Educational neuroscience, neurotechnology, and the translation of ‘learning brains’ into policy and practice

Ben Williamson | University of Edinburgh

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Publication

Your Brain on ChatGPT: Accumulation of Cognitive Debt when Using an AI Assistant for Essay Writing Task

‹ Research

June 10, 2025

People

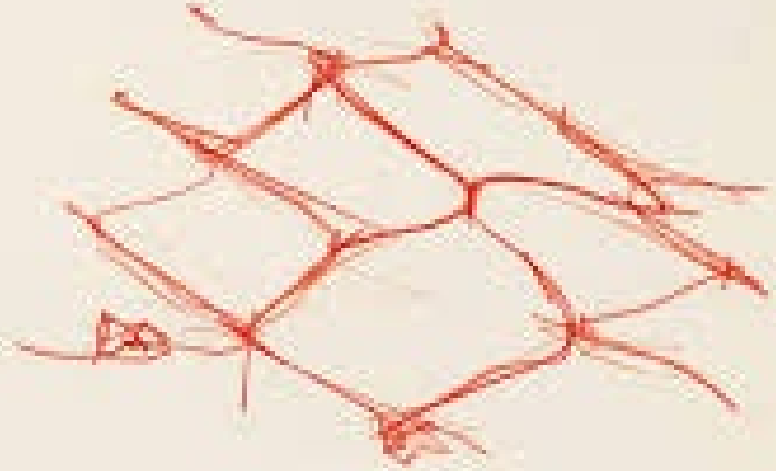
Nataliya Kos'myna
Research Scientist

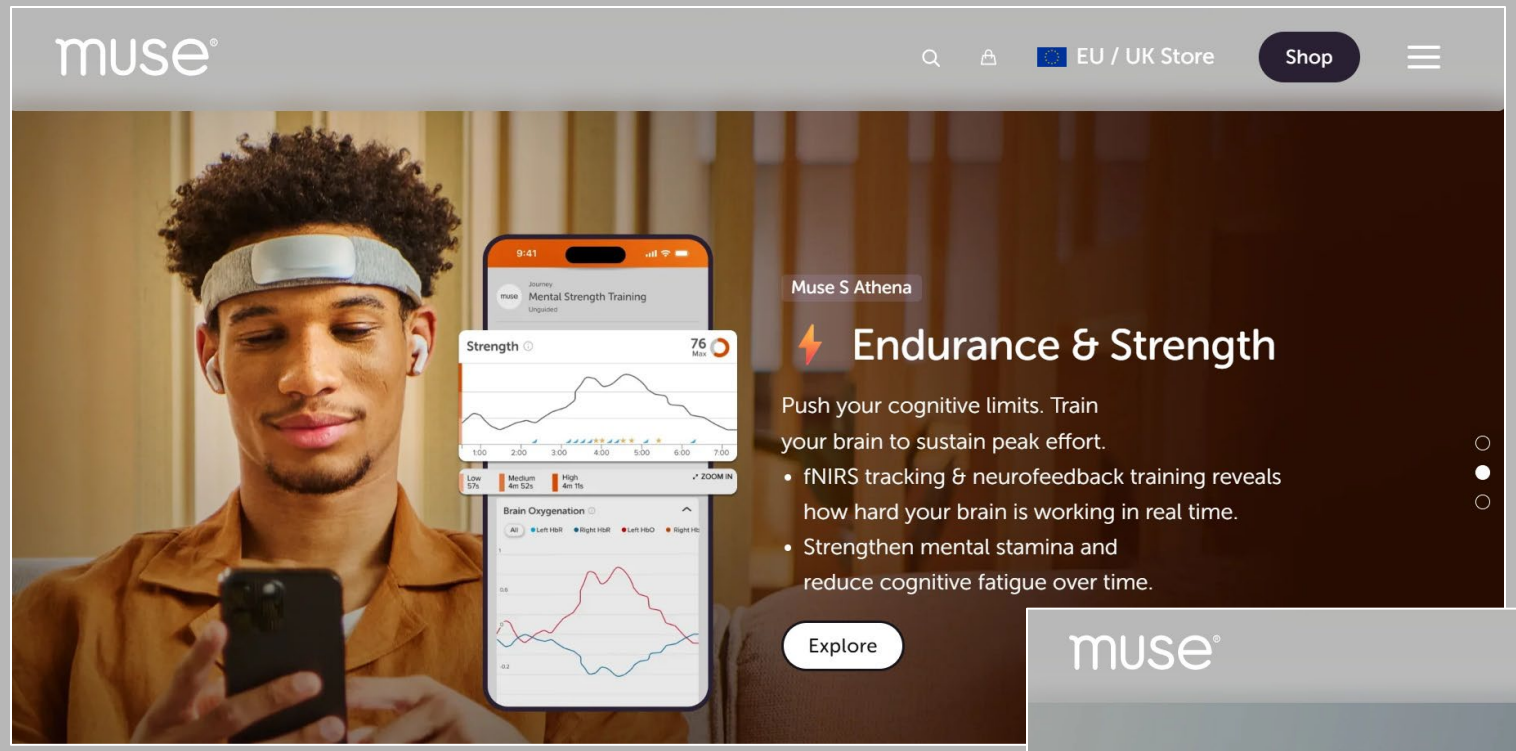
We used electroencephalography (EEG) to assess cognitive load during essay writing … EEG revealed significant differences in brain connectivity … While LLMs offer immediate convenience, our findings highlight potential cognitive costs … LLM users consistently underperformed at neural, linguistic, and behavioral levels.

