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# Embodied cognition, digital cultures and sensorimotor debility.

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**Abstract**

This paper reflects on the qualities of life in digital cultures, the design of digital technologies and the philosophical history that has informed that design. The paper takes as its critical perspective the field of embodied cognition as it has developed over the last three decades, in concert with emerging neurophysiology and neurocognitive research. From this perspective the paper considers cognitive, neurological and physiological effects that are becoming noticed in user populations. This paper is informed by two decades of research into embodied cognition and its relationship with digital technologies and digital cultural practices - work that itself is grounded in two decades of R+D in technologies for embodied interaction.

## Keywords

Embodied cognition, enactive cognition, material engagement, cognitivism, computationalism, mind-body dualism, embodied interaction, digital cultures, skill, sensorimotor debility.

## Introduction

**A preamble on cognition and embodiment: Enactive, Embodied, Performative and Materially Engaged perspectives on the intelligences of (art)making.**

Through the second half of the C20th, discussions of the cognitive aspects of arts practices relied on an internalist/computationalist mode of explanation, which became more hegemonic as the new discipline of cognitive science accrued authority and power. This occurred largely due to the sympathies between cognitive science and paradigms of AI, itself propelled due to the rapid development of digital computing. Putnam's *functionalism* (later recanted) provided a philosophical argument that cognition was a matter of manipulation of symbolic tokens in an abstract (and, theoretically, immaterial) reasoning space, and was agnostic as to whether it was implemented in silicon or neural tissues.

In the late 1980s, the Common-Sense Problem hit the AI community with a force that could no longer be evaded. Thinkers such as Hubert Dreyfus, Lucy Suchman, John Searle, Stevan Harnad, Rodney Brooks, Francisco Varela, David Kirsh, Edwin Hutchins, Andy Clark, Philip Agre, Andy Pickering, Maxine Sheets Johnstone, Mark Johnson, Evan Thompson and others were showed that such explanations were deeply unsatisfying and inadequate, particularly in the case of practices with a substantial embodied component. This resulted in the emergence new paradigms of cognition that provided space for social and spatial dimensions of cognition, and began to blur the distinction between '*intelligence*' and '*skill*'. Seen from this perspective, that distinction is more of a dogmatic hierarchy than a cognitive reality.

These new paradigms include Situated, Embodied, Distributed, Enactive and Extended approaches. The related notion of Material Engagement was more recently added (Malafouris). Taken together, these paradigms provide the basis for the development of a new language with which to discuss the cognitive dimensions of intelligent practices in the world, that characterize human cultures. Such perspectives are, in my opinion, crucially relevant to understanding the cognitive complexity of arts practices, in the engagement with tools and materials, in movement within and with respect to spaces and objects, and in relation with social structures, traditions, rituals, and stories. Just as importantly, these perspectives help us understand ourselves as cognitively and biologically whole creatures, as opposed to creatures divided into minds and bodies.

## Computer culture

This paper draws upon a career-long engagement with the development of computer technology, especially in its cultural aspects, as well as a long-term concern with embodied cognition, and the relationship of both these with arts, design and making practices. I have been deeply involved in the cultural applications of computational technologies since the 1980s. As such I have observed the ongoing rapid development of digital and networked tools, more or less from the origins of the personal computer, and have been an attentive student of the diverse social and cultural changes that have ensued. This paper is informed also by personal experience as a college and university level teacher over 30 years. My path through technoculture has been unusual. My work in spatialised and embodied practices of sculpture, performance and installation led me to focus on the interactive and embodied aspects of digital technologies in the *performative idiom* (as Andy Pickering would say) and not in ongoing (re)production in the *representational idiom* - the creation and transmission of imagery and sound. In my opinion, such manifestations are more the-same-as than different from their predigital predecessors – video, tv, cinema, radio, audio recording, and the distribution of texts. From the outset, I felt that the *real* novelty in the new technologies lay in sensing and real-time computing. I still believe this. This orientation led me into a long critical analysis of computer culture vis a vis embodied practices, and it is from this perspective that I want now to focus my critique of contemporary digital technologies.

