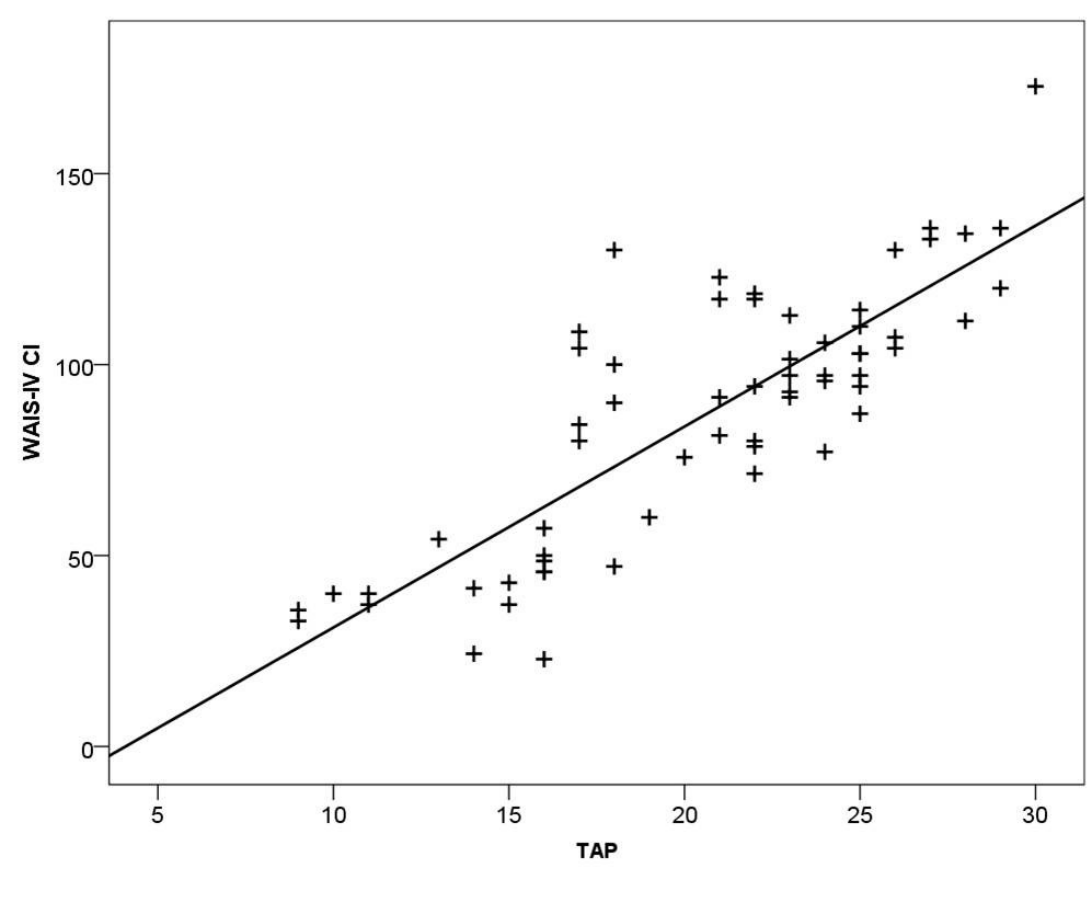


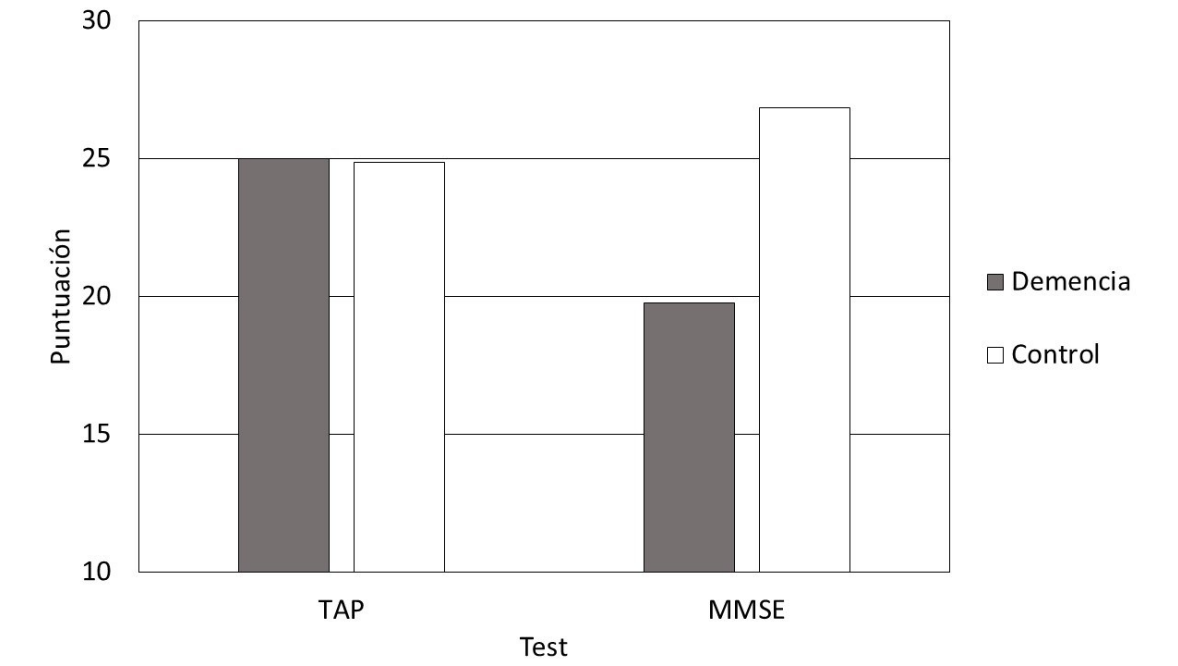
r = -.60



Two important things about lexical reading

1. It is highly correlated with IQ scores