Being Brains

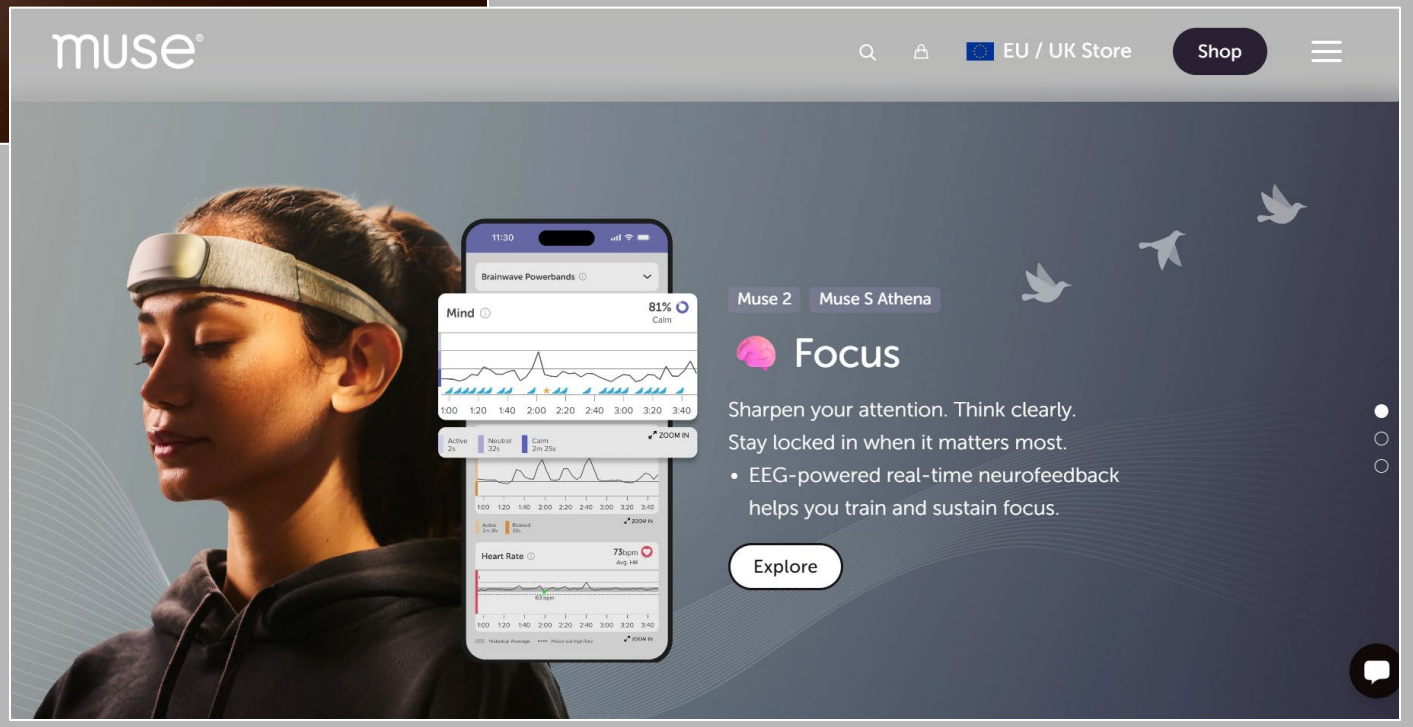
Making the Cerebral Subject

Fernando Vidal and Francisco Ortega





"Athena transforms real-time brain activity into actionable insights, personalized training, and measurable progress....



...It's powered by Muse's AI-driven Foundational Brain Model (FBM), which is trained on over 80,000 sessions from the world's largest EEG database."

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DOI: 10.1002/rev3.70070

REVIEW AND SYNTHESIS

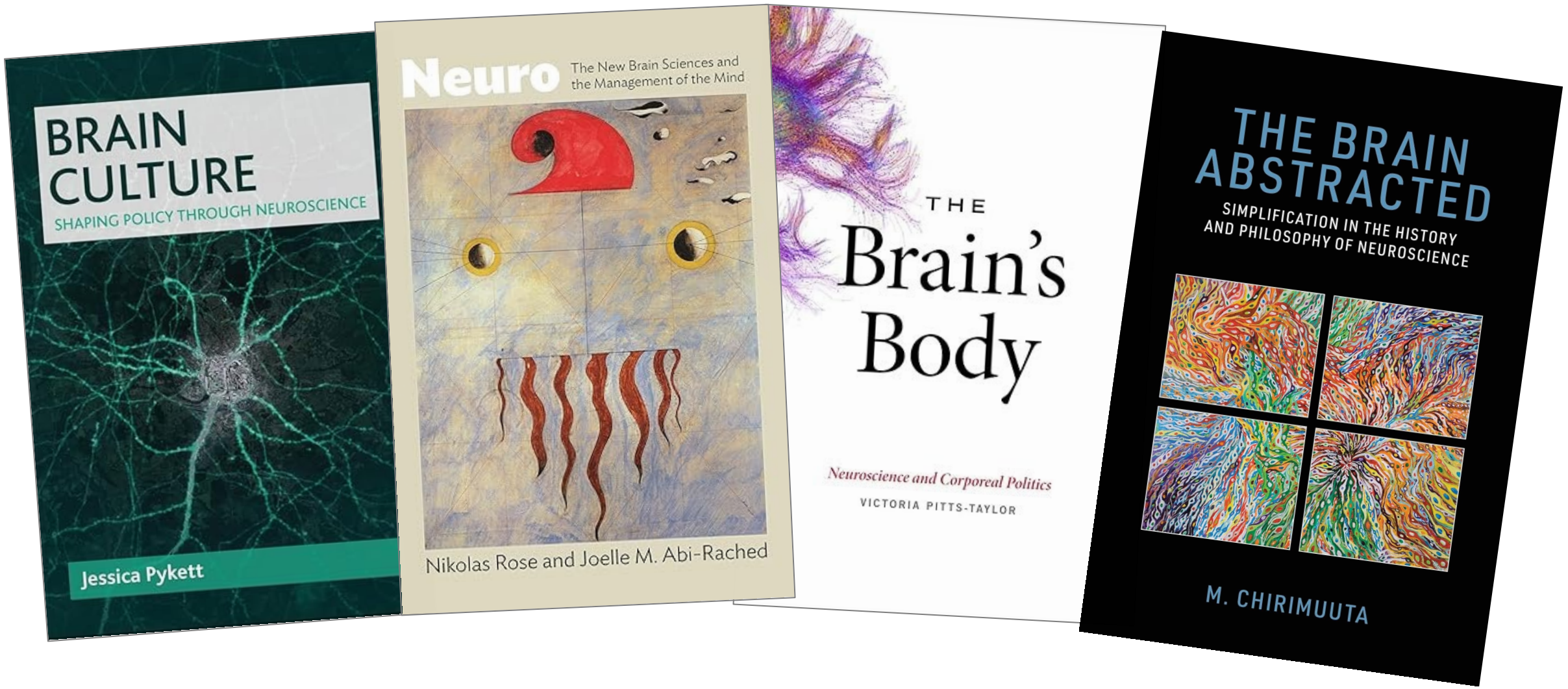
Review of Education BERA

A scoping review of educational neurotechnology: Methods, applications, opportunities, and challenges

