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ORIGINAL ARTICLE

Wittgenstein's Certainty is Uncertain: Brain Scans of Cured Hydrocephalics Challenge Cherished Assumptions

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Abstract The philosopher Ludwig Wittgenstein chose as his prime exemplar of certainty the fact that the skulls of normal people are filled with neural tissue, not sawdust. In 1980 the British pediatrician John Lorber reported that some normal adults, apparently cured of childhood hydrocephaly, had no more than 5 % of the volume of normal brain tissue. While initially disbelieved, Lorber's observations have since been independently confirmed by clinicians in France and Brazil. Thus Wittgenstein's certainty has become uncertain. Furthermore, the paradox that the human brain's information content (memory) appears to exceed the storage capacity of even normal-sized brains, requires resolution. This article is one of a series on disparities between brain size and its assumed information content, as seen in cases of savant syndrome, microcephaly, and hydrocephaly, and with special reference to the Victorian era views of Conan Doyle, Samuel Butler, and Darwin's research associate, George Romanes. The articles argue that, albeit unlikely, the scope of explanations must not exclude extracorporeal information storage.

Keywords Female brain · Head size · Information storage capacity · Long-term memory · John Lorber · Neuronal reductionism · Plasticity limits · Redundancy · Supernatural explanations · Ventricle size

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Introduction

Death and taxes are vernacular designations for ultimate certainty. However, for Ludwig Wittgenstein, the ultimate certainty was the presence of brain tissue. In his seminal text *On Certainty* (1969, p. 18e) he declared: "Now would it be correct to say: So far no one has opened my skull in order to see whether there is a brain inside; but everything speaks for, and nothing against, its being what they would find there?" And this was more than an introspective I-have-a-brain-therefore-I-am. It also applied to others:

> I … am sure, that my friend hasn't sawdust in his … head, even though I have no direct evidence of my senses to the contrary. I am sure, by reason of what has been said to me, or what I have read, and of my experience. To have doubts about it would seem to me madness. (Wittgenstein 1969, p. 36e)

Thus the great 20th century philosopher admitted to a certainty so great that a person might justifiably, in his own words, "throw away the ladder after he has climbed up on it." As far as the brain was concerned there could be no dilemma. Yet he could still aver that, "what we cannot speak about we must pass over in silence" (Wittgenstein 1922, p. 189). Here we return the ladder and break the silence.

There is a dilemma, and it comes from neuroscience itself. Some years ago there was a TV series—"Candid Camera"—where unsuspecting people monitored by hidden cameras were put in preposterous positions. In one setup, a car without an engine was discretely pushed into a gas station. An attendant emerged to fill it up. On being asked to check the oil, he duly opened the bonnet and began to scratch his head. The hilarious altercation that followed, with the driver angrily remonstrating that the car would have needed an engine to get to the station, and the

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attendant declaring that one was not present, encapsulates the dilemma now facing neuroscientists worldwide. There are a few people on this planet—for most intents and purposes just like you and me—whose "bonnets" (their skulls), when "opened" (x-rayed), reveal, at best, only 5 % of the expected amount of brain tissue!

It doesn't take a neuroscientist to appreciate the dilemma. The logic is simple. A neuroscientist may find abundant neural tissue in a thousand skulls of normal individuals, thus certifying the close correlation between presence of tissue and normality. But the entire house of cards tumbles to the ground when individual one thousand and one is normal, yet has no tissue! Admittedly, in practice the distinction is not so stark. Individual one thousand and one is found to have approximately 5 % of the brain tissue volume that is characteristic of each of the one thousand others. But we suspect that Ludwig would be no less surprised by 5 %, than by 0 %.

Recovered Hydrocephalics

In the 1970s a British pediatrician, John Lorber, reexamined, in adult life, the brains of people who had been treated as children for hydrocephaly, or "water on the brain" (Lewin 1980). In these children the circulation of fluid in the ventricles of the brain is blocked. Yet fluid continues to enter the brain, so the ventricles expand and brain volume increases. In early life the skull bones allow this expansion, and an enlarged head may be the first sign that all is not well. By inserting a small tube (shunt), surgeons are able to drain off the excessive fluid, so relieving the pressure. If successful, the ventricular expansion is reversed and head size returns to normal. When the operation is carried out early, before the skull bones begin to fuse, a child can expect a normal life.