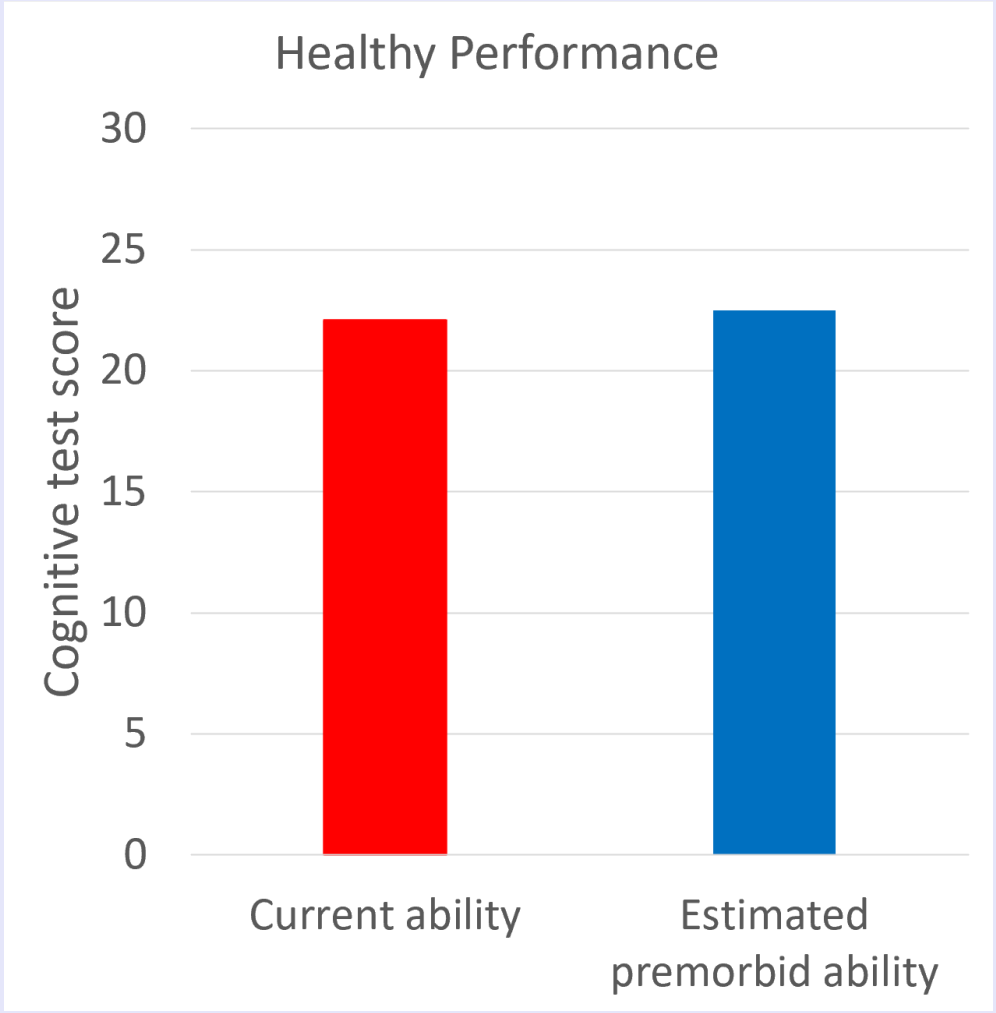


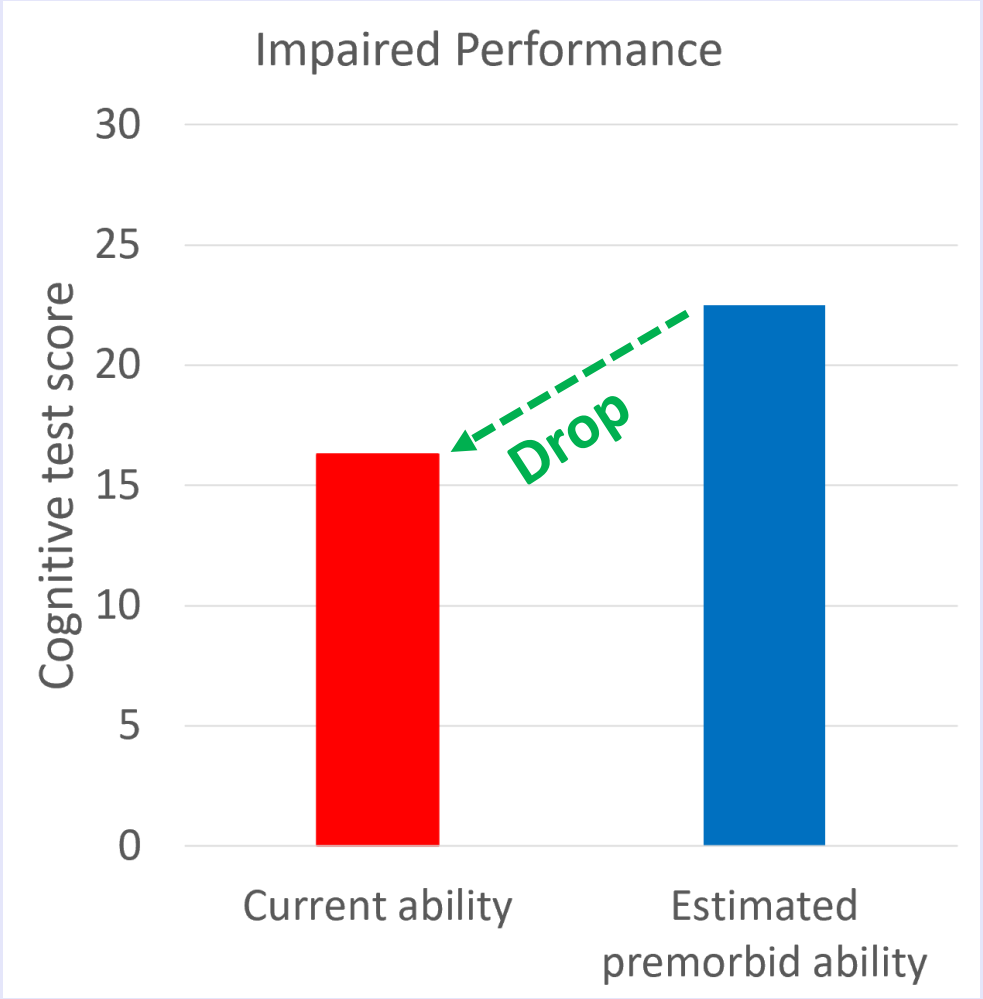


2. It is resistant to cognitive impairment

Pluck, G., Almeida-Meza, P., Gonzales-Lorza, A., Muñoz-Ycaza, R., & Trueba, A. (2017). Estimación de la función cognitiva premorbida con el Test de Acentuación de Palabras. *Revista Ecuatoriana de Neurología, 26*(3), 226-234.