Ali Nouri

Five types of "neurotechnology" identified in research in education

(1) measurement of brain structure and function with EEG, fMRI, etc
(2) neurofeedback for regulating brain activity
(3) non-invasive brain stimulation
(4) brain–computer interfaces (BCIs) for monitoring and regulating brain activity
(5) neurotechnologies that integrate with AI to analyse or predict outcomes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Learning brains: educational neuroscience, neurotechnology and neuropedagogy

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ABSTRACT

Educational neuroscience seeks to conceptualise the neural underpinings of learning and other educational outcomes, as a route to proposing brain-based pedagogic interventions. As educational neuroscience has begun deploying new neurotechnologies, it has generated diverse data-driven conceptualisations of the 'learning brain'. The data-intensive technological and methodological apparatuses used in educational neuroscience support the configuration of multiple 'learning brains' as the basis for neuropedagogic interventions: (1) a 'plastic' brain, (2) a 'synchronized' brain, (3) an 'engaged' brain, and (4) a 'computational' brain. Various sociotechnical arrangements of instrumentation, information, incubation, imagination and implementation that constitute contemporary neurotechnological instantiations of educational neuroscience are analysed. The core argument is that the neuro-informational malleability of the datafied learning brain is being mobilised to strengthen educational neuroscience as a source of expertise in brain-based pedagogies. This has novel implications for determining what education scientifically *is* and normatively *should be*, and for proposed 'neurogovernance' interventions.

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Brain; data; educational neuroscience; neurogovernance; neuropedagogy; neurotechnology

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Brokering the brain: neuroscientific knowledge, technologies, and the translation of neuro-expertise into educational practice

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ABSTRACT

Educational neuroscience has expanded its influence since the 1990s, positioned as advancing new forms of intervention in educational policy and practice. Simultaneously, the gap between the neuroscience lab and the classroom has preoccupied educational debate. Yet, little is known about the discursive practices by which educational neuroscience seeks to translate science into application. In this paper, we analyse the translational knowledge brokering discourses that promote neuroscience in educational research, policy, and practice. We find three principal translational discourses at work in educational neuroscience: coalition building, promising to transform expertise in education; school partnerships, encouraging teachers and children to adopt neuroscientific lenses; and commercialisation, which presents marketable neurotechnological solutions to educational challenges. Such translational activity is frequently framed as emancipatory, pledging to address inequalities and centre critical educational expertise. However, it still foregrounds the brain, rather than its social and educational contexts, as the locus of intervention to address social problems.

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KEYWORDS
Educational neuroscience; emancipatory framing; knowledge brokering; translational discourses

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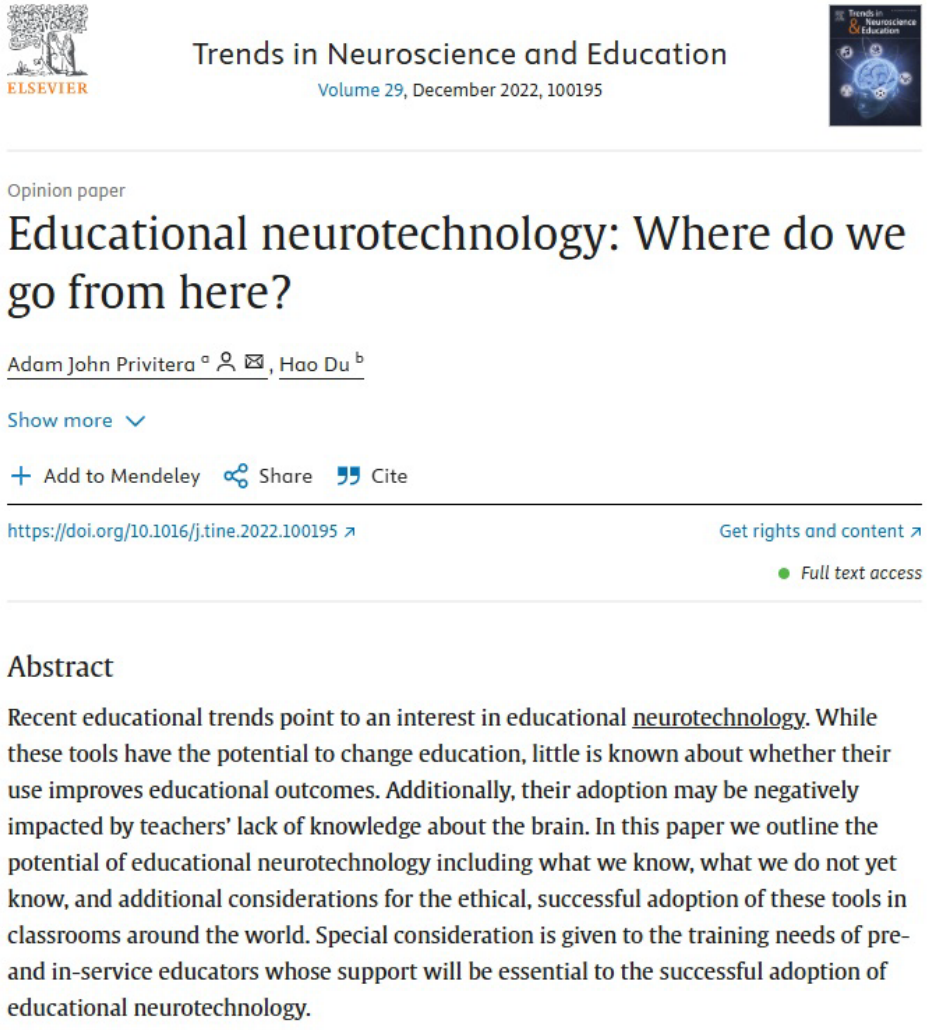
1 Neuro-digital translation

- Specific laboratory “setups” of scientific procedures, methods and technologies “have generated the truths of contemporary neuroscience” (Rose and Abi-Rached 2013)
- “Brain facts” are products of “a vast number of contributing factors, co-produced by a collection of circumstances, social interests and institutions” (Slaby and Choudhury 2018)
- The “brain knowledge” generated through neuroscientific setups shapes how human subjects are understood and treated, and how policy and practice proposals are formulated as “neurogovernance” interventions (Pitts-Taylor 2016; Pickersgill 2023)



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Trends in Neuroscience and Education
Volume 29, December 2022, 100195

Opinion paper

Educational neurotechnology: Where do we go from here?

