The String Measure, Evoked Potential Correlate Research, and Psychometric IQ

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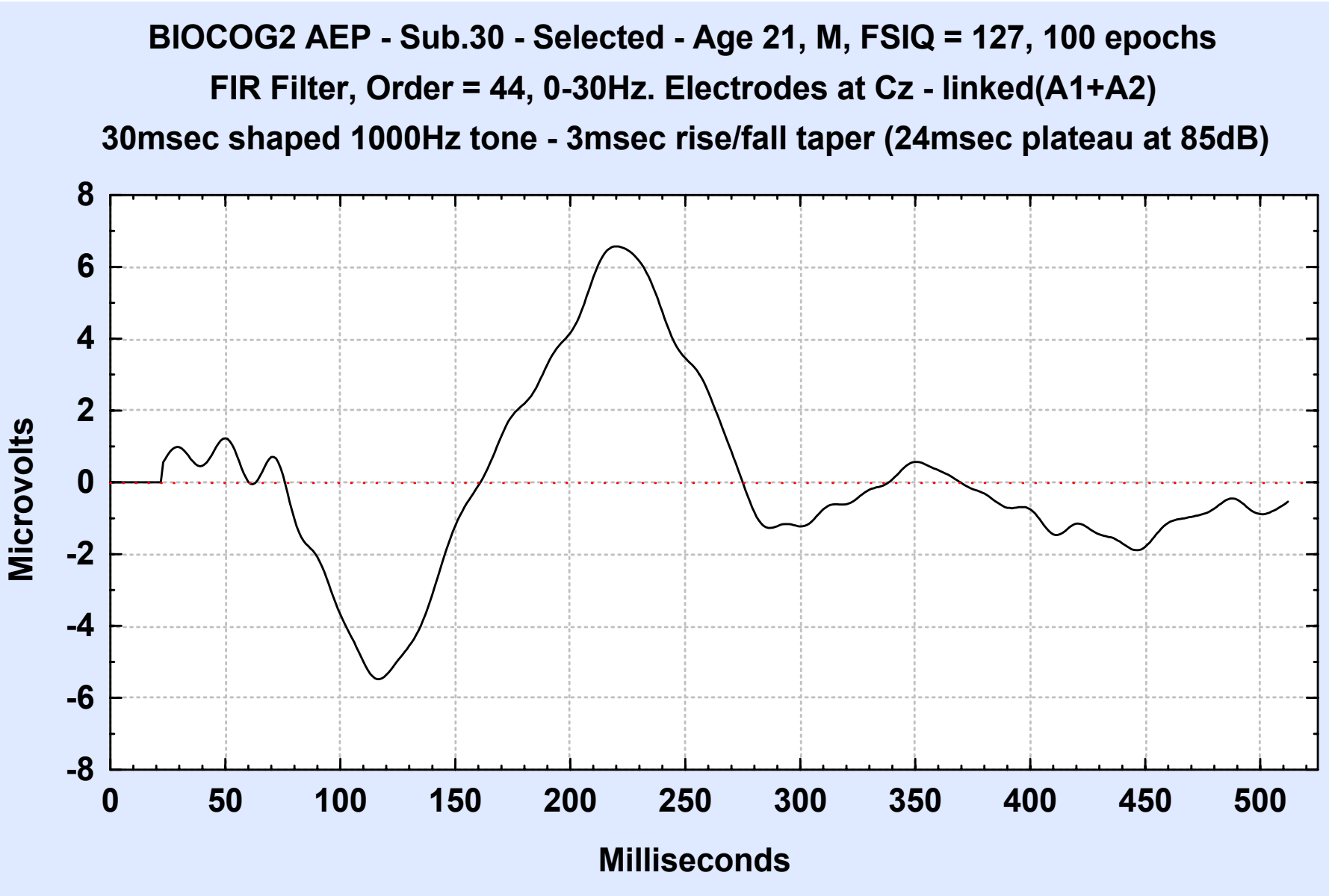
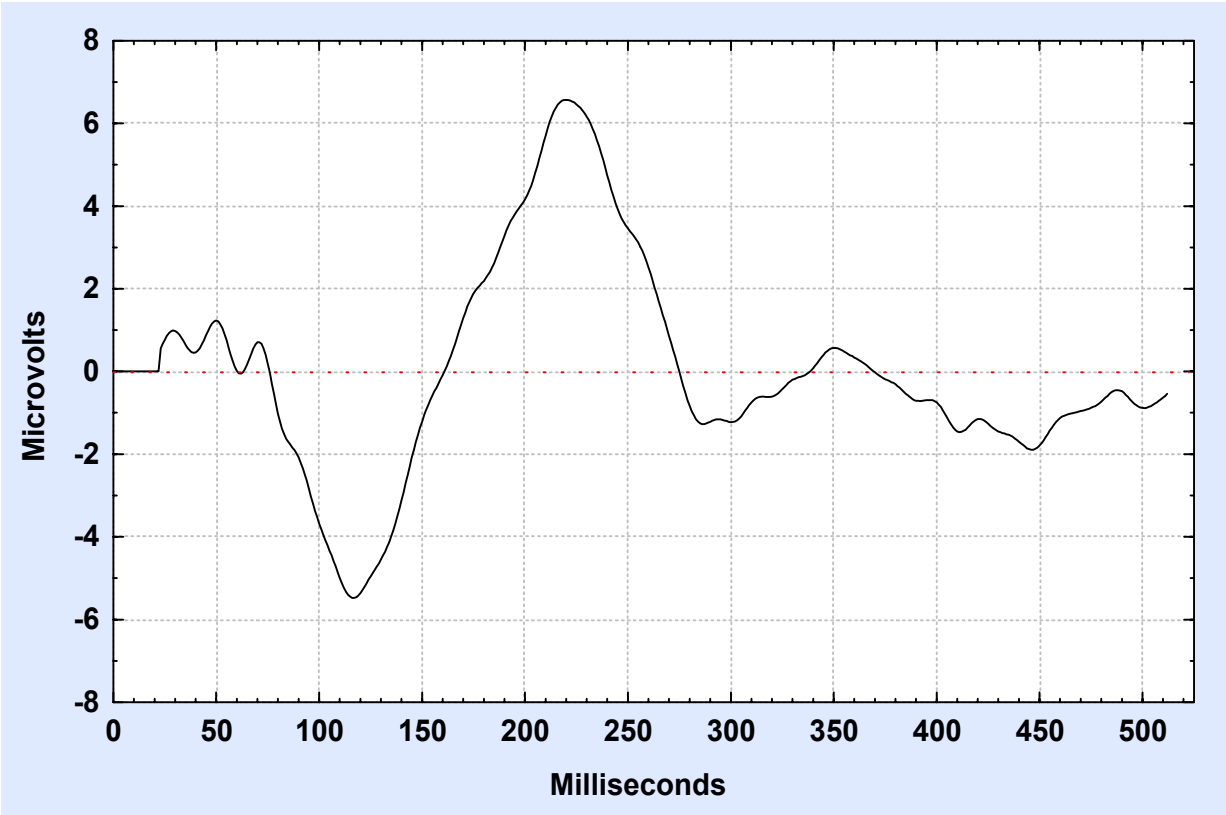
Paper given at the British Psychophysiology Society conference, London 13th December, 1999