Lest this sounds like technological determinism, I hasten to add that I take William Gibson's observation that '*the street finds its own uses for things'* to be unquestionable. Moreover, many of the technologies we carry around today originated not in research labs of universities nor in development labs of corporations, but in the studios of artists and the garages of interdisciplinary mavericks. With all due respect to the discipline of Engineering and my many engineer friends, engineering is a discipline almost devoid of creativity, and we wouldn't have it any other way. I don't want anyone monkeying around with the wing of the aeroplane I'm on. The discipline of Engineering perfects ideas, it makes them safe and cheap and easy to manufacture, but it seldom takes the great innovative leaps we call creative.

The philosophical basis upon which digital culture has formed is - no surprise – inherently and deeply rationalist. It committed itself from the outset to the Cartesian mind/body dualism which was installed, axiomatically, in the very foundation of the discipline. This is evidenced by the unquestioned belief in the immateriality of information, reified in the fundamental distinction of *hardware and software*. The discipline's core formal ideas – Turing's universal machine, George Boole's mathematical logic, von Neumann's serial processing architecture, Newell and Simon's Physical Symbol System hypothesis and Putnam's functionalism – are all consistent with a body-denying unreconstructed humanist belief system – all of which continues to have negative and dangerous effects on the diverse aspects of human culture and particularly the arts. The insidious aspect of this *not* that these ideas have created a powerful technological landscape with specific affordances and specific constraints. The insidious aspect is that, as our *paradigmatic technology* (Bolter), this architecture been taken to be explanatory of our biological systems, from DNA to brain and all the rest. Let us take three aspects to unpack some of these ideas:

Von Neumann architecture: the input-processing-output conception of the Von Neumann architecture - the basic architecture of every computational device you've ever owned – is quite obviously borrowed from the industrial production line. Raw materials are assembled into information objects and output in packets! This architecture mirrors mechanistic theories of human cognition that separate and serialise sensing, mental processing and acting. This architecture makes sensing and acting 'peripheral' and assumes all the cognitive heavy lifting is in the processing – inescapably - of *symbols*. The problem is that this conception of cognition is simply wrong.

Boolean Algebra is the work of an eccentric Victorian country reverend who sought in mathematics a transcendental universal language. George Boole knew nothing of electronics or even electricity. His system of logical reasoning deals specifically with quasi-mathematical symbols, expunged of materiality and affect. It is absurd for us to imagine that this system of mathematical logic, when electronically automated, might have the potential to simulate the human mind or have immediate relevance and universal applicability to any and all aspects of our human biological and social lives.

Code. At the heart of the notion of modern computing is c*ode* - this writing in machine languages that organises generic and unformed computational matter as a specific machine - that breathes a kind of life-force into dumb minerals. As hardware/software is mind/body reified, so the privileging of *code is hylomorphic*. According to Aristotle, creative action is always preceded by idea - a preconceived idea is imposed on formless matter. Embracing computational analogies is to embrace dualistic hylomorphism as a native quality of the world, and as an accurate representation of human cognition. Any artist, any chef, any farmer, knows that the work emerges in the making, in a sensitive attention to process, in process. This is what Andy Pickering calls the *Dance of Agency*. The privileging of code is the privileging of the immaterial symbolic over the embodied and enacted.[1]

Students of the history of technology, especially the industrial revolution, will be familiar with the idea that social and legal mechanisms lag years or decades behind new technologies. According to Hakim Bey, in the early days of any technology, there is a *Temporary Autonomous Zone (*TAZ). A technology has to become well established, before suggestions of troubles are recognized (usually dismissed as spurious or anti-social by vested interests), the tests and measurements are made, activism and lobbying by the most egregiously effected changes public opinion, before laws are passed and regulations are enforced. For instance, there is not, anywhere yet (as far as I'm aware, and certainly not in the USA), a legal structure that has mechanisms for

[1] To pursue similar ideas at a more abstract level, it is worth noting the emphasis in (some) computational discourses on objects (object-oriented ontologies etc) just at a time when in other quarters there is increasing interest in relational and processual ontologies. This seems ironic - computing is nothing if not processual.

interrogating working AI systems and collecting evidence from them. They simply do not exist as entities in the law.