Adam John Privitera [a], Hao Du [b]

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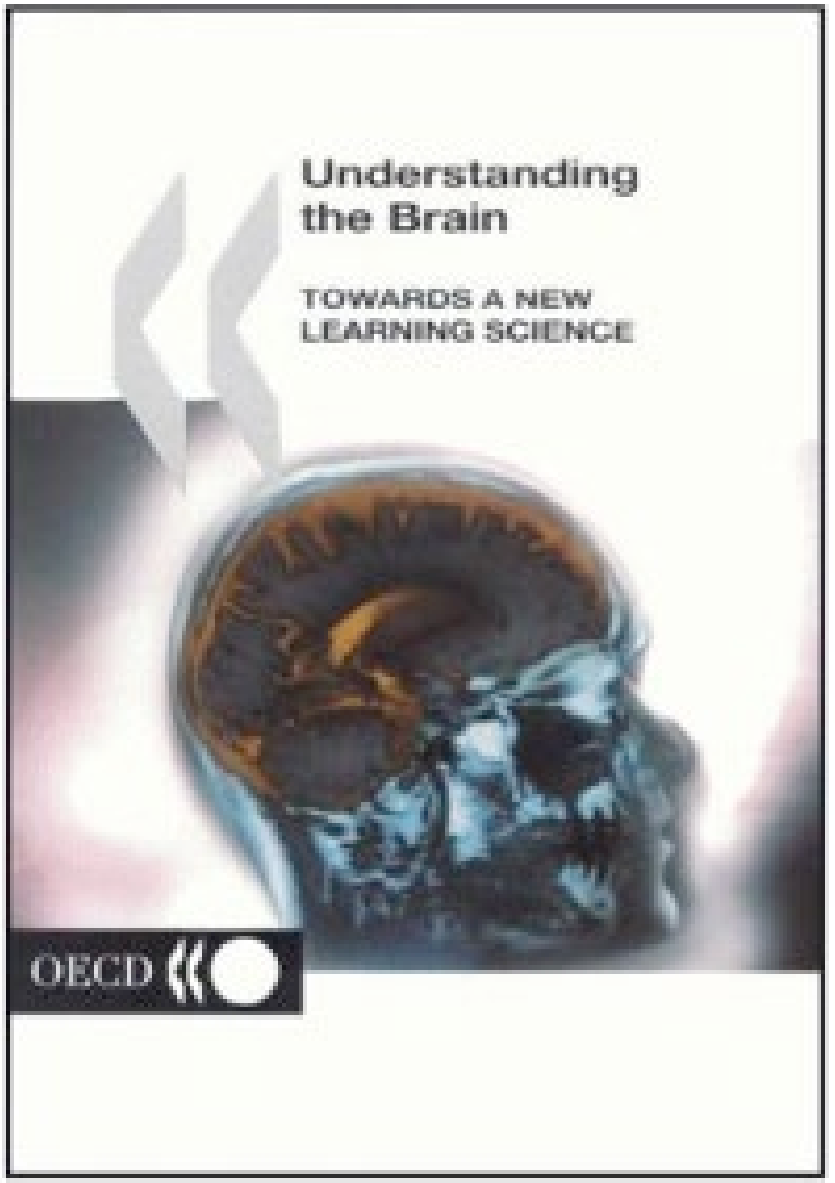
Abstract

Recent educational trends point to an interest in educational neurotechnology. While these tools have the potential to change education, little is known about whether their use improves educational outcomes. Additionally, their adoption may be negatively impacted by teachers' lack of knowledge about the brain. In this paper we outline the potential of educational neurotechnology including what we know, what we do not yet know, and additional considerations for the ethical, successful adoption of these tools in classrooms around the world. Special consideration is given to the training needs of pre- and in-service educators whose support will be essential to the successful adoption of educational neurotechnology.

The informationalization of the learning brain

- “With the advent of functional imaging technology, cognitive neuroscience is beginning to produce important research on the neural foundations of cognitive performance” (OECD 2002)
- “Technologies of non-invasive brain scanning and imaging are opening up totally new approaches” (OECD 2007)
- “Advancements in neuroimaging techniques from 1990 to the present, in terms of both measurement accuracy and data analysis … began to link observable learning in classrooms to molecular-level changes in brains” (Tokuhama-Espinosa 2021)
- “New analysis techniques also include machine learning algorithms to decode brain activation patterns automatically with high accuracy” (van Atteveldt et al 2018)



