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Cognitive neuroscience and education: unravelling the confusion

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This paper critically examines the application of research into cognitive neuroscience to educational contexts. It first considers recent warnings from within the neuroscientific community itself about the limitations of current neuroscientific knowledge and the urgent need to dispel popular 'neuromyths' which have become accepted in many classrooms. It also criticises the use of over-simplified neuroscience to add scientific credibility to curricular reform, as has been the case in the rationale behind the recent implementation of the Northern Ireland Revised Curriculum. The paper then draws on the philosophy of Wittgenstein to highlight a further conceptual confusion which often surrounds the application of neuroscience to education.

Introduction: recent research into cognitive neuroscience and education

This paper examines the application of research from cognitive neuroscience to education. This consideration takes place in a context where schools are being bombarded with so-called brain-based learning packages. Several recent publications have, however, expressed caution (OECD, 2002; Goswami, 2004, 2006; Hall, 2005). Goswami (2006), Director of the Centre for Neuroscience in Education at the University of Cambridge, has written of the 'astonishing' speed with which packages claiming to be based on brain science have gained widespread currency in schools and which, not being subject to rigorous scrutiny, often represent little more than 'neuromyths', a term first coined by the OECD report on brain learning (OECD, 2002).

A decade ago Bruer, referred to as 'the most outspoken critic of a premature application of brain research to education' (Blakemore & Frith, 2005, p. 9), claimed that the 'neuroscience and education argument may be rhetorically appealing, but scientifically, it's a bridge too far' (Bruer, 1997, p. 5). Bruer viewed cognitive psychology as a potential intermediate level of analysis, necessary to link brain

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science to education, but urged caution in attempting to make *direct* links between classroom learning and neuroscience:

> Neuroscience has discovered a great deal about neurons and synapses, but not nearly enough to guide educational practice. Currently, the span between brain and learning cannot support much of a load. Too many people marching in step across it could be dangerous. (Bruer, 1997, p. 15)

In the intervening years, this 'misapplication of science to education' (Goswami, 2006, p. 2) has if anything intensified, encouraged by a hunger for information about the brain in schools, and despite warnings (also reported by Goswami, 2006) from most scientists that filling the gulf between current science and direct classroom application is premature. Geake and Cooper (2003) have argued for a more considered 'middle path, but with cautious optimism that the relationship between cognitive neuroscience and education will be for the long term' (p. 7). They ask educationalists to give neuroscience a 'fair hearing' (p. 8) and argue that the embrace of neuroscience by educationists is a necessary means to stem the 'increasing marginalisation of teachers as pedagogues' (p. 11) from politicians and boardroom directors with their predominantly instrumental objectives. Geake and Cooper conclude that 'there are implications and applications for education in cognitive neuroscience' (p. 17) and they look forward to the day when there might be enough known about brain activity to monitor learning and evaluate the effectiveness of instruction.

Geake (2005, p. 12) is quick to point out that there have been mistakes made in the past as 'intellectually unscrupulous characters' have expounded over-simplistic theories, such as learning-styles, left and right brain thinking or 'Brain Gym' exercises. Geake insists that 'university educationists need to provide a rigorous critical filter lest more neuro-nonsense infects the nation's schools' (p. 12). It is now time, Geake argues, that education not only takes account of the developments in neuroscience but also begins to make a contribution to the future agenda of neuroscientific research. Geake concludes that 'a cognitive neuroscience-education nexus should be a two-way street' (p. 12). Goswami (2006) similarly notes that there is much that neuroscience needs to learn from classroom practitioners who need to be encouraged to feed back important research questions. Goswami criticises the neuroscientific community for their inadequate communication skills and calls for a network of communicators of neuroscientific research 'who can bridge the current gulf between neuroscience and education by providing high-quality knowledge in digestible form' (p. 7). At the level of the classroom there is therefore an acknowledged need for better two-way communication between the complex world of cognitive neuroscience and the equally complex world of education, and a necessity for a 'critical filter' to protect classroom teachers from 'neuro-nonsense'.

