Two recent research studies have recently been published that offer some fascinating insights into our intelligence and how we might augment it.

First some educational background to give the studies some useful context, looking at 3 different ways of looking at intelligence and IQ – one of which is through the interesting lens of entropy, a concept – it turns out – that's key to both physics and cognitive neuroscience.

3 Angles on Intelligence

1. Psychometrics

Psychometricians define intelligence in terms of 9 underlying factors that they uncover from scores on IQ tests, all contributing to general intelligence (g). This psychometric approach to cognitive performance is adopted in i3 Mindware and its content feed.

2. Intelligence in Action

There is also a more applied conception of intelligence.

From the innovation culture comes and emphasis on productivity, captured by:

“An intelligence is the ability to solve problems, or to create products, that are valued within one or more cultural settings.” H. Gardner

From the AI movement comes an emphasis on goal achievement, captured in these definitions:
“Achieving complex goals in complex environments.”
B. Goertzel

“Intelligence is the ability to use optimally limited resources – including time – to achieve goals.” R. Kurzweil

This angle on intelligence is the one adopted by HighIQPro and its content feed.

3. Intelligence and Brain Entropy

Greater entropy in the neural signalling in the brain – when it is at rest, not focused on some task – is getting attention among cognitive neuroscientists as an exciting new angle on understanding the nature of intelligence.

What is brain entropy? How is it measured by cognitive neuroscientists?

Entropy is a measure of the complexity and irregular variability in brain activity from one moment to the next. It measures the number of neural states a given brain can access and is marked by greater long-distance correlations in brain network activity. Low entropy is characterized by orderliness and repetition, and less long-range network synchrony.

You see the lowest levels of entropy when we are in deep sleep – or, at the extreme, coma. Brain entropy is lower in individuals with ADHD. And brain entropy decreases with age as shown here (article):
With more entropy (and thus complexity) in the brain’s connectivity, it can better adapt to dynamically changing environments rich with unpredictable events. Thus brain entropy can be understood as:

*A measure of the brain’s overall flexibility or readiness to encounter unpredictable stimuli …to model and predict the outcomes of a complex, chaotic world*

In a recent study, researchers at New York University’s School of Medicine measured brain entropy using functional MRI scanners in 900 healthy participants, who also completed measures of their verbal intelligence and reasoning ability outside of the scanner.

The New York researchers found that brain entropy correlates with intelligence. Vocabulary performance and superior reasoning ability was associated with greater entropy in the frontal regions of the brain.

“These results suggest that entropy is a reliable predictor of intelligence, and provides unique information not captured by developmental status and educational status alone”

**Entropy & Strategic Intelligence**

Some scholars have an even broader understanding of intelligence as entropy.

In very broad terms, entropy can be understood as a measure of the number of possible states a system can branch into over time. According to the physicist Wissner-Gross ([ref1], [ref2]), intelligent behavior in any system – not just human brains – is the

“Physical process of trying to capture as many future histories as possible”

Future histories are the set of possible future outcomes/options available to a system at any given moment. The higher the amount of entropy a system has, the more future histories are available.
Intelligent behavior maximizes the system's entropy over the long-term according to Wissner-Gross’s theory.

“Intelligence should be viewed as a physical process that tries to maximize future freedom of action and avoid constraints in its own future.” Dr. Alexander D. Wissner-Gross

On this theory, intelligence systems – including intelligent humans – don’t like to be trapped!

On this intriguing theory of intelligence, goal seeking is “investment in future bottlenecks in path space” Goals are seen as short-term bottlenecks that open up future possibilities over the longer-term.

This high level theory of intelligence devised by a physicist understands intelligence more in terms of strategic action and strategic positioning.

On this view, intelligent action that opens up future possibilities can be seen as inherently creative as well as adaptive.

**Two Interventions that Increase Brain Entropy**

1. Working Memory Training and Entropy

This [recent study published in Frontiers of Human Neuroscience](https://www.frontiersin.org/journals) demonstrated that:

(a) High working memory performers had higher entropy compared to low working memory performers. (They used an EEG measure called ‘spectral entropy’)

(b) Working memory training (e.g. IQ Mindware apps) resulted in increasing entropy which predicts improvements in subsequent independent working memory test scores – i.e. an improvement in IQ.

The study concludes:

“16 subjects’ behavioral scores were obviously increased after training, indicating that individuals’ working memory (WM) performance could be promoted effectively through training, consistent with [previous studies]. For 15 in 20 subjects’ working memory scores increased (or declined) with the increase (or decline) of entropy before and after training, which demonstrated that the variations in entropy could be predictive of the WM performance variations. The findings revealed the consistent changes in [working memory] scores and entropy by training”
A new study in *Scientific Reports* is the first to examine whether and how ingesting a nootropic – caffeine – affects brain entropy.

Remarkable though it sounds, the results show caffeine causes a widespread increase in brain entropy.

**Caffeine Caused a Widespread Increase of Resting Brain Entropy**

*Da Chang, Donghui Song, Jian Zhang, Yuanqi Shang, Qiu Ge & Ze Wang*

For the caffeine study, Da Chang at Hangzhou Normal University in China and other researchers scanned the brains of 60 participants – 30 men and women – at baseline, and also after they ingested a 200mg caffeine pill (roughly approximate to two cups of coffee). The scans showed that caffeine increased brain entropy across nearly the entire cerebral cortex, but especially in “lateral prefrontal cortex (known to be critical to reasoning and general intelligence), as well as the visual cortex, and motor network, which the researchers linked to caffeine’s known beneficial effects on “attention, vigilance, and action/motion function.”

“Increased resting brain entropy indicates increased resting brain activity irregularity or complexity, suggesting an increase of information processing capacity in the resting brain”
So consider this – as you enjoy your morning coffee, you are increasing the entropy throughout your brain. This natural brain stimulant is not only waking you up, but also boosting your brain’s useful anarchy – its complexity and information processing capacity!