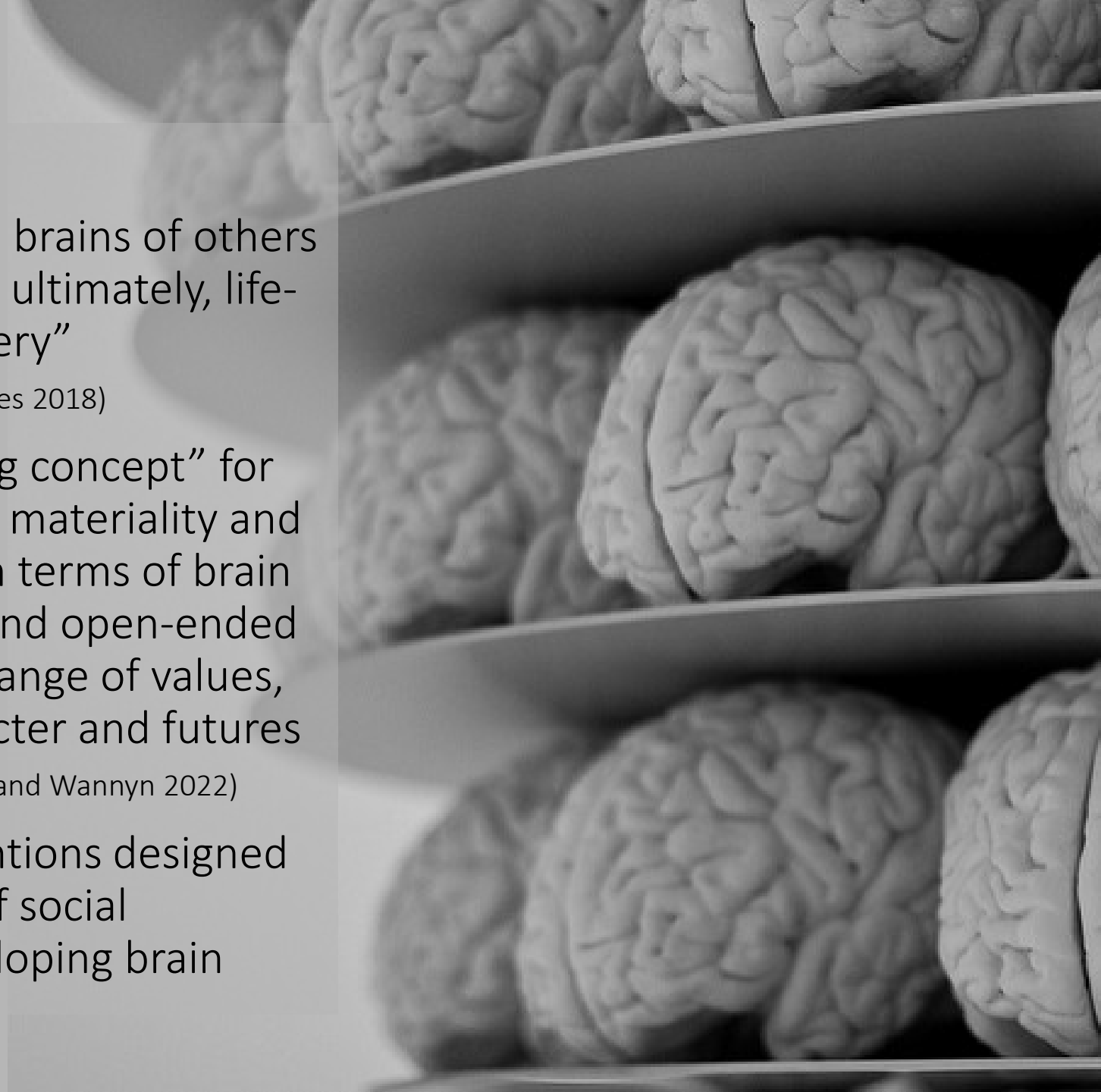
Plasticity

- “Teachers rewire and restructure the brains of others in ways that can be as biological and, ultimately, life-changing as the effects of neurosurgery”

  (Howard-Jones 2018)

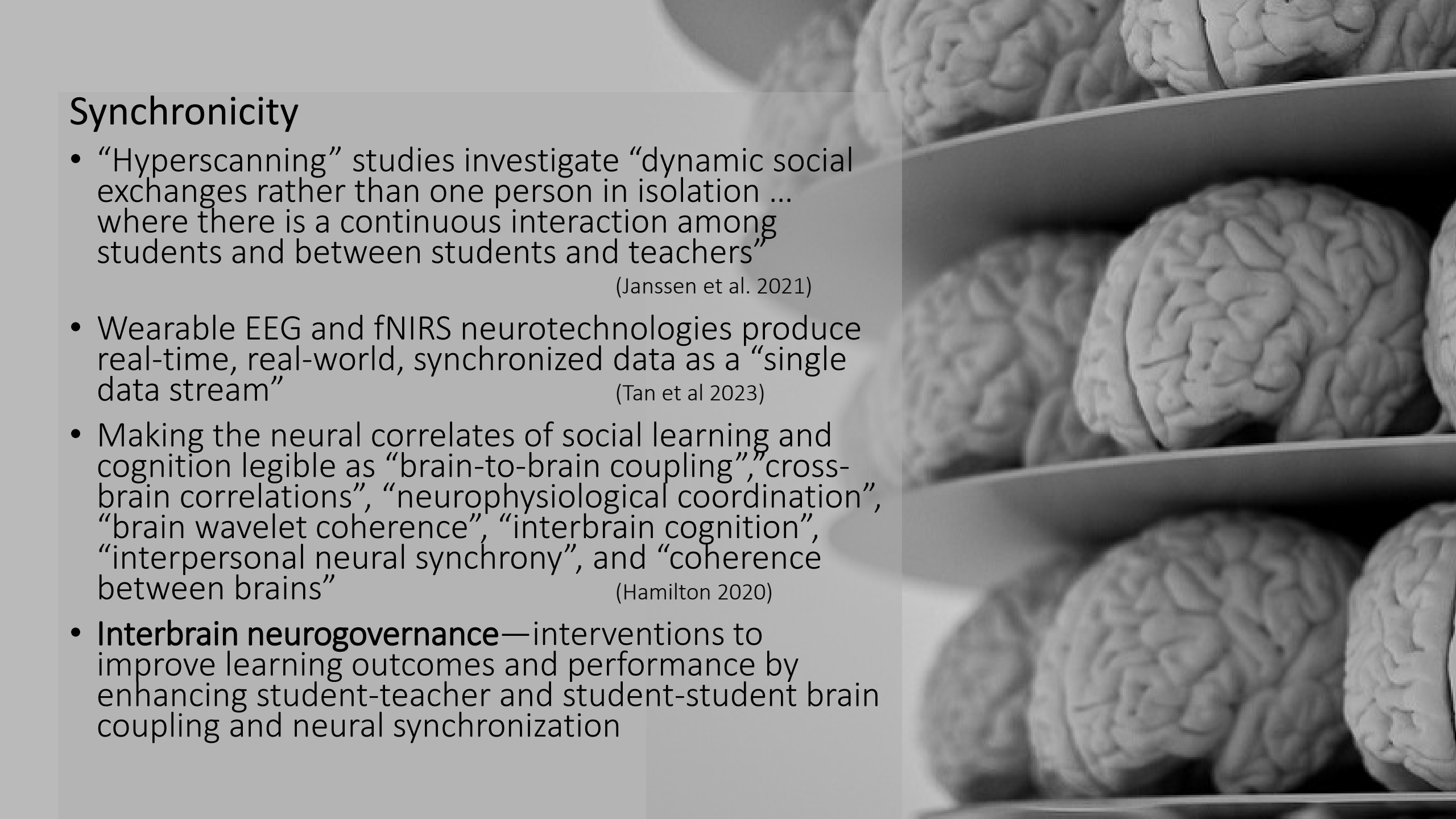
- Neuroplasticity functions as “enabling concept” for educational neuroscience, “denoting materiality and specificity of learning and teaching in terms of brain processes” while also being “vague and open-ended enough to encompass and reflect a range of values, hopes and anxieties about the character and futures of children and youth” (Choudhury and Wannyn 2022)