Goswami (2006) and Geake (2005) both refer to conferences held recently in Cambridge and Oxford respectively at which teachers were able to hear first-hand from leading neuroscientists about the progress which is being made in the field of research but also about the limitations of their knowledge in many areas. Not surprisingly, Goswami (2006, p. 6) notes that 'the teachers were amazed by how

little was known' and that rather than being told 'what works' in the classroom, many of the teachers were somewhat disillusioned and frustrated on hearing that there was in fact no scientific basis for many of the brain-based programmes which they had been using in schools. Unfortunately conferences such as these are rare and the number of teachers who can attend remains relatively small. What is needed instead is a national approach to tackling the neuromyths which have become accepted in so many areas of education.

The Northern Ireland Revised Curriculum

The debate is relevant not just on the classroom level but also in terms of curricular organisation on a regional/national scale. The words of caution expressed above have unfortunately come too late for the teachers and pupils in Northern Ireland. There the Revised Curriculum has been implemented in phases since September 2007. This new curriculum comprises nine learning areas (including Learning for Life and Work) each of which is infused with the following 'skills and capabilities': Personal and Interpersonal Skills; Critical and Creative Thinking Skills; Communication; Application of Number; and Information and Communication Technology (CCEA, 2003a, p. 32). The curriculum is outlined as a series of statements of minimum entitlement, a move away from the rigidity of the former programme of study, and schools are encouraged to interpret the curriculum in innovative ways to promote collaborative learning across learning areas.

Scientific support is claimed by the architects of the Revised Curriculum by reference to neuroscience. In a brief section of the rationale entitled *The Learning Challenge*, the Council for the Curriculum, Examinations and Assessment (CCEA) (2003a, p. 22) notes that 'recently neuroscience has established a number of factors which are critical to learning and to motivation, about how our brains process information'. The following paragraph sketches out the neuroscientific rationale for this major curricular reform (CCEA provides no references to the primary source literature):

> We now know that the human brain creates meaning through perceiving patterns and making connections and that thought is filtered through the emotional part of the brain first. The likelihood of understanding taking place is therefore increased significantly if the experience has some kind of emotional meaning, since the emotional engagement of the brain on some level is critical to its seeing patterns and making connections. Learning is particularly effective when we have opportunities to apply what is being learned and when we can transfer learning from one situation to another. Neuroscience, therefore, highlights the need for learning to be emotionally engaging to the learner, particularly during the 11–14 age range when so much else is going on with adolescents to distract them from school. (CCEA, 2003a, p. 22)

CCEA also uses neuroscience to place collaborative project work, in which learning is contextualised, relevant and emotionally engaging, at the centre of the curriculum:

> Recent brain research indicates that the brain searches for patterns and interconnections as its way of making meaning. Researchers theorise that the human brain is constantly searching for meaning and seeking patterns and connections. Authentic learning situations

> increase the brain's ability to make connections and retain new information. When we set the curriculum in the context of human experience, it begins to assume a new relevance. (CCEA, 2003b, p. 3)

CCEA argues repeatedly that learning must be 'connected', and that learning must be approached 'in a more connected way' (CCEA, 2003a, p. 22). CCEA takes 'connectedness' to mean that the traditional emphasis on teaching discrete subjects is somehow outdated and discredited by recent neuroscience. CCEA instead stresses the value of interdisciplinary skills and greater collaboration between pupils and among subjects as a preparation for the world of work:

> Our current emphasis on learning within separate subject disciplines dates back at least a century and is based on the notion that each subject is a distinct form of knowledge with separate characteristics, concepts and procedures which encourage efficient learning. Over the last decade, we have begun to learn more about how the brain processes information and the multi-faceted nature of work in the modern world. We are beginning to question the wisdom of compartmentalising learning while expecting young people to cope with multi-dimensional problems. There is growing recognition that separate subject teaching may prevent pupils from seeing the relationships between subjects. (CCEA, 2003b, pp. 2–3)

Morrison (2006) has already criticised CCEA's use of neuroscience to justify its curriculum innovations. Morrison (2006) suggests that 'there is little evidence that neuroscientists share the same beliefs as brain-based learning enthusiasts' (p. 9) and that CCEA is attempting to 'bolster their case' by invoking 'science'. In its response to Morrison, CCEA claims that it now takes the 'middle ground' in its approach to neuroscience (CCEA, 2006, p. 10) and appears to play down its influence on its revision of the curriculum in Northern Ireland:

> CCEA emphasises, again, that neuroscience is not, and was not, the sole or prime foundation for the review of the Northern Ireland curriculum. The review was based on a raft of research, consultation and trialling to which neuroscience makes but one contribution. (CCEA, 2006, p. 11)

So far this paper has outlined the debate about the application of neuroscience to education from within the neuroscientific community, which, in light of recent research and ongoing gaps in knowledge, acknowledges that popular 'neuromyths' in schools must be dispelled and that there needs to be a much tighter regulatory process established to defend schools from future myths. In terms of the development of the Northern Ireland Revised Curriculum, however, there seems to have been little attention paid by the neuroscientific community to the claims made by CCEA (cited above), which are sweeping and unsubstantiated at best. In the following section a more fundamental, philosophical warning is also offered with regard to the risk of conceptual confusion arising from the application of neuroscience to education. This warning is derived from the (later) philosophy of Ludwig Wittgenstein.

Wittgenstein and irreducible uncertainty

In the *Philosophical Investigations* (§138–242) Wittgenstein considers what happens when a child continues a mathematical sequence such as (1,3,5,7…) and notes that

it is generally assumed that there must be an inner mental explanation or cause for the pupil's responses to, say, an examination question:

> If one says that knowing the ABC is a state of the mind, one is thinking of a state of a mental apparatus (perhaps of the brain) by means of which we explain the *manifestations* of that knowledge. (*Philosophical Investigations*, §149)

However, Wittgenstein argues that any such attempt to map the exact nature of that 'mental apparatus' which is the supposed source of the response can only lead to ultimate confusion:

> We are trying to get hold of the mental process of understanding which seems to be hidden behind those coarser and therefore more readily visible accompaniments. But we do not succeed; or, rather, it does not get as far as a real attempt. For even supposing I had found something that happened in all those cases of understanding,—why should *it* be the understanding? … And if I say it is hidden—then how do I know what I have to look for? I am in a muddle. (*Philosophical Investigations*, §153)

Similarly in the *Zettel* Wittgenstein writes that we must resist the temptation to find a specific mental process to accompany understanding, and counsels us not to think of understanding as a mental process at all:

> But don't think of understanding as a 'mental process'.—For *that* is the way of speaking that is confusing you … That way of speaking is what prevents us from seeing the facts without prejudice … . So let us not think we *must* find a specific mental process, because the verb 'to understand' is there and because one says: Understanding is an activity of mind. (*Zettel*, §446)

While we seem naturally drawn to believe in mental processes, Wittgenstein encourages us to stop looking for ever more speculative *explanations* and instead to accept the visible *descriptions* of the child's understanding which are manifest in their response. What at first appears to be the preliminary to the solution is in fact the solution itself:

> Here we come up against a remarkable and characteristic phenomenon in philosophical investigation: the difficulty—I might say—is not that of finding the solution but rather that of recognising as the solution something that looks as if it were only a preliminary to it. 'We have already said everything.—Not anything that follows from this, no, *this* itself is the solution!'
>
> This is connected, I believe, with our wrongly expecting an explanation, whereas the solution of the difficulty is a description, if we give it the right place in our considerations. If we dwell upon it, and do not try to get beyond it.
>
> The difficulty here is: to stop. (*Zettel*, §314)

However, Wittgenstein does not deny the inner, as Behaviourists might argue, but claims instead, as Hacker (1997, p. 43) notes, 'What we so misleadingly call "the inner" *infuses* the outer' and thus the child's understanding is manifest in the response and cannot be reduced, analysed or interpreted further. For Wittgenstein the inner and outer are intertwined, and so any attempt to isolate the inner will necessarily fail. Moreover the language we use to talk about the inner will remain *irreducibly uncertain*, since there is no way to move to a position of certainty.