What is the "String" Measure? .1



What is the "String" Measure? .2

A measure of the contour length of an evoked potential (averaged or otherwise). In this particular domain of investigation, it has always been computed on an averaged evoked potential.



How is it computed?

- **Rhodes, Dustman, and Beck** (1969) - hand calculated - excursion measure - contour length calculated using a map-reading wheel.
- **Hendrickson and Hendrickson** (1980) - hand calculated - using thread overlaid on a plotted AEP, then pinned down, and finally stretched out and a measure of the total length of the string made.
- **Hendrickson and Hendrickson** (1980) - computer-based summed squared differences between consecutive points of the AEP.

How is it computed? - Formulae

Hendricksons

$$\frac{\sum_{i=2}^{N}(v_{i-1}-v_i)^2}{N-1}$$

Absolute Value

$$\frac{\sum_{i=2}^{N}|v_{i-1}-v_i|}{N-1}$$

Square Root

$$\frac{\sqrt{\sum_{i=2}^{N}(v_{i-1}-v_i)^2}}{N-1}$$

Where N = No. of sample points

v_i = data value i of N

Why is it computed?

- An index of Waveform Complexity - peaks/troughs.
- A theoretically derived and deduced parameter - the Hendrickson model of "pulse-train" nerve conduction (11ms pulse equi-spaced intervals (21), 22 pulses per train, hence ~230ms EP epoch in response to a stimulus).