Taking advantage of new brain-scanning technology, Lorber anticipated that the adult brains of treated hydrocephalics would appear normal. For an example of a normal brain, see the scans at the left in Fig. 1 (de Oliveira et al. 2012). Here brain tissue, encased within the outer skull bones (white), is seen as the usual "gray matter" (gray) and "white matter" (pale gray), and there are small black central areas (labeled "LV"). These are the fluid-containing ventricles. On the far right are the corresponding scans of a hydrocephalic whose surgery had failed and who remained severely impaired neurologically. Almost the entire skull is filled with ventricular fluid (black) and there remains only a small surrounding rim of actual brain tissue. Given the extent of tissue loss, it is astonishing that he is alive. Yet 60 of the 600 cases Lorber studied displayed such extreme brain scans. Ventricular fluid occupied at least 95 % of cranial capacity!

Shocking enough. But now for what really rocked the neuroscientists. Half of Lorber's 60 cases were of above-normal intelligence (as determined by standard IQ tests). The central scans in the figure—virtually indistinguishable from the severely impaired case on the right—are representative of this group. And doubtless a candid camera would have caught Lorber's jaw dropping when, among them, he found a student who was "socially completely normal" and had a first class honors degree in mathematics (Lewin 1980, p. 1232):

> Instead of the normal 4.5 cm thickness of brain tissue between the ventricles and the cortical surface, there was just a thin layer of mantle measuring a millimeter or so. The cranium is filled mainly with cerebrospinal fluid. … I can't say whether the mathematics student has a brain weighing 50 or 150 g, but it's clear that it is nowhere near the normal 1.5 kg.

Of course, when Lorber presented his findings at a conference in 1980—under the title "Is Your Brain Really Necessary?"—he met with much scepticism. Journalist Roger Lewin related in *Science* how experts had pointed to difficulties in the interpretation of brain scans, and had even declared that "Lorber's style is less scientific than it might be." To the accusation that he was being "overdramatic," Lorber replied, "Of course these results are dramatic, but they're not overdramatic. One would not make the claim if one did not have the evidence" (Lewin 1980, p. 1232).

But the ripples cast on the neurobiological pond soon faded. Lorber disappeared from view. He died in 1996 at the age of 82. Nevertheless, his results were considered dramatic enough to warrant a TV documentary. Barry Beyerstein of the Brain Behavior Laboratory at Simon Fraser University quipped (Beyerstein 1999, p. 17):

> The telecast employs the ever-popular theme of a brave outsider struggling against a mulish establishment to suggest that, once again, the so-called 'experts' aren't as bright as they think they are. Along the way, the program encourages the misapprehension that there is a huge reserve of unnecessary brain mass that can be casually dispensed with.

And in the "Ask the Experts" section of *Scientific American,* he attacked what he called "the 10 % myth," which implied that "90 % of the average brain lies perpetually fallow" (Beyerstein 2004).

Lorber Confirmed

Nearly three decades after Lorber's initial claim, no respectable neuroscientist had risen to his defense and Lorber was still an easy target. In January 2007 the