As digital cultures have elaborated and insinuated into diverse aspects of human cultures (particularly in richer nations, but proliferating into the 'developing world' in TAZy, William-Gibsony ways) effects unpredicted (or predicted but unheeded) have occurred. As Philip Agre would observe, in a discipline inclined to reflexivity, these irruptions of technical problems might be taken as *indicators* (in a Foucauldian sense) of *problems in principle*. But the world of digital technologies is not such a place. That world has quickly become an alliance between a community following a technological agenda rooted in a faulty philosophical ground, and a community who recognizes the opportunity for the accumulation of unimagined wealth - and is (still) laughing all the way to the bank.

So it is that, in 2019, roughly 35 years since the introduction of the personal computer, 25 years since the emergence of the world wide web, and 15 years since the emergence of mobile computing on handheld devices, we are coming to understand some subtle and insidious aspects of the technology (or more accurately, emerging technosocial formations) – that span political, economic, social, and personal dimensions. We encounter new problems - physiological, psychological, social and political: from the development of new kinds of adolescent neuroses (*The stressed years of our lives*) to the destabilisation of the political system of a powerful nation by a small nation, without firing a shot. The *ecstasy of communication* (Baudrillard) has become the agony of communication. TAZ is everywhere. From the '*dark satanic mills'* of the industrial revolution to the 'pollution' of the 1970s to seabirds and whales with bellies full of plastic, the TAZ - the anarchic openess of the technological moment - is morally agnostic. The TAZ may be exploited by activists and hackers, or it may be exploited by terrorists, rogue states or corporate interests.

Corporations are always keen to show us the advantages that their products offer, and no doubt, they have wonderful qualities: we enjoy access to, and sharing of, information of all kinds, opportunities to create communities of niche interests, location of obscure artifacts and commodities, and the rest. Yet it must also be noted that like any vast, wealthy and powerful enterprise, this new technopolitical establishment will be slow to recognize or admit culpability that may negatively impact their reputation or bottom line. These industries have the capacity to hire the smartest people, and they understand well the ways to render 'dangerous' results dubious and to buy off potentially critical institutions with gifts. So it is that Monsanto has endowed agriculture research centers in every major land grant university in the USA. The tobacco industry wrote the playbook that the petroleum industry, the sugar industry, the agrochemical and pharmaceutical industries and technology giants now follow (*Merchants of Doubt*). And 'fellow travelers' - in this case states and educational institutions - once invested, will be slovenly in recognising unexpected deficits.

Given all this, any attentive student of technopolitical history will be unsurprised when:

1. Negative effects of new technologies show up
2. Innocent people, communities and environments are negatively impacted.
3. These impacts are suppressed, denied or otherwise made dubious by vested interests.

I believe we are seeing such impacts, especially among the *born digital generation*. And they span the gamut: physiological, psychological and social, economic and political.

## Skill and intelligence

This may sound like a trivial thing to say, but skilled making involves the combination of bodily precision and application of calibrated muscular force. For the entirety of human history, from paleolithic flint knapping to blacksmithing to the making of swiss watches, to chopping a tree with an axe, sailing a boat, shaping a pot on the wheel or playing a violin - *human culture has been defined and made glorious by skilled activities that involve the combination of judgement with commensurate bodily force.*

Much has been made of Heidegger's notion of 'ready to hand'. What is often absent from that discussion is a recognition that 'ready to hand' implies the integration of an intact tool with a well-practiced bodily knowledge. 'Ready to hand' is not so much a quality of the tool but a quality of the user's training. A tool cannot be 'ready to hand' without a complementary *corpus* of bodily knowledge specific to that kind of tool, the context such a tool is used in, and the behavior of the materials worked with it. Due largely to the harnessing of fossil fuels, in the industrial period, the role of human muscle power was reconfigured. But it still took muscular precision to control the steam engines, locomotives, and the heavy and light machinery of mines and mills that functioned, effectively, as *force amplifiers* (a term taken up by the US military mid C20th).