The Hendrickson Postulate

- Low IQ individuals have "noisy" nerve transmission systems - resulting in a brain response (EP) to a fixed stimulus that is composed of a greater number of desynchronised action potentials in nerves, relative to synchronised "pulse train" discharges. Averaging such EPs produces a smooth contour waveform (because of the random content in each EP).
- Higher IQ individuals have less "noise" in their signal transduction and transmission systems, resulting in their EPs being more synchronised in time. Action Potential response is more reliable and consistent - to each stimulus - hence, averaging of these EPs will permit the "pulse-train" activity to each stimulus to be better represented in the contour of the AEP (akin to jitter). Hence, low IQ individuals will have a shorter string length than those with a high IQ - thus the expected positive correlation between "string" and IQ.

The Hendrickson 9-point Paradigm

❶ ***Stimulus Parameters***: constant - no on/off transients, preferred auditory stimulus, 85db, 30msec duration, binaural, headphones.
❷ ***Stimulus Presentation***: Pseudorandom - between 1 and 8 secs
❸ ***Electrodes***: Ag-AgCl recommended
❹ ***Amplifier*****:** 10KHz frequency response Pre-amp/Main Amp
❺ ***Calibration Signal***: prior to each epoch
❻ ***Recording***: Digital only
❼ ***A/D sampling frequency***: minimum of 1KHz
❽ ***Analysis Period Epoch***: 250ms maximum
❾ ***Number of epochs per subject***: constant number between 32-100 (Blinkhorn and Hendrickson, 1982).

The Key Confirmatory Results

Author	Date	N	IQ test	Mode	r	r_c	Epochs
Hendricksons*	1980	20	WISC	Visual	+0.77	-	400
Hendricksons	1982	219	WAIS	Auditory	+0.72	-	90
Blinkhorn & Hendrickson	1982	33	RAPM	Auditory	+0.45	+0.84	32
Haier et al	1983	23	RPM	Visual	+0.50	-	64
Caryl and Fraser	1985	10	AH4	Auditory	+0.78	-	100
Vetterli and Furedy*	1985	20	WISC	Visual	+0.80	-	400
Stough et al	1990	20	WAIS	Auditory	+0.71	+0.86	100
Gilbert et al	1991	21	SFT(IQ)	Auditory	+0.41	-	45
Batt et al**	1999	35	WAIS	Auditory	+&-ve	-	50
Stough and Bates***	Submit	50	WAIS	Auditory	+0.64	+0.77	100

Notes

* = rescored Ertl and Schafer (1969) printed AEPs waveforms

** = No significant correlations with full scale IQ, but -ve correlations between String and Verbal IQ, and +ve between string and Performance IQ

*** = Submitted to Personality and Individual Differences. Contact cstough@swin.edu.au or timothy.bates@mq.edu.au

The Key Negative Results

Author	Date	N	IQ test	Mode	r	r_c	Epochs
Mackintosh	1986	18	RAPM	Auditory	-0.33	-	100
Vogel et al *	1987	236	IST +	Aud &Vis	0.0	-	256
Barrett and Eysenck	1992	40	WAIS	Auditory	-0.44	-	100
Widaman and Carlson	1993	48	WAIS	Auditory	0/-ve	-	256
Bates and Eysenck**	1993	70	MAB	Joint	-0.61	-	75+
Barrett and Eysenck(1)	1994	49	MAB	Auditory	0.02	-	100
Barrett and Eysenck(2)	1994	40	MAB	Auditory	-0.02	-	100
Barrett and Eysenck(3)***	*pend*	54	MAB	Auditory	0.05	-	100
Burns et al	1996	40	WAIS	Visual	0.0	-	100
Batt et al	1999	35	WAIS	Auditory	+&-ve	-	50

The shaded studies are those that most closely follow the Hendrickson paradigm.

* = many German IQ tests, and both stimulus modalities

** = actually, Project TITAN in the Biosignal Lab (but Philip Morris withdrew funding from the lab and requested myself and Hans to give our data to their other group working in NZ)

*** = the BIOCOG-3 project - a test-retest reliability study for BIOCOG-2 (1994) - one year test interval.

Reasons put forward to explain non-replication

❶ Stimulus Parameters - amplitude, shaping, mode, type
❷ Number of epochs averaged
❸ Period of waveform over which the calculation is made
❹ Signal conditioning (amplitude and bandwidth)
❺ A/D Sampling Speed
❻ Task confounding with subject attentional demands (the Bates and Eysenck (1993) hypothesis)
❼ Instructions given to subjects
❽ Subjects falling asleep during task
❾ Waveform complexity as a function of some, as yet unknown, individual difference characteristic
❿ Scaling, normalisation, and amplitude relationships

What do I conclude?