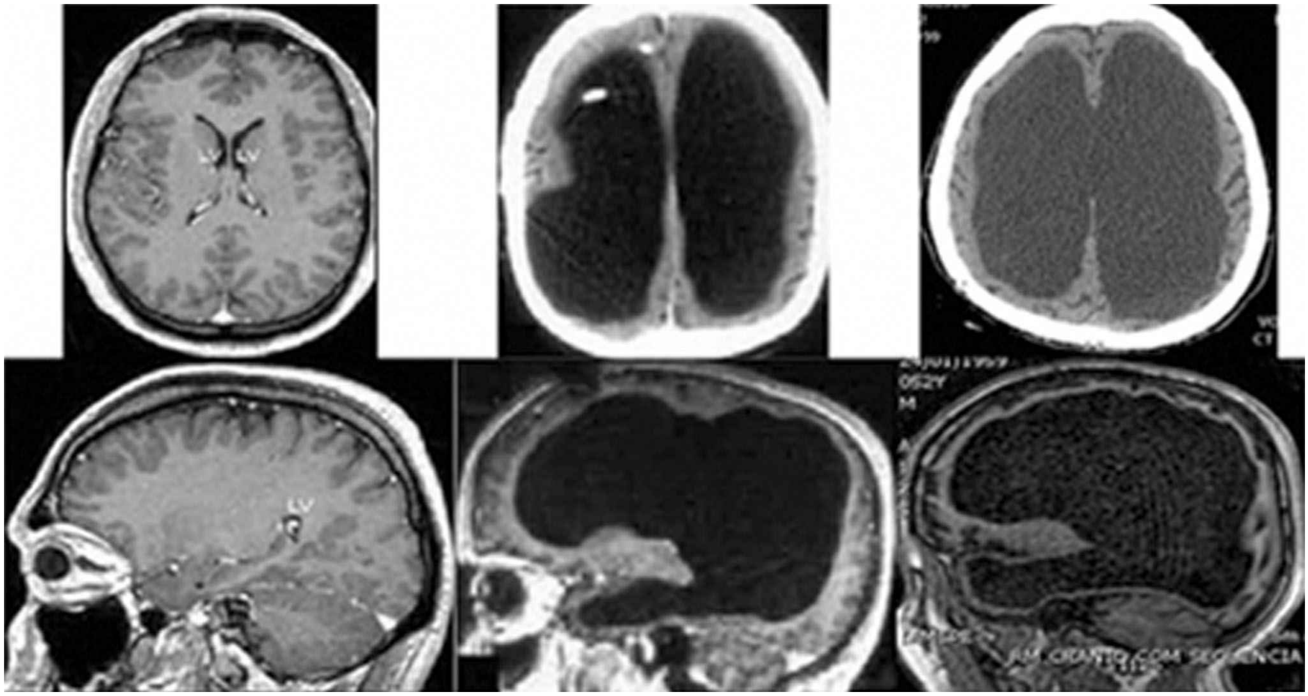

Fig. 1 Brain scans. Normal adult appearance (*left*). Enlarged ventricles (*middle* and *right*). Reproduced under Creative Commons License from *Frontiers in Human Neuroscience* (Forsdyke 2014)

anthropologist John Hawks—with dual interests in Sherlock Holmes and human skulls—set out to dissect Lorber's claim "part by part" (Hawks 2007). In *A Study in Scarlet* the great detective had opined that a brain should scale with the amount of information it contained (i.e., memory), and could easily become overloaded (Doyle 1887, Chap. 2):

> I consider that a man's brain originally is like a little empty attic, and you have to stock it with such furniture as you choose. A fool takes in all the lumber of every sort that he comes across, so that the knowledge which might be useful to him gets crowded out, or at best is jumbled up with a lot of other things, so that he has a difficulty in laying his hands upon it. Now the skillful workman is very careful indeed as to what he takes into his brain-attic. He will have nothing but the tools which may help him in doing his work, but of these he has a large assortment, and all in the most perfect order. It is a mistake to think that that little room has elastic walls and can distend to any extent. Depend upon it, there comes a time when for every addition of knowledge you forget something that you knew before. It is of the highest importance, therefore, not to have useless facts elbowing out the useful ones.

Thus, Hawks was highly sceptical of Lorber, concluding that the story of the mathematics student was "quite obviously incredible" and that Lorber had really been on a well-intentioned publicity-binge "to show that hydrocephalus is a condition that can be successfully overcome" (Hawks 2007).

A few months later, however, there appeared in *The Lancet* the first of two independent confirmations suggesting that Lorber should not have been so lightly dismissed. Under the title, "Brain of a White-Collar Worker," French neurologists reported a "massive ventricular enlargement" (like the central subject in the above figure) in the brain scan of a civil servant who was married with two children and had come to them with relatively mild neurological symptoms that responded to treatment (Feuillet et al. 2007). And Brazilian neurosurgeons later reported a similar case (figured centrally in Fig. 1; de Oliveira et al. 2012).

Female Brains Don't Scale

For me, these hydrocephalic cases provided welcome support for the argument that the size of a human brain scales neither with its information content—specifically, with what the experts call "long-term memory"—nor with intelligence. When gathering material for a biography of the neurophysiologist George Romanes, who, with Charles Darwin, was a founder of the science of evolutionary psychology, I had been entertained by an article—"Mental

Differences between Men and Women." Here "the missing five ounces" was of much concern:

> Seeing that the average brain-weight of women is about five ounces less than that of men, on merely anatomical grounds we should be prepared to expect a marked inferiority of intellectual power in the former. … The disabilities under which women have laboured with regard to education, social opinion, and so forth, have certainly not been sufficient to explain this. (Romanes 1887, pp. 654–656)

Apologizing for the "almost brutal frankness" of his remarks, there followed a litany of what seemed to be the self-evident intellectual deficiencies of women, including in the "power of amassing knowledge." But when Romanes compared men and women in a reading test:

> The palm was usually carried off by the ladies. Moreover, besides being able to read quicker, they were better able to remember what they had just read—that is to give a better account of the paragraph as a whole. One lady, for example, could read exactly four times as fast as her husband, and could then give a better account. (1887, p. 657)

Shortly thereafter a woman, Philippa Fawcett, beat the top man, known as the "Senior Wrangler," in the Cambridge Mathematics Tripos. But alas, when it came to women's "unnatural, and therefore impossible, rivalry with men in the struggles of practical life," Romanes, like most of his fellow Victorians, was not to be moved by such facts:

> How long it may take the woman of the future to recover the ground which has been lost … it is impossible to say; but we may predict with confidence that, even under the most favourable conditions as to culture, … it must take many centuries for heredity to produce the missing five ounces of the female brain. (1887, p. 666)

Savants and Microcephalics Don't Scale

Unaware of the hydrocephalic work, I used studies of rare individuals with exceptional memory (savant syndrome), and with exceptionally small heads (microcephalics), to argue against the scaling of human head size with brain information-content (Forsdyke 2009). With one prominent exception, those with savant syndrome tend to have normal-size heads. The presumed high information-content of their heads does not match their head size (Treffert 2010). On the other hand, while most microcephalics are intellectually impaired, there are a few cases where intelligence is normal; hence, long-term memory is likely to be normal. Again, presumed information-content does not match head size.

These arguments were supported, albeit indirectly, by some frank admissions of ignorance by neuroscientists at New York's Columbia University. Nobelist Eric Kandel (2006, p. 423) declared that "in the study of memory storage, we are now at the foothills of a great mountain range. … To cross the threshold from where we are to where we want to be, major conceptual shifts must take place." Fusi and Abbott (2007) called for "radical modification of the standard model of memory storage," and Firestein (2012) echoed this in his book—*Ignorance. How It Drives Science*. Furthermore, our brain's storage capacity for visual detail is now seen as enormously greater than previously estimated. This led researchers at MIT (Brady et al. 2008) to challenge the standard "neural models of memory storage and retrieval."

Why Doesn't Size Matter?

Given the doubts of these neuroscientists and the growing appreciation that brain size does not scale with information quantity, it would seem timely to look anew at possible ways our brains might store their information. Broadly, three hypotheses exist:

1. Information relating to long-term memory is held within the brain in some chemical or physical form consistent with current knowledge of brain chemistry and physiology. This "standard model" has many versions (e.g., Tsien 2013) that need not detain us.
2. Information relating to long-term memory is held within the brain in some extremely minute, subatomic, form, as yet unknown to biochemists and physiologists. Those who have witnessed in recent decades the vast increase in the power of computers to store large quantities of information in progressively smaller spaces should not be surprised if evidence for this alternative eventually emerges.
3. Information relating to long-term memory is held outside the brain. Since most nonneural tissues and organs appear unsuited for this task, this extrapolates to long-term memory being *outside* the body—extracorporeal! Amazingly, this startling alternative has been on the table for at least two decades. A Georgetown University professor of computing science has sketched out how it might work (Berkovich 1993, 2014). A 10th century Arabic philosopher-physician even had a version (Avicenna 1631).

Only with hypotheses two and three, which seem so improbable, do we really confront the dilemma posed by the brain scans of hydrocephalics. Yet some neuroscientists still seek to reconcile the scans with standard models. Indeed, Lorber originally suggested that the "primitive deep structures that are relatively spared in hydrocephalus" may have allowed his subjects to live normal lives, so that "there must be a tremendous amount of redundancy or spare capacity in the brain" (Lewin 1980, p. 1233). This implied that normally much of the brain is simply idling, ready to act as a backup should the need arise.

Somewhat more convincing was a "plasticity" explanation advanced by Bateson and Gluckman (2011). In similar fashion, the Brazilian neurosurgeons invoked the "resilient adaptation of brain networks" associated with "the ability of neuronal tissue to reassume and reorganize its functions" (de Oliveira et al. 2012). These plasticity explanations imply that, in keeping with the sometimes amazing recoveries reported for severe brain injuries—U.S. Congresswoman Gabrielle Giffords may be a recent example—an otherwise-occupied part of the brain can change to compensate for a defective part.

However, there must be *rules* for redundancy and plasticity. There *must be limits*. It is a matter of elementary logic that, at some stage of brain shrinkage, these explanations must fail. The drastic reduction in brain mass in the hydrocephalic cases seems to demand *unimaginable* levels of redundancy and/or plasticity—*superplasticity*. How much brain must be absent before we abandon these explanations and admit that the standard model, however incarnated, will not work?

The philosopher Marek Majorek was surprised at the lack of astonishment—the seeming cognitive dissonance—of clinicians "dryly" reporting both the hydrocephalic cases and others where individuals functioned well with only half a brain (hereditary or surgical loss of one cerebral hemisphere; Fig. 2). On a report in *The Lancet* entitled "Clinical Picture: Half a Brain," he commented (Majorek 2012, p. 124):

> Yet it seems that the report should have been supplied with a large red title stating something to the effect "A major medical miracle: normal life with half a brain!", published not only in an academic journal but on the first pages of every major newspaper in the world, and extensively discussed in professional journals.