Through the C20th, as electricity infrastructure proliferated (in more wealthy, industrialised countries) the idea of *labor-saving devices* animated the design and production of commodities, from vacuum cleaners and washing machines to power steering. This trend has proceeded with little in the way of checks and balances, the reduction of physical effort being seen as an unquestionable good. This results in absurd behaviors many of us engage in: using the money we earn at our labor-saving jobs (that sicken us with their reduction of effort) in order to pay for specialized therapy involving peculiar machinery in specialized locations. This therapy is designed to burn off the calories that petro-chemical driven agribusiness has provided us, while doing no productive work. This, in the face of the fact that human work is *by definition*, sustainable. Humans convert conveniently available low-grade energy sources (plant material) into physical power in a highly efficient way. Try feeding a bunch of kale to your iPhone or your Tesla.

In 'postindustrial' nations, physical labor has been reduced to the bare minimum - the swiping of touchscreens and tapping of keyboards, a kind of work in which both sensorimotor precision and physical effort have been actively designed out (as has cognitive effort, such as using mental arithmetic to calculate the amount of change required in a purchase). We call this insidious trend *user friendly* and *intuitive*. Do we look forward to the day that we can float in a bath of blood-temperature saline solution, driving computational events with eye movements, or do we dream of *direct neural jacks*? What a liberation that would be! A brain in a vat! To be finally free of the inconvenience of our bodies! This narrative is deeply embedded in western judeo-christian culture, from medieval mortification of the flesh to modern extropians.

In my opinion, we have fallen into a dangerous trend of deskilling and dumbing-down. Some will object that the new tools have brought with them new kinds of sensorimotor skilling. I do not contest this, but see below. This dumbing down is rooted in a fundamental humanist assumption - as fallacious as it is fundamental - that there is a distinction between mind work and body work. But: *the idea of a separation between mind and body is ideological, counterfactual and without any scientific basis. The corollary to this argument is that the skill/intelligence binary is also false.* The intelligence/skill dual is the mind/body dual. This artificial separation is destructive of defining qualities of what it is to be a successful human. The hardware/software dual also is the mind/body dual. All of them are of the order of axiomatic assumptions and all are scientifically dubious.

As Gilbert Ryle reminds us, Descartes got into philosophical hot water with his *res cogitans/res extensa* dual, partly because there are clearly aspects of living that bridge or mix the two and are thus neither one nor the other: how does a physical experience, like feeling the heat of a flame, become a thought? How does the thought of a word become speech? John Haugeland, in his wonderful essay *Mind Embodied and Embedded*, finds no 'interface' (in a systems-theoretic sense) between mind and world. In this spirit, I argue that there is no principled separation between skill (in the sense of sensorimotor capability) and intelligence.

Socio-politically, this purported separation has served to ensure that the MBA in the corner office gets paid ten times what the machinists in the basement get. In short, it is a classist blue collar vs white collar scenario. It daily reinforces the denigration of the intellectual value of artisanal practice with respect to those who only poke keyboards. (This should concern us here directly). Sadly, this tendency is perpetuated par-excellence in the academy – the academy being the temple in which abstract symbolic knowledge is worshipped. Thus another unfortunate alliance has emerged between the academic culture of abstract knowledge (and the abstraction of knowledge) and the machine that knows nothing but symbols (of which more below).

## In(tro)ducing sensorimotor debility

Along with the well-publicized range of advantages of digital technologies that we all take pleasure and profit in, and that hardware, software and internet companies take pride in publicizing, there is also emerging an increasingly long litany of social, physiological, and cognitive deficits that receive limited attention, for obvious commercial reasons. Many of these can seem trivial (or are represented that way by the same vested interests), but taken together, they indicate a disquieting trend. Here I focus on what I call *Sensorimotor Debilities*, as opposed to social, psychological and political implications. (In this discussion, I draw upon Jasbir Puar's elaboration of the idea of 'debility' to develop a theorization of sensorimotor debility of the 'born digital'.)

Clinical and anecdotal evidence point to a rapid decline in a variety of key physiological markers of bodily competence - from visual acuity to manual dexterity - among young adults over the last 15-20 years. This time period corresponds with the emergence of the born-digital generation: children who have been 'weaned' with digital touch screens. A substantial reconfiguration of cognitive and sensori-motor capabilities is occurring in communities where screen-based technologies are ubiquitous, especially, for obvious developmental reasons, where infants and children are overexposed. Some of this is trivial and some is, I believe, substantial, negative and problematic.