Premorbid estimators allow for better detection of cognitive impairment





Regression for premorbid estimation of cognitive function

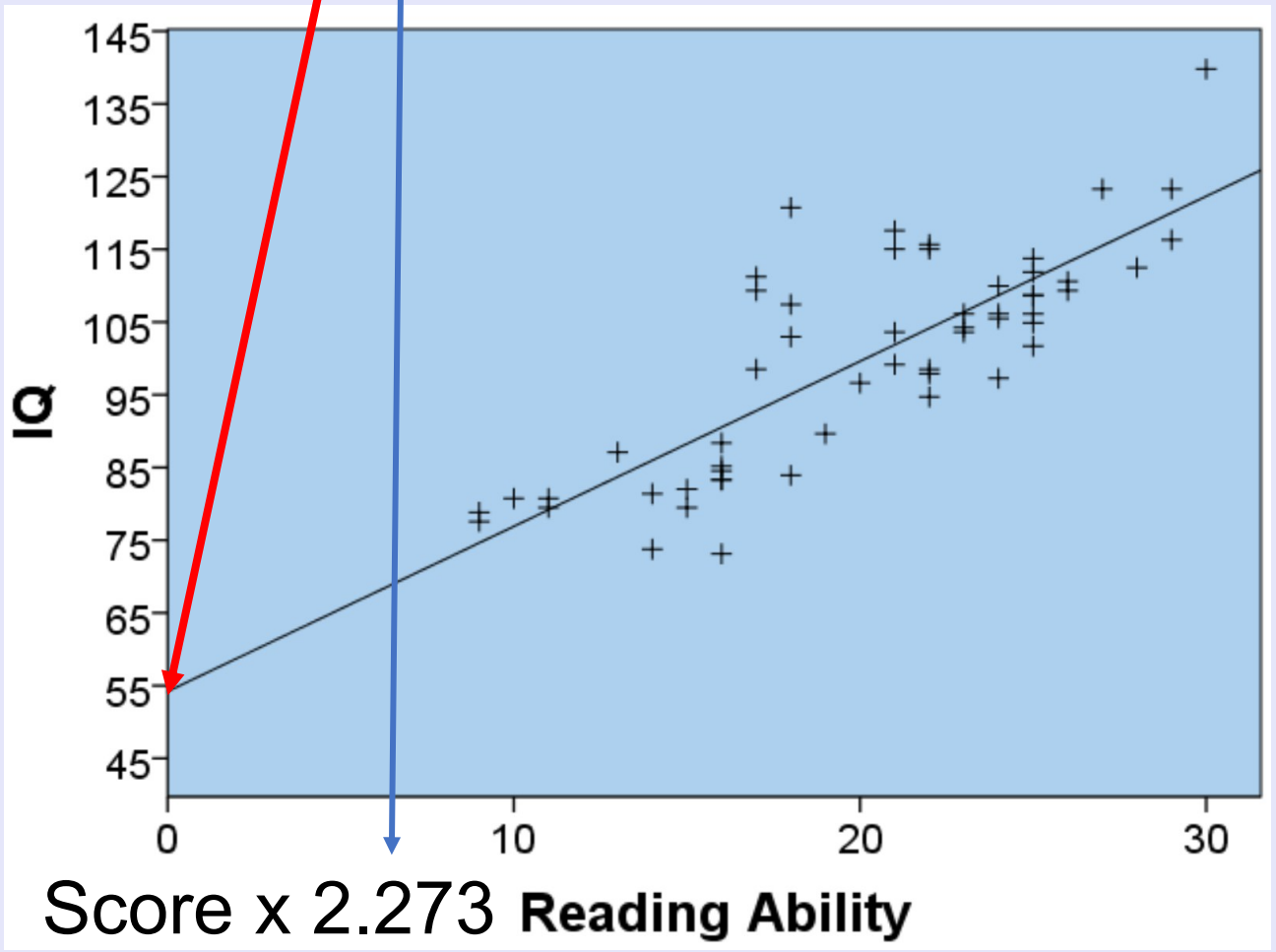
So, IQ = 54.209 + (Reading Score x 2.273)

- When the formula is known, anybody can use it to estimate IQ scores
- Useful for clinical work, useful for research.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	54.209	4.674		11.597	.000
	Reading Ability	2.273	.224	.812	10.131	.000

a. Dependent Variable: IQ_1



- Executive function scores are often poorly correlated with lexical tasks.
- Usually only verbal tests of executive function show potential.
- JEF may be appropriate for premorbid estimation.

Correlation r Values Between Lexical Task Scores and Executive Function Task Scores From Study 3

Executive test	WAT	SpanLex	SCIRT[a]	Median
Cognitive estimates[a]	−.53***	−.61***	−.61***	−.62***
Proverb interpretation[a]	.68***	**.70****	**.71****	**.72****
Phonemic fluency	.49**	.59***	.63***	.56***
Semantic fluency	.46**	.47**	.57***	.49**
Alternating fluency	.63***	**.79****	.66***	**.76****
Reading span	.68***	.68***	.64***	**.73****
RMET	.55***	.53**	.60***	.64***
Faux pas[a]	.49**	.52**	.36*	.45**

Note. WAT = Word Accentuation Test; SpanLex = Spanish Lexical Decision Task; SCIRT = Stem Completion Implicit Reading Test; RMET = Reading the Mind in the Eyes Test. All correlation coefficients are Pearson's *r* values, except. [a] Spearman's rho due to nonnormal data distributions. *r* values > .70 are indicated in bold.
* $p < .050$. ** $p < .010$. *** $p < .001$ (two-tailed).

Pluck, G. & Ruales-Chieruzzi, C. B. (2021). Estimation of premorbid intelligence and executive cognitive functions with lexical reading tasks. *Psychology & Neuroscience, 14*(3), 358–377.

Conclusions

- Ecological assessment of executive function is needed in clinical cognitive assessment, but challenging to implement.
- One solution is extended, computerized tasks ‘non-immersive VR’, such as JEF.
- Although at the group level, it did not distinguish cerebrovascular patients (without MCI) from control, it was sensitive to impairment in some patients.
- The association of age with performance decline also suggests its sensitivity to neurological function.
- The robust correlation with lexical decision suggests premorbid estimation of function may be possible.

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Thanks to the funder: Chulalongkorn University, Faculty of Psychology- Research Affairs