- Biosocial neurogovernance—interventions designed to ameliorate the biological effects of social deprivation and poverty on the developing brain



Synchronicity

- “Hyperscanning” studies investigate “dynamic social exchanges rather than one person in isolation … where there is a continuous interaction among students and between students and teachers” (Janssen et al. 2021)
- Wearable EEG and fNIRS neurotechnologies produce real-time, real-world, synchronized data as a “single data stream” (Tan et al 2023)
- Making the neural correlates of social learning and cognition legible as “brain-to-brain coupling”,”cross-brain correlations”, “neurophysiological coordination”, “brain wavelet coherence”, “interbrain cognition”, “interpersonal neural synchrony”, and “coherence between brains” (Hamilton 2020)
- **Interbrain neurogovernance**—interventions to improve learning outcomes and performance by enhancing student-teacher and student-student brain coupling and neural synchronization



Attention

- Educational neurotechnologies are proposed to be able to detect and measure student attention, engagement, and to monitor learners' mental and emotional states

(Privitera and Du 2022)

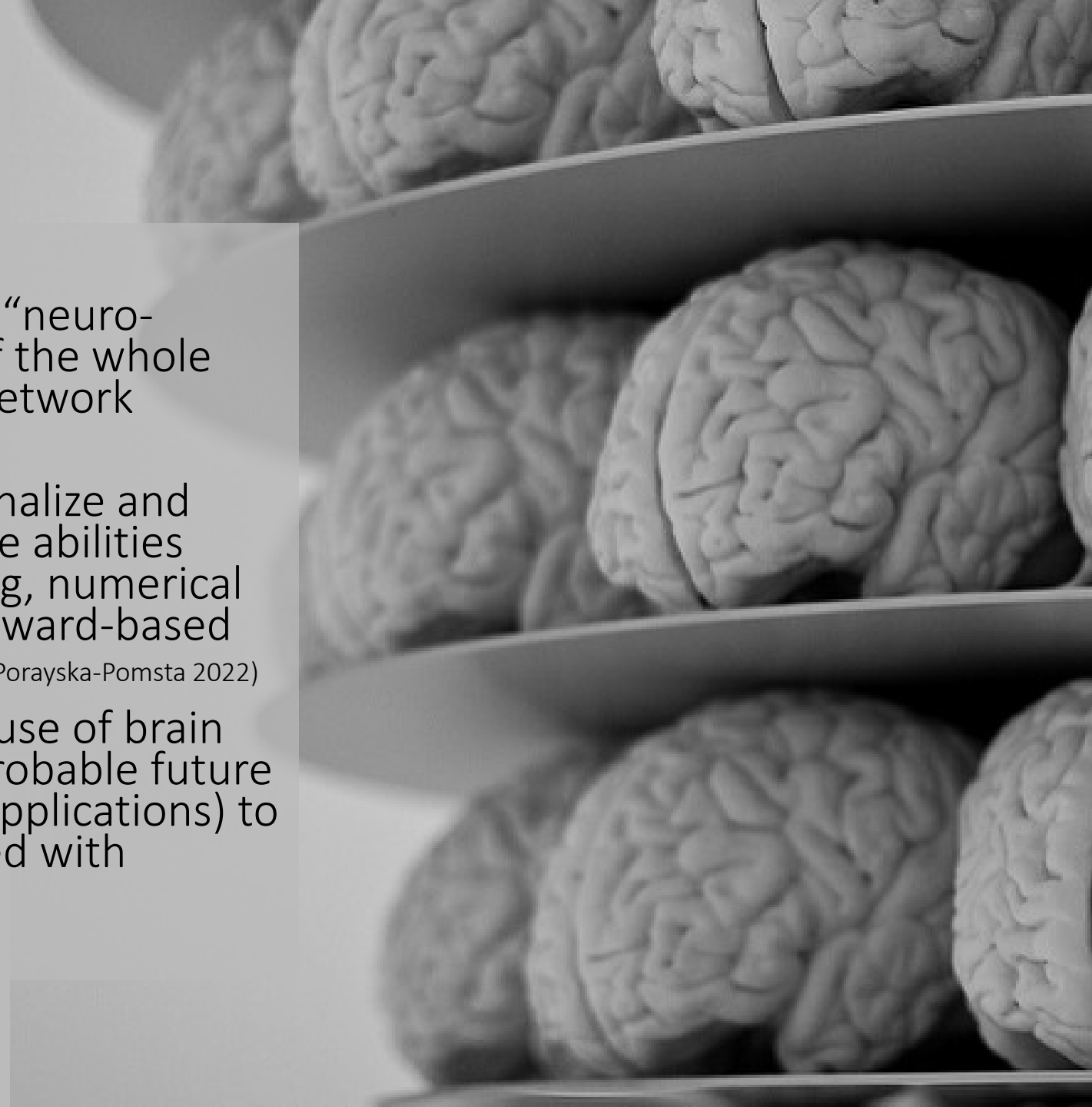
- Using EEG neuroimaging to study attention in real-world classroom settings to "predict children's learning success" and identify the "different attention brain mechanisms [that] underlie educational achievement" (Matusz 2022)
- "Neuro-adaptive learning" systems combining portable brain imaging to capture neurophysiological measures of attention with artificial intelligence technologies to deliver more engaging brain-personalised education

(Davidesco et al 2021)

- **Attentional neurogovernance**—pedagogic interventions deploying neurotechnologies to survey, adapt to and stimulate the learning brain for enhance engagement and attention