This crisis of sensorimotor competence, according to my analysis, has been caused by the convergence of three historical forces:

1. The long-standing Enlightenment-humanist privileging of reason and of abstraction;
2. a technology of abstract symbol manipulation that has become broadly influential; and
3. a neoliberal educational agenda that slashes 'soft' or 'applied' aspects of learning, because they are expensive, under a smokescreen of the valorization of STEM (Science, Technology, Engineering and Mathematics).

This scenario should be of immediate concern to artists, artisans, craftspeople, and makers of all kinds, as well as to educators and proprietors of educational institutions, not simply because refined and complex sensorimotor capabilities are demonstrably positive qualities for humans to have, but because, according to contemporary theories of cognition, capabilities traditionally understood as 'mental' are taken to be based in bodily experience.

## Developmental psychophysiology

It is a bald historical fact is that thirty years ago, and for the entire prior history of the human race - except in rarefied laboratory contexts - screen-based interactivity simply did not exist (and there only sixty years). It's probably not necessary (in this community) to remind ourselves of the growing evidence of social and cognitive deficits induced by digital technologies, especially when overused in early childhood. Anyone with a basic grounding in developmental psychology, or anyone who has a child, understands the hard and extensive work an infant does in order to integrate their senses and their physiology and to understand the world of space and mass and light and gravity. As we know from the famous *kittens in baskets* experiment of Hein and Held, an infant remains functionally blind unless - at a critical time in neural development - it calibrates its visual system through bodily movement. Proprioception and kinesthesia are the source for knowing ourselves and the world, and these senses bring vision and hearing 'into focus'.

The kinds of hands-on making and play that were more or less the entirety of childhood experience in the past have been substantially replaced by screen-based activities. An assessment of the general impact of this is overdue. If you'll pardon the scatological pun, the *interfaeces* are hitting the fan. As long ago as the mid 1990s, German insurance companies were running free summer camps for kids so they could scrape their knees, fall off bicycles and burn their fingers in candle flames. Why? In their overmediated lives, these children had not learned the true consequences of accidents, and it was costing the insurance companies money. So much money that it was a cost saving to offer free summer camps.

In a recent article in the Guardian entitled "*Medical students raised on screens lack skills for surgery"*, Roger Kneebone, a professor of surgical education at Imperial College London, lamented that his students often do not have a basic understanding of the physical world. He insightfully notes: "*We are talking about the ability to do things with your hands, with tools, cutting things out and putting things together … which is really important in order to do the right thing either with operations, or with experiments. You need to understand how hard you can pull things before you do damage to them or how quickly you can do things with them before they change in some way."[1]*

A recent study shows that childhood and adolescent myopia rates have risen alarmingly in the last 15-20 years. "*Another remarkable change shown by our survey was that the proportion of high myopia (7.9% to 16.6%), especially very high myopia (0.08% to 0.92%) significantly increased during a 15-year period*." The authors continue: "*The etiology of myopia still remains unclear. However, genetic and environmental factors are widely believed to play an important role. Near work is one of the important environmental factors."[2]*

The impact of these changes, and the specificity of the time period, is not lost on public health personnel. And it stands to reason. If visual, neuro-optical and visuomotor capabilities are developed through active practice in childhood, and if a child's visual focus is largely on a flat perpendicular illuminated surface 40 cm from their face; then clearly, visual capacities that involve focusing on the horizon, rapidly changing focal distance, rapidly changing location of visual attention in the visual field, or attending to events in peripheral vision, or in low or high light conditions - simply will not develop. If manual activities are reduced to slapping a screen or poking a button, all manner of sensorimotor acuities and capabilities will fail to develop. Moreover, understandings of materiality and fundamental physics will be absent or erroneous.