For Majorek, such reports "radically challenge" the assumption that the brain alone provides the basis of our conscious experience ("neuronal reductionism").

Fig. 2 Brain scan of a seven-year-old girl who led a normal life with minimal impairment after removal of her dominant cerebral hemisphere at age three to relieve the symptoms of chronic focal encephalitis (Rasmussen syndrome). Reproduced with permission from *The Lancet* (2002; see Majorek 2012)

Cloud Computing

A modern metaphor for information relating to long-term memory being held outside the brain is "cloud computing." Even though the Internet emerged in the 1990s, it has taken two decades for cloud computing to become established. With respect to long-term memory, a stand-alone computer can be regarded merely as a terminal for manipulating data, and one retrieves from, and store files at, some remote location by way of the Internet. There are imaginative attempts to relate this to the workings of individual brains (Al Shargi and Berkovich 2009). The brain is seen as a receptor/transmitter of some form of electromagnetic wave/particle for which no obvious external structure (e.g., an eye) would be needed. Considering the universe as a holographic information storage device, and invoking the "spooky" physical principle of "non-locality" (Rudolph 2008), a "possible 'hardware' implementation" has been described (Berkovich 1993).

While various versions are considered in more detail elsewhere (Clark 2008; Noë 2009; Forsdyke 2011), they all fall far short on evidence. However, the rare hydrocephalic cases described here suggest that we should be cautious when tempted to cast aside the astonishing idea of personal information—long-term memory—being stored elsewhere. There are those, like Berkovich and Majorek, who urge us to lift our eyes to new horizons (Pribram 1991; Talbot 1991). Although some may lack a formal training in neuroscience, we should listen carefully. After all, Nature is not obliged to conform to our preconceptions. And, to return to Sherlock Holmes: "How often have I said to you that when you have eliminated the impossible, whatever remains, *however improbable*, must be the truth?" (Doyle 1890, p. 93).

The importance of this extends beyond neuroscience and into the clinic. Perhaps in these terms we will someday be able to explain the strange "voices" experienced by schizophrenics, and the bizarre condition described by the American Psychiatric Association (manual of psychiatric conditions; DSM-5) as "disassociative identity disorder" (otherwise "multiple personality syndrome")? And, of course, when speaking of extracorporeal memory we enter the domain of "mind" or "spirit," with corresponding metaphysical implications. In the words of Canadian philosopher Ian Hacking (1995), we begin to "secularize the soul." Indeed, "the scientific search for the soul" was how Francis Crick (1995) described his own brain studies. Perhaps we should return to 1867 and harken to an exchange between two of Charles Darwin's contemporaries, Robert Chambers and Alfred Russel Wallace: "My idea is that the term 'supernatural' is a gross mistake. We have only to enlarge our conceptions of the natural, and all will be alright" (Wallace 1905, pp. 285–286). We chuckle on learning how spiritualists duped such characters. Yet the possibility now emerges of at least some grains of truth amidst the dross that we poor creatures, imprisoned within the second decade of the 21st century, can understand no better than those imprisoned in the latter decades of the 19th could fathom "the missing five ounces" (Romanes 1887; Forsdyke 2014, 2015). Amongst the early 20th century beliefs of Wittgenstein (1969, p. 37e) was "that it isn't possible to get to the moon; but there might be people who believe that that is possible … they are wrong and we know it." It seems that yet another of his certainties must now topple.

Conclusion

Three independent studies agree that there are, among us, people leading normal lives with approximately 5 % of the quantity of brain tissue found in others. Even those without expertise in the interpretation of brain scans can appreciate the Brazilian team's photo (Fig. 1). The French team's photo (Feuillet et al. 2007) is no less spectacular, as is recognized by Bateson and Gluckman (2011) who give it as an example of brain plasticity, and by Majorek (2012) who also considers the recovery of hemispherectomized subjects (Fig. 2). Drawing on sources both literary (Doyle 1887, 1890) and historical (Romanes 1887; Wallace 1905), the present article has explored some philosophical, neuroscientific, and clinical implications of Lorber's now validated observations (Lewin 1980). Developing the thesis, made here and in earlier articles, that human brain size does not scale with its information content, it has been argued that the scope of possible explanations should not exclude extracorporeal information storage. This thesis is defended against those who might exclude it because Lorber's work is not credible (Hawks 2007), or who might deem plasticity and redundancy explanations as more plausible.

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