This notion of *irreducible uncertainty* is further illustrated in Wittgenstein's discussion of pain. In the *Philosophical Investigations* he writes that there can be no criteria which can be used to justify him saying 'I am in pain'. It simply makes no sense to talk about knowing, or not knowing, or doubting that one is in pain (§288). Justification by criteria of a psychological attribute such as pain is unnecessary and meaningless, because, as Wittgenstein continues, it is to confuse psychological with physical attributes:

> What I do is not, of course, to identify my sensation by criteria: but to use the same expression again. But this is not the *end* of the language-game: it is the beginning.
>
> But isn't the beginning the sensation—which I describe?—Perhaps this word 'describe' tricks us here. I say 'I describe my state of mind' and 'I describe my room.' You need to call to mind the differences between the language-games. (*Philosophical Investigations*, §290)

Wittgenstein chooses the examples of describing his room and describing his mind to illustrate that there is an important distinction between physical and psychological attributes. In accordance with Newtonian science the length (a physical attribute) of, say, a table is an intrinsic property of the table alone and will not vary according to the measuring instrument (the ruler or the tape measure). The physical attribute of the length of the table can thus be measured so that any uncertainty (regarding the measurement) can be reduced. Moreover the probability in the measurement can be said to be subjective, since it can be reduced by improved measurement. If one considers the mind, on the other hand, the situation is quite different: to take Wittgenstein's illustration once more, to *measure* pain (a psychological attribute) leads us into considerable confusion. How can it be measured? Wittgenstein proposes the absurd scenario of a clinical thermometer being used first to verify the pain before treatment rather than simply observing the crying and the moaning of the patient (MS 176). Such a measurement of pain is both unnecessary and meaningless. Ter Hark (1990, pp. 147–148) also refers to the necessary and non-causal 'indeterminacy' in Wittgenstein's concept of pain, and notes that the indeterminacy is not removed by surgical inspection or a thermometer reading, even though the pain has been 'measured':

> For while the concept of pain has now been determined in the sense that it has been measured, the indeterminacy in our concept of pain has not been removed. It has not been removed because the measurable manipulation of pain produces an entirely *different* concept of pain from ours. (Ter Hark, 1990, p. 148)

As Ter Hark remarks, measuring pain with a thermometer is to change the very concept of pain, since the uncertainty of the psychological attribute of pain cannot be reduced. While physical attributes are intrinsic (the length of the table is a property of the table alone), psychological attributes are necessarily relational in nature, so that any attempt to measure them produces a quite different measurement (such as a thermometer reading) which is a joint property of the psychological attribute and the measuring instrument. In short, psychological attributes are inherently different from physical or mechanical attributes. We can measure the length (a *physical* attribute) of a piece of wood with certainty, but cannot measure the pain (a psychological

attribute) experienced by a human being with certainty because of the inherent vagueness of *psychological* attributes. As Marie McGinn (2003, p. 89) remarks, Wittgenstein wants us to accept the 'vagueness' of psychological description as 'part of its essence' and to accept that it is logically impossible to isolate and measure the inner.

In relation to education the indeterminacy of psychological attributes (such as understanding) is not removed by a computer-generated print-out of neural processing, because this form of measurement creates a quite different concept. In the light of Wittgenstein's philosophy we might therefore conclude that cognitive neuroscience can certainly reveal much about brain functioning, but there can be no logical link between fMRI data and educational attributes. Cognitive neuroscience may offer detailed pictures of neural networks, but, just as a thermometer fails to measure pain, so a brain scan fails logically to measure understanding: the concepts involved are simply different and the indeterminacy remains. Cognitive neuroscience therefore at best offers insights into the neural *concomitants* of thinking, but it offers no privileged access into the hidden world of the inner, that inner world being already manifest in external behaviour. Rather than representing a panacea to education, the cognitive neuroscientific enterprise in relation to education is therefore necessarily limited.

Unravelling the conceptual confusion

The confusion is highlighted in recent collaborative work on the philosophical foundations of neuroscience by a leading neuroscientist, M.R. Bennett, in association with an eminent Wittgensteinian scholar, P.M.S. Hacker. Bennett and Hacker (2003) first cite an array of neuroscientists who have ascribed a wide range of psychological attributes to the brain, such as Crick (1995), Edelman (1994), Blakemore (1977), Young (1978), Damasio (2004), Libet (1985). In the light of what Wittgenstein writes of the misguided Cartesian separation of the inner and outer, Bennett and Hacker (2003) ask whether we know 'what it is for a brain to see or hear, for a brain to have experiences, to know or to believe something?' (2003, p. 70) for while we know what it is for a person to reason or to present arguments, do we really have any idea what it could mean for a *brain* to do these?