## The Right to Maim

In her recent book *The Right to Maim*, Jasibir Puar observed that "*Debility is thus a crucial complication of the neoliberal transit of Disability rights."[3]* She explains her use of the term: "*Debility addresses injury and bodily exclusion that are endemic rather than epidemic or exceptional, and reflects a need for rethinking overarching structures of working, schooling, and living rather than relying on rights frames to provide accommodationist solutions*." [ibid p2] She goes on to observe: "*Technological platforms—new media, prosthetic technologies, biomedical enhancements—mediate bodily comportments, affects, and what is recognized as bodily capacity and bodily debility. Technology acts both as a machine of debility and capacity and as portals of affective openings and closures*." [ibid p3] Without trivializing her important work, I think it is not inappropriate to borrow her terminology to describe my current subject. She goes on, pointedly to assert "*Capacity and debility are, on the one hand, seeming opposites generated by increasingly demanding neoliberal formulations of health, agency, and choice—what I call a liberal eugenics of lifestyle programming—that produce, along with biotechnologies and bioinformatics, population aggregates*." She asks "*Which bodies are made to pay for "progress"?"* [ibid p13] and appropriately, she puts 'progress' in quotes. It is entirely pertinent for us to consider the bodies that pay for that 'progress', in what ways those bodies pay, and who profits. These bodies include factory workers in Shenzen, Amazon warehouse staff, and students in schools.

## Post-corporeal pedagogy and practice.

It is incumbent on this community, I believe, to consider the ramifications of this new, general condition of sensorimotor debility – for the arts, for pedagogy, for cognition, and for the general ability to succeed in the world. Some may argue that skills of map reading, like mental arithmetic, are just redundant in our technological context. Clearly as we adapt to new technologies, our capabilities and skills change. But there is a fine and obscure line to be drawn between technology-specific skills - like using an abacus or a slide rule or read a clock face - and the loss of cognitively fundamental understandings which undergird not simply bodily skills but our ability to form intuitions and utilise concepts and metaphors. Where does this sensorimotor disability come from? In my opinion the cause is an unfortunate combination of two trends:

- the general phenomenon of the digital, and in particular the overexposure of children, from a young age, to touch screens, graphical interfaces and the false physics of animation and games.
- The neo-liberal rationalization of schooling, focusing on STEM learning, and the increasingly academic and abstract tone of education in general and the concomitant elimination of art and vocational classes and facilities (woodshop, art classes, sewing, cooking, etc)

This combination has created a generation for whom the minimising of lived experience of material engagement has resulted in shortcomings in embodied cognition and basic 'common sense'. Sensorimotor competence has traditionally been taken for granted in pedagogical planning as part of the formation of students. In the academy, numerical and text-based scholarship continues to be the focus. Such activities assume embodied competence and leverage concepts and intuitions that, traditionally, have come as part of the student package. Today these abilities are measurably less often present, but curriculum designers appear not to have noticed. (It is worth noting that professionals 'in the know' in places like Silicon Valley, are increasingly sending their kids to screen-free schools and encouraging diverse embodied activities). There is a deep irony to the fact that it was precisely a shortage of this kind of 'common sense' that caused first generation symbolic AI to come crashing down in the late 1980s (amid phenomenologically inflected critiques by Hubert Dreyfus, Stevan Harnad, Lucy Suchman, Terry Winnograd and others.)

In my experience of teaching sensorimotor skill-based practices for 30 years, this change is glaring. While I have no hard data, it is my firm conviction that over this period, student's general familiarity with manipulating matter has declined precipitously. This is consistent with the observation of Roger Kneebone and other specialists in diverse fields. In the last four years, I have personally mentored over 60 students from my university in hands-on building projects. Most of these students are from the school of engineering and most in mechanical engineering. This work involves diverse materials and tools, simple design and precise measurement. I have often been alarmed by a lack of familiarity with procedures involving hand tools and basic materials. To these students, simple procedures like marking divisions along a straight line using a ruler, using a plumb line to establish verticality or a compass to draw a circular arc, seem arcane or incomprehensible.

These students are quite unfamiliar with activities in which precise movement and application of carefully judged force occur simultaneously (like holding a screwdriver forcefully against the head of a screw while applying a rotating force to the tool and thus the screw). This kind of skill is ubiquitous in making, yet the majority of these students appear unfamiliar with this general capacity for effective action in the world. While compasses and calipers and scales, mallets and chisels and handsaws seem quaintly old fashioned to these students, there is a deeper and more troubling issue of significance to general cognitive capability. In addition to pragmatic skills, embodied experience not only provides the basis for a common-sense understanding of materials and terrestrial physics that informs design decision making (for instance, in the construction of bridge), but embodied experience provides a major source for metaphors and concepts applied in more abstract thinking. (Johnson, Lakoff, Lakoff and Johnson, Lakoff and Gallese, et al).