Neurocomputation

- “Connectomics,” “neural networks,” “neuro-simulations” and “brain mapping” of the whole learning brain with artificial neural network algorithms and (neuro)AI
- Artificial neural networks informationalize and model “education-relevant” cognitive abilities including the development of reading, numerical cognition, executive function, and reward-based behaviours (Thomas and Porayska-Pomsta 2022)
- **Probabilistic neurogovernance**—the use of brain models and simulations to predict probable future brain wiring and intervene (with AI applications) to improve brain organization associated with academic achievement



2 Neuro-policy translation

- Educational neuroscience has "advanced owing to the motivation among researchers to […] build direct bridges between pedagogy and what is known about brain structure and function from state-of-the-art technologies […], leading to the promise of visualizable, objective evidence-based recommendations for teaching and learning" (Choudhury and Wannyn 2022)

Education and the Brain: A Bridge Too Far

JOHN T. BRUER

Educational Researcher, Vol. 26, No. 8, pp. 4–16

Brain science fascinates teachers and educators, just as it fascinates all of us. When I speak to teachers about applications of cognitive science in the classroom, there is always a question or two about the right brain versus the left brain and the educational promise of brain-based curricula. I answer that these ideas have been around for a decade, are often based on misconceptions and overgeneralizations of what we know about the brain, and have little to offer to educators (Chipman, 1986). Educational applications of brain science may come eventually, but as of now neuroscience has little to offer teachers in terms of informing classroom practice. There is, however, a science of mind, cognitive science, that can serve as a basic science for the development of an applied science of learning and instruction. Practical, well-founded examples of putting cognitive science into practice already exist in numerous schools and classrooms. Teachers would be better off looking at these examples than at speculative applications of neuroscience.

The teachers' questions arise out of the perennial interest in the brain and neuroscience that has always existed at the margin of educational research and reform discussions. Recently, however, interest in how neuroscience might improve education has moved from the margins to center stage. Educators and education policy experts are the most vocal enthusiasts. Educational writers, likewise fascinated by the brain but puzzled by the mind, have picked up on this enthusiasm. Over the past year, there have been numerous books, journal articles, policy studies, and stories in the media about how our emerging understanding of brain development and neural function could revolutionize educational practice.[1] Neuroscientists, while interested in how their research might find application outside the laboratory and clinic, are more guarded in their claims. Often they are puzzled by the neuroscientific results educators choose to cite, by the interpretations educators give those results, and by the conclusions educators draw from them.

This article examines those results, interpretations, and conclusions—a set of claims that I will call the neuroscience and education argument. The negative conclusion is that the argument fails. The argument fails because its advocates are trying to build a bridge too far. Currently, we do not know enough about brain development and neural function to link that understanding directly, in any meaningful, defensible way to instruction and educational practice. We may never know enough to be able to do that. The positive conclusion is that there are two shorter bridges, already in place, that indirectly link brain function with educational practice. There is a well-established bridge, now nearly 50 years old, between education and cognitive psychology. There is a second bridge, only around 10 years old, between cognitive psychology and neuroscience. This newer bridge is allowing us to see how mental functions map onto brain structures. When neuroscience does begin to provide useful insights for educators about instruction and educational practice, those insights will be the result of extensive traffic over this second bridge. Cognitive psychology provides the only firm ground we have to anchor these bridges. It is the only way to go if we eventually want to move between education and the brain.

The Neuroscience and Education Argument

The neuroscience and education argument relies on and embellishes three important and reasonably well-established findings in developmental neurobiology. First, starting in infancy and continuing into later childhood, there is a dramatic increase in the number of synapses that connect neurons in the brain. This synaptic proliferation (synaptogenesis) is followed by a period of synaptic elimination. Second, there are experience-dependent critical periods in the development of sensory and motor systems. Third, in rats at least, complex, or enriched, environments cause new synapses to form.

The argument runs as follows. Starting in early infancy, there is a rapid increase in the number of synapses or neural connections in children's brains. Up to age 10, children's brains contain more synapses than at any other time in their lives. Early childhood experiences fine-tune the brain's synaptic connections. In a process that we might describe as synaptic pruning, childhood experiences reinforce and maintain synapses that are repeatedly used, but snip away the unused synapses. Thus, this time of high synaptic density and experiential fine-tuning is a critical period in a child's cognitive development. It is the time when the brain is particularly efficient in acquiring and learning a range of skills. During this critical period, children can benefit most from rich, stimulating learning environments. If, during this critical period, we deprive children of such environments, significant learning opportunities are lost forever. As one popular article put it, "with the right input at the right