Rejecting the idea that such utterances are the result of any new scientific discovery revealing that the brain engages alone in such activity, Bennett and Hacker (2003, p. 71) deduce that there is in fact 'no such thing as the brain's thinking or knowing, seeing or hearing, believing or guessing, possessing or using information, constructing hypotheses etc.' and that such beliefs are instead the result of conceptual confusion. Bennett and Hacker (2003) quote Wittgenstein who, in the *Philosophical Investigations*, notes that 'Only of a human being and what resembles (behaves like) a living human being can one say: it has sensations; it sees, is blind; hears, is deaf; is conscious or unconscious' (§281). So why has such a form of description been adopted so unquestioningly by neuroscientists? For Bennett and Hacker (2003, p. 72) it is the result of a 'mutant form of Cartesianism' where

psychological attributes once ascribed to the mind, Descartes' immaterial *res cogitans*, are now ascribed unreflectively to the material brain instead.

In the rationale for the Northern Ireland Revised Curriculum, for instance, CCEA (2003a) states that, 'We now know that the *human brain creates meaning* through perceiving patterns and making connections …' (p. 22, emphasis added). However, Bennett and Hacker (2003) argue that the brain is not a logically appropriate subject for psychological attributes and that only a human being can be said to see or be blind, hear or be deaf, ask questions or refrain from asking. It therefore makes no sense to ascribe psychological attributes to the brain. The resulting combination of words is not false: 'rather it says nothing at all, for it lacks sense' (p. 72) since psychological predicates are predicates which apply essentially to the whole living animal and not to its parts. Consequently the authors argue that it is not the eye (let alone the brain) that sees, but rather we see with our eyes. Bennett and Hacker refer to this mistake of ascribing to the constituent parts of an animal attributes that logically apply only to the whole animal as the 'mereological fallacy in neuroscience' (p. 73). Moreover, they note that localised brain activity detected by PET or fMRI does not show that the brain is thinking, reflecting or ruminating: 'it shows that such-and-such parts of a person's cortex are active when the *person* is thinking, reflecting or ruminating' (p. 83). To know that the person is thinking depends then not on the computer-generated image of the excitation of cells in their brain when they are thinking, but rather on behavioural criteria such as the expression on their face. Furthermore, the neural events which take place during the pain of toothache are merely concomitants of the person's feeling toothache. The human being, not the brain, feels the pain. In the *Philosophical Investigations* Wittgenstein writes that the feeling of pain cannot be ascribed to the individual part of the body but to the whole person, and hence one comforts the *person* in pain, not the body part:

> But isn't it absurd to say of a *body* that it has pain?—And why does one feel an absurdity in that? In what sense is it true that my hand does not feel pain, but I in my hand?
>
> What sort of issue is: Is it the *body* that feels pain?—How is it to be decided? What makes it plausible to say that it is *not* the body?—Well, something like this: if someone has a pain in his hand, then the hand does not say so (unless it writes it) and one does not comfort the hand, but the sufferer: one looks into his face. (*Philosophical Investigations*, §286)

Bennett and Hacker (2003) conclude by maintaining that it makes no sense to attribute psychological attributes to either the mind (Cartesianism) or to the brain (cognitive neuroscience). Instead psychological attributes must be ascribed to the whole person 'who is a psychophysical unity, not a duality of two conjoined substances, a mind and a body' (p. 106). Far from discrediting neuroscientific research, Bennett and Hacker simply argue that neuroscientists are often guilty of conceptual confusion in ascribing psychological attributes to the physical organ of the brain. Hacker (1997, p. 51) summarises the point neatly:

> Brains do not have opinions, argue, hypothesize or conjecture. It is we who do so. To be sure, we could not do so if our brain were destroyed; but then we could not have toothache or walk without a brain either—yet it is not the brain that has toothache and walks to

> the dentist. If one is asked what one thinks of the weather, should one say, 'My brain is thinking it over; give it a minute, and it will tell me, and then I'll tell you'? (Hacker, 1997, p. 51)

As Bennett and Hacker would suggest, further confusion surrounding the application of neuroscience to education could be eliminated by 'careful attention to conceptual questions' (p. 107). In so doing, neuroscientists would cease to pose misguided questions, to devise misconceived experiments or to misinterpret the results and implications of such experiments: 'What needs to be said can be said clearly, and saying it clearly will benefit, not diminish, the actual achievements of neuroscience' (p. 107).