This a lack of experience in embodied artisanal practices (broadly conceived), combined with overexposure to digital tools that are designed to preclude the necessity for fine neuromuscular judgement (in the interests of being 'user friendly' and 'intuitive') is generating sensorimotor debility. (As a corollary, I have noted that students who have some native sensitivity to tasks involving sensorimotor judgement and force often have training in traditional musicianship (playing guitar, violin or piano etc) where an understanding of how to modulate manual force is critical.)

## A perfect storm

Most of us appreciate the convenience of navigation with Google maps or shopping on Amazon. These applications are popular because they make complex tasks simpler, they deliver a success experience, and that's why we like them. By the logic of the market, this is why they survive and are profitable, while apps with clunky interfaces rapidly go extinct. Pedagogical software - being largely marketed by companies operating in similar commercial contexts to other consumer software development – is designed according to the same logic. Software is conceived around the premise that the 'customer' - in this case students - *expect* a success experience, and if it is to be economically successful, the software will deliver it. There appears to have been little consideration of whether such rationalisations are appropriate in 'educational' software. Education is by definition - and should be - inherently difficult. The process of failing, recognizing the reason for failure, then repeating the action and achieving success is fundamental to learning. In order to remain commercially profitable, pedagogical software continually delivers a success experience. This can't be good, personally, professionally, for educational institutions or for society and economy at large.

The exigencies of neoliberal education often call for constraint of context in order to deliver the 'lesson' defined by the syllabus with surgical precision, unencumbered by tedious setup processes. As such, fundamental aspects of acting in the world are abstracted away. For instance, in an engineering design package like Solidworks, an environment of perfect Euclidean geometry is simply given. Planes are perfectly flat, infinitely thin and precisely perpendicular.

Dimensions and angles are automatically available. It is not necessary to know how to make measurements! This is more than simply deskilling, it gives students a falsely inflated sense of their own ability. A related way that these packages deliver a success experience is by making automatic fixes to user errors, hidden 'behind the scene' or in this case, behind the GUI. Taking the map for the territory (Borges) is a fundamental danger here. *Any software simulation is a model, and a model is by definition a simplification and a rule-based abstraction*. Students become adept at manipulating these abstracted environments, but there remain questions regarding the transferability of these skills of abstract manipulation to the real world. Here neoliberal education policy duplicates the phenomenon of the 'toy problem' that was the stock in trade of first-generation AI research. According to Brooks, Agre and others, the use of highly constrained environments in which to test systems not ready for real world applications was seen as a contributing factor in the demise of those methods.

## Conclusion

In Western cultures, the notion that there is a distinction between mind work and body work is deeply entrenched, philosophically rooted in the Cartesian mind/body dualism. The skill/intelligence distinction is a corollary and is similarly *axiomatic* and ideological. The (false) distinction between skill and intelligence has directed the development of technologies (and specifically technologies that are deemed 'cognitive'), along paths that seek to minimize bodily engagement, dexterity, and physical effort. The rise of 'information technologies' – themselves rooted in dualistic notions – has compounded the problem.

The long-standing Enlightenment-humanist privileging of reason and of abstraction, combined with the emergence of a technology of abstract symbol manipulation, and a neoliberal educational agenda that slashes 'soft' or 'applied' aspects of learning (because they are expensive), under the smokescreen of valorizing STEM when they are actually valorizing abstract symbol manipulation, have created a perfect storm for sensorimotor competence.

This scenario should be of immediate concern to artists, artisans, craftspeople, and makers of all kinds, as well as to educators and proprietors of educational institutions, not simply because hand-eye coordination and refined sensorimotor capabilities are demonstrably positive qualities for humans to have, but because, according to contemporary theories of cognition, capabilities traditionally understood as 'mental' are understood to be based in bodily experience. There is an urgent need to examine and critique computer tools and software interfaces in terms of their sensorimotor qualities.

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