- The string measure was properly formulated and derived by the Hendricksons from their theory of nerve transmission.
- They demonstrated both simulation and empirical results to support their theory.
- Given the key proposition of a constant stimulus, and a carefully implemented EEG protocol, deductions from their theory meant that replication should have been a straightforward matter. It was not. Further, subsequent neuroscience has negated the theory of nerve transmission as postulated by them.
- Basically, **End of story** - but no, like some awful thing in a horror film, it still lives! Why?

The Fatal Flaw in ALL of this "Biological Correlate" Work

➠ **Investigators have forgotten the basic tenets of science and are now engaged in phenomena identification and inductive, post-hoc, inference (see Bates and Eysenck, 1993).** That is, the measure was derived from a specific theory of nerve transmission. That nerve transmission does **not** occur in this manner has been shown elsewhere. So, we are left with a measure that has no fundamental theoretical foundation.

➠ To continue with the string measure, we have to have a real theory of **EXACTLY** what it is purporting to measure. You cannot make scientific measurement without having *a priori* specified its meaning. This is fundamental to quantitative scientific measurement. **The Hendricksons to their real credit specified precisely the underlying theory and postulates, then developed a measure that would test these postulates directly.**

The Fatal Flaw in ALL of this "Biological Correlate" Work (cont.)

➠ To propose that the string measure is indexing waveform "complexity" is entirely operational. We no longer know what it is we are measuring, but merely, that what we measure shows variance within individuals (akin to IQ).

➠ The **"*arousal*"** theory of Bates and Eysenck (1993) is a post-hoc explanation of a phenomena. However, it has been successfully tested by Bates et al (1995) under the rubric "an attentional theory"- *"string length measures energy expended during information processing"* (p.369). String length is hypothesised to be an ***efficiency*** index when recorded to an attended task, and a ***capacity*** index when recorded under conditions of rest. High IQ individuals are hypothesised to expend more energy to unattended than to attended stimuli, hence, a +ve string-IQ correlation for these stimulus conditions (and -ve for attended stimuli). Unfortunately, Burns et al (1996) and Batt et al (1999) have failed to replicate the initial results of Bates et al (1995)