Conclusion

In this paper an attempt has been made to show the urgent need for what Geake (2005) calls a 'critical filter' in order to prevent the unchallenged application of 'scientific' claims to education, whether on the level of classroom teaching methodologies, or on the broader level of curricular reform. The application is seductive in many respects and there is little doubt that the very mention of the word 'neuroscience' adds a veneer of scientific respectability to any curriculum innovation or brain-based package. However, this paper has highlighted not only the caution which has been expressed in recent years from within the neuroscientific community itself but has also highlighted the more fundamental conceptual confusion which often bewitches our thinking and which encourages us to over-generalise, to over-simplify or to fall victim to the mereological fallacy in ascribing to the constituent parts of a person attributes that logically apply only to the whole person.

As McGinn (1993, p. 698) notes, Wittgenstein's work describes how our misconceptions arise because of language, and reveals 'both how our language-game tempts us to false pictures of the mental, and the emptiness of the pictures it prompts us to construct'. Rather than accepting the fundamental and necessary indeterminacy of the mental, Wittgenstein argues that we feel the need (ever tempted by our language) to imagine a hidden, inner realm, which we are desperate to penetrate, reveal and detail. For as long as we are tempted by language, we will continue our vain search for the certainty of inner mental states to determine the *best* way to learn, the *best* way to teach, and (in the case of Northern Ireland) the *best* curriculum model. The radical contribution of Wittgenstein's philosophy to education is surely to demonstrate that at the heart of the problem lies language. In response to the criticism that philosophy has made no progress since the time of Plato, Wittgenstein replies:

> The reason is that our language has stayed the same and tempts us again and again towards the same questions. For as long as there will be a verb 'to be', which seems to work like 'to eat' and 'to drink', for as long as there will be adjectives 'identical', 'true', 'false' and 'possible', for as long as there will be talk of a passage of time and of an extent of space etc., etc., then people will run up against the same puzzling difficulties again and again, and they will stare at something which no explanation seems to be able to remove. (*The Big Typescript*, p. 286)

Attempts to solve the problems of education through cognitive neuroscience must therefore be seen as an attempt to reduce the irreducible uncertainty of the mental. Furthermore, CCEA's Revised Curriculum must be seen as not so much a step forward as another unwitting step in a 'curriculum spiral', the result of conceptual confusion.

It is necessary, finally, to consider the two possible future scenarios presented by Geake and Cooper (2003) of a teacher–parent interview at a primary school where a parent is discussing the poor mathematics results achieved by her son, Chris. In the first scenario the teacher has available a neuro-imaging report compiled as Chris undertook his assessment tasks wearing a neuro-imaging headset. The results were later statistically analysed by computer and the parent-teacher report generated. Based on this computer-generated report the class teacher identifies Chris's relatively weak short-term memory and recommends a remedial course to strengthen the relevant circuit. The parent is pleased at the decisive action taken by the teacher and is impressed by her 'professionality'. In the second scenario the teacher admits to a frustrated parent that she doesn't know what is causing Chris's problem, but recommends that the parent goes to see an external agency (*Cognitive Services Inc.*) specialising in cognitive processing. The teacher's words succinctly express her lack of confidence in herself and in her profession: 'How would I know what to do? After all, I'm only a teacher. I don't know what is causing the problem' (p. 18). It is the contention of Geake and Cooper that the future teacher's professionalism depends on their embracing cognitive neuroscience and on their offering the parent a detailed analysis of the problem and suggestions for remedial action based on neural imagery of Chris's mental processing. In light of the conceptual confusion outlined above, this paper argues, however, that the classroom teacher is foremost an educator not a neuroscientist. While neuroscience can reveal what is happening in the brain as Chris thinks, the imagery is never more than a neural concomitant of that thinking, and there will always be uncertainty about educational processes because educational or psychological attributes are logically and irreducibly uncertain. The answer to Chris's problem therefore does not lie in privileged glimpses into the functioning of his brain, but rather in careful examination of the facts as they appear before the teacher's eyes in the performance of the pupil. A teacher's skill in helping the pupil based on experience in the classroom (rather than the neuroscience laboratory) thus needs no apology, but instead can be celebrated as the epitome of professionalism.

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