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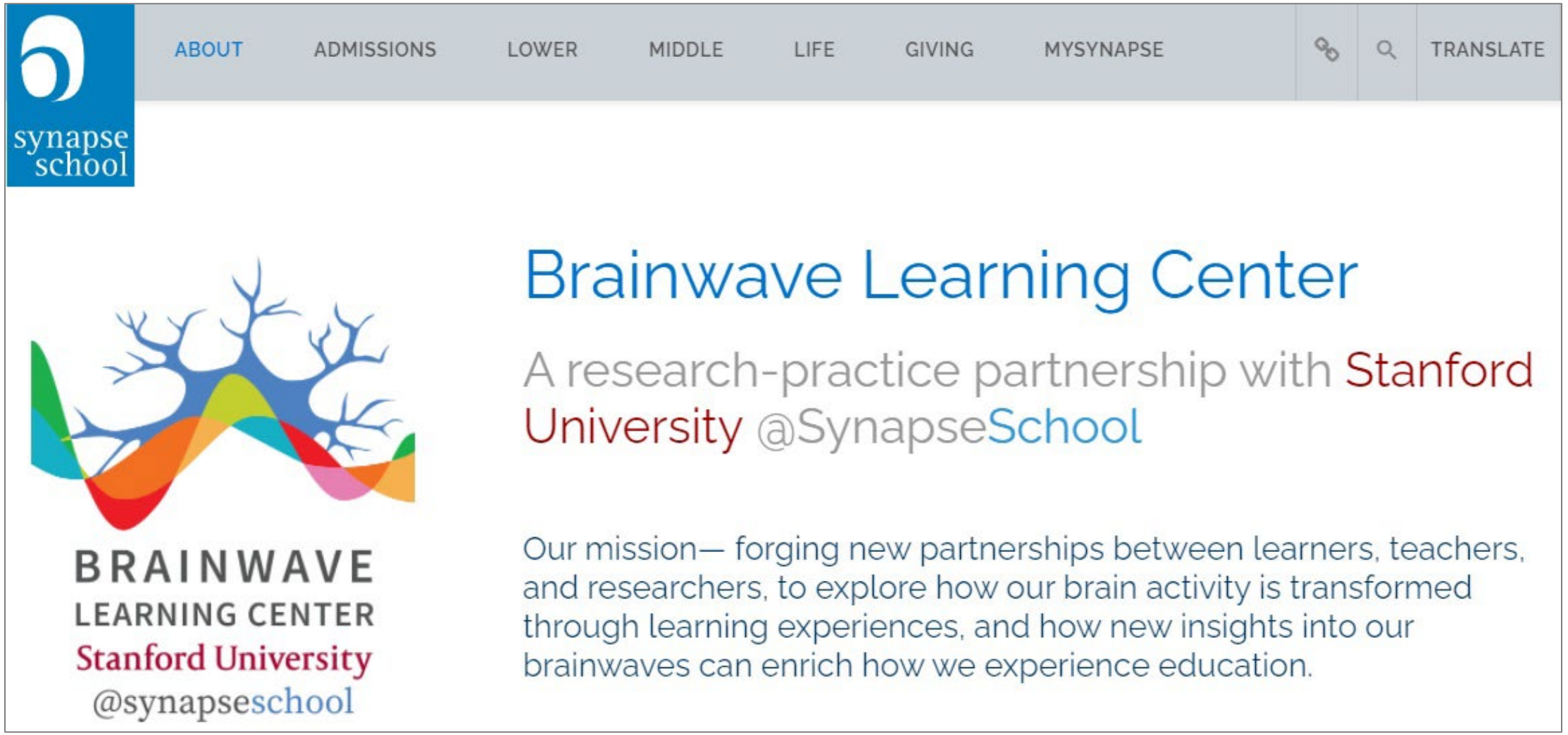
Coalition building

"Communicating research to support the evolution of teaching. Learnus is a community dedicated to bringing educators and those who specialize in the study of the brain, the mind and behaviour together in order to use the insights gained from high quality research to improve and enrich learning for all" (Learnus)

School partnerships



Commercialization

Policy influencing

"How can we bridge the gap between what science tells us about learning and what happens in classrooms every day? … Since 2016, the IBE has been working to close this gap. Through its science of learning knowledge brokerage initiative, it translates cutting-edge research into practical, credible knowledge that can inform policy, improve teaching, and enhance learning" (UNESCO IBE 2025)

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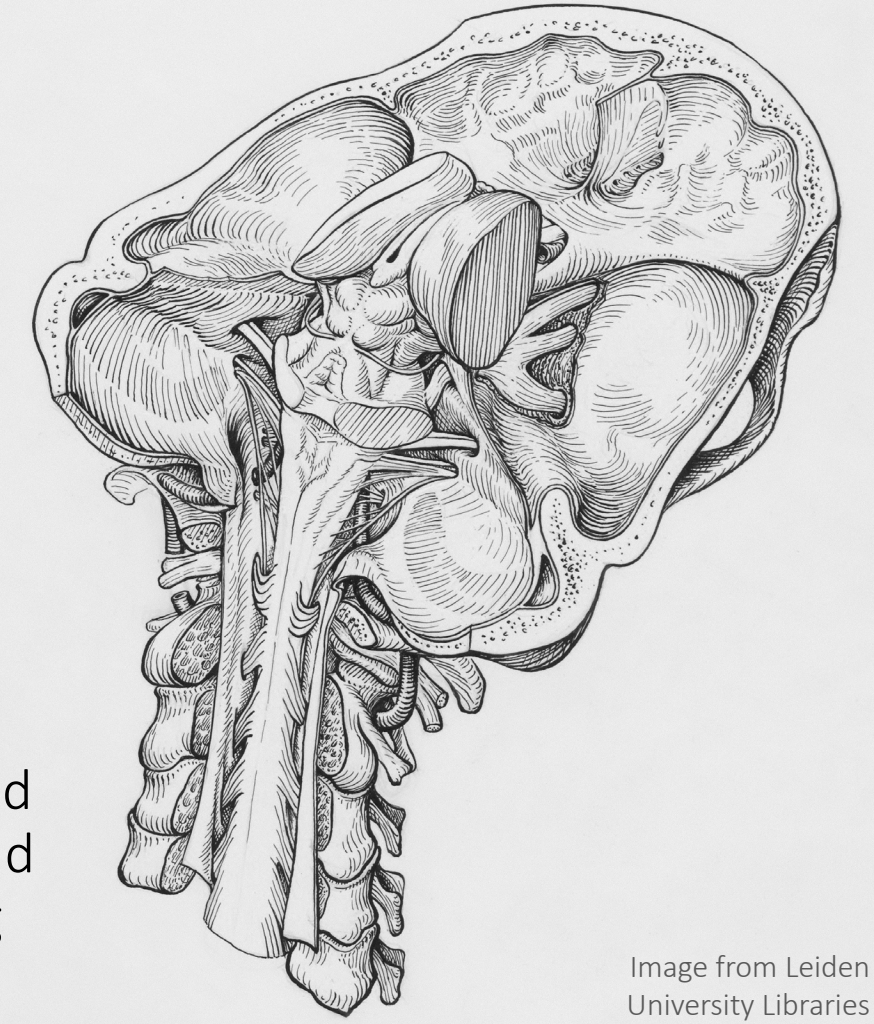
Conclusion

- Educational neuroscience constructs neuro-informationalized “brain facts” through investigative neurotechnology setups
- The “learning brain” has been translated into a digital object of knowledge and attention, propelled as the authoritative, objective, neurobiological basis for pedagogic interventions
- Neurotechnologies are promoted as translational technologies to “bridge the gap” to practice
- The learning brain has become an object of neurogovernance—a neurobiological resource to be managed, enhanced, optimized for purposes spanning pedagogic, commercial and governmental agendas
- How can we work to “bridge the gap” between social and neuro scientific understandings of neurotechnologies and their potential impact on educational research, teaching pedagogies, students and schooling systems?



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