Some questions we might ask

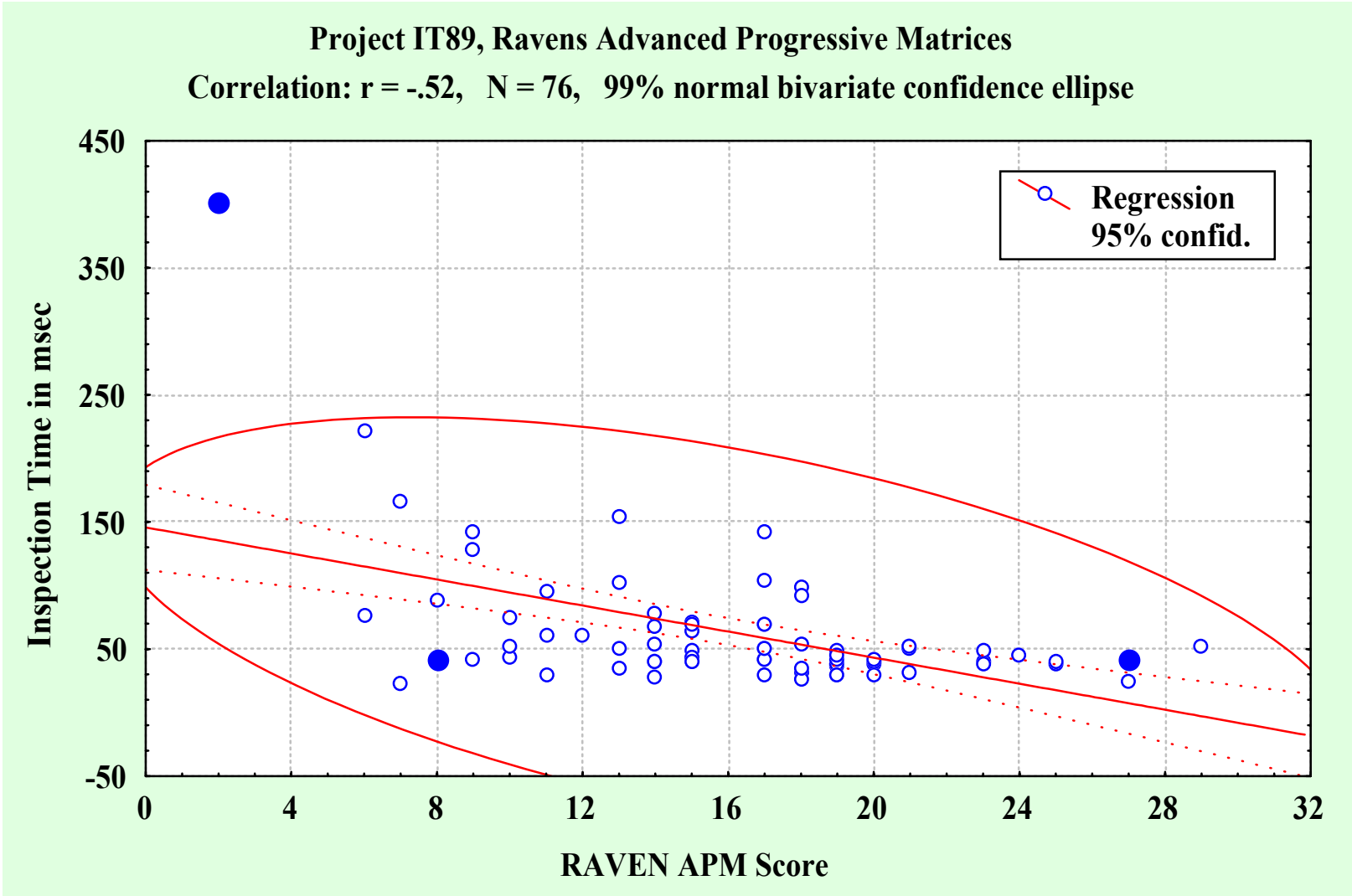
- The Robinson Arousability Hypothesis as an explanation?
- Are AEPs a useful or even valid research tool in this area?
- A proper theory of **intelligence** rather than an assumption that the IQ score is semantically and quantitatively isomorphic to "intelligence?
- A properly specified measurement model?

My conclusions .1

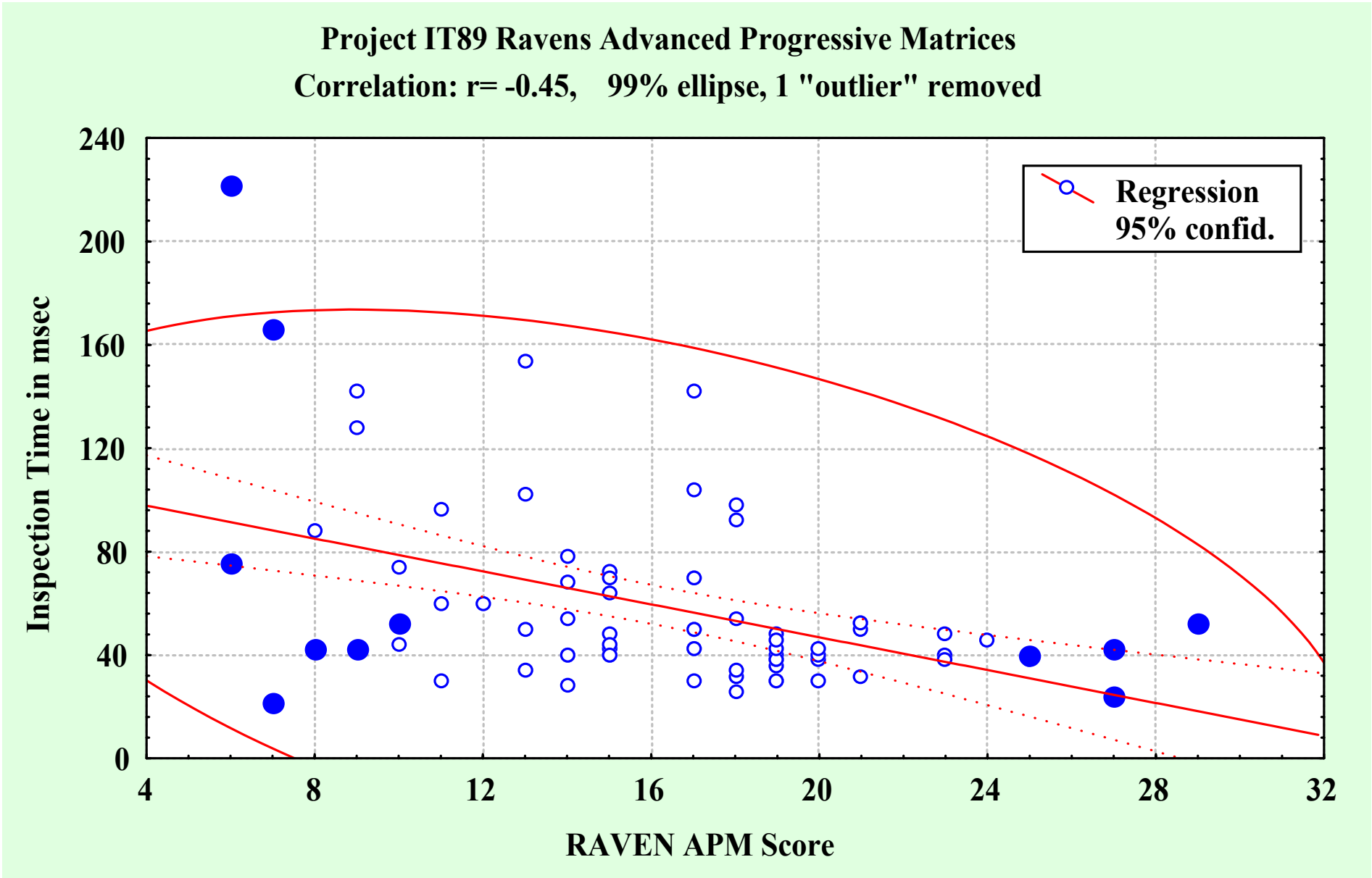
➠ Biological "correlate" research is ***phenomena identification*** under another guise. **As a scientific paradigm, it is doomed to failure**. 20 years of chronometric and biological correlate research has given us practically no causal understanding of how these phenomena are occurring. This is because we work with a criterion measure for which we have little meaningful causal explanatory theory (IQ), and develop instrumental measures within other domains that have no mathematically specified mapping functions between the criterion variable and these measures. As any other quantitative scientist might reasonably ask *"what did you expect would happen if you go about research in this manner?"*

➠ The string measure has no coherent and properly specified theory behind it, and therefore should be discarded in favour of measures that are founded upon such theory.

An example of what I am talking about in "correlational" research. The problem of theoretically "impossible" cases embedded in published "supportive" results. Taken from the presentation: Individual Differences: the end of an era. Where do we go from here? Downloadable from: http://www.liv.ac.uk/~pbarrett/present.htm



Note the “impossible” cases with very low RAPM and very low ITs



My conclusions .2

- The Robinson propositions concerning the oscillatory component genesis of EPs **must be** empirically replicated. From this replication, other tests of his work would then be worth pursuing. But, his "arousability" theory uses measures of continuous waveform oscillation amplitude, frequency, and phase characteristics as measures of underlying inhibitory and excitatory brain processes.
- The Arousal/Attentional (***efficiency*** **and** ***capacity***) propositions of Bates and Eysenck need careful attention. Although I do not consider their work a "theory", the ideas they have proposed do have very serious merit and I think can be formulated as something approaching a deductive/abductive scientific theory rather than their current status as a piece of informed speculation.

My conclusions .3

- A proper theory of intelligence is required, that treats IQ scores as outcome variables (with all that means for their use as "criterion" scores), and that defines the constituent processes that are causal for "intelligence". Measures can then be generated or better identified from existing tasks for these causal constituents.
- As Nick Burns has argued and empirically demonstrated (Burns, Nettelbeck, and Cooper, 1999), **if** we are to use psychometric test scores as criterion variables, then we should be using a full range of scores (within a 10-dimensional psychometric model of intelligence, such as found within the Woodcock-Johnson test battery).

My conclusions .4

➠ Finally, we need much more empirical work in this area, and work that is based upon **coherent and properly quantified theory** rather than continual "look-see" work that relies upon correlations and covariances as the primary source of quantified empirical results (Structural Equation Modelling is of no value in this domain - it merely allows an investigator to maintain the pretence of causal relations). Instead, what is required are deduced mathematical mapping functions (and unit concatenation operations) that represent the theoretical isomorphism put forward to explain the relationship between two or more variables, **and a precise specification of the causal order or causal variables within such a function**.