# Artificial intelligence in clinical practice: Implications for physiotherapy education

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**Abstract**
About 200 years ago the invention of the steam engine triggered a wave of unprecedented development and growth in human social and economic systems, whereby human labour was either augmented or completely supplanted by machines. The recent emergence of artificially intelligent machines has seen human cognitive capacity enhanced by computational agents that are able to recognise previously hidden patterns within massive data sets. The characteristics of this technological advance are already influencing all aspects of society, creating the conditions for disruption to our social, economic, education, health, legal and moral systems, and which may have a more significant impact on human progress than did the steam engine. As this emerging technology becomes increasingly embedded within devices and systems, the fundamental nature of clinical practice will evolve, resulting in a healthcare system that may require concomitant changes to health professions education. Clinicians in the near future will find themselves working with information networks on a scale well beyond the capacity of human beings to grasp, thereby necessitating the use of artificial intelligence (AI) to analyse and interpret the complex interactions of data, patients and the newly-constituted care teams that will emerge. This paper describes some of the possible influences of AI-based technologies on physiotherapy practice, and the subsequent ways in which physiotherapy education will need to change in order to graduate professionals who are fit for practice in a 21st-century health system.

**Keywords**: artificial intelligence, health professions education, physiotherapy education


## Introduction

For thousands of years the trajectory of human progress showed only a gradual increase over time with very little change in the material aspects of ordinary people's lives over the course of successive generations (Morris, 2011). But about 200 years ago there was a sharp increase in human social and economic development, which saw the curve of population growth and productivity veer sharply in an almost vertical direction (ibid.).

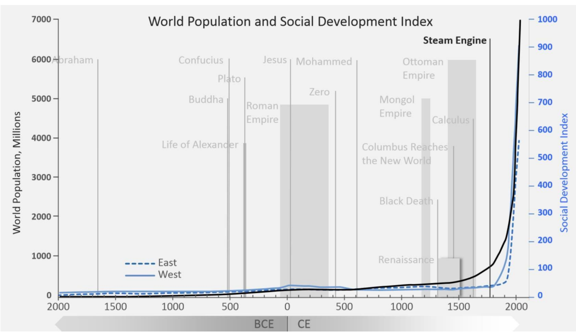

Figure 1: World population and social development index (Morris, 2011). *Click on image to enlarge.*

The invention of the steam engine started the Industrial Revolution and brought with it a range of technological advancements that enabled human beings to generate enormous quantities of energy, removing the biological bottleneck that limited the amount of work that could be performed by human and animal labour. The introduction of machine power significantly increased our capacity to shape our physical environment and created the conditions for the mass production of material goods, improving the quality of life across all levels of society (Brynjolfsson & McAfee, 2014). As the steam engine enhanced our ability to do physical work, the rise of computing machines will create the conditions for cognitive enhancement that will enhance our capacity for intellectual work. We are currently at an inflection point beyond which we will see human cognition first augmented, and then surpassed, by artificially created intelligence, leading to a transformation of our social and economic conditions that will be no less profound than those that were introduced by the steam engine (ibid.).

## Artificial intelligence

To understand more clearly what is meant by artificial intelligence (AI), it may be useful to consider what we mean by intelligence and by extension, what we do not mean. Intelligence is a general mental ability that involves reasoning, planning, problem solving, abstract thinking, comprehending

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complex ideas, and learning from experience. It also reflects a broad and deep capacity for understanding our environment (Gottfredson, 1997). This definition of intelligence says nothing about self-awareness, consciousness, emotion or morality, nor that there is anything essentially human about intelligent behaviour. In addition, there is nothing in this definition of intelligence suggesting that non-human intelligent behaviour should replicate human thinking processes. Indeed, "there are lots of ways of being smart that aren't smart like us" (Winston, 1992). Today, AI is a cross-disciplinary field of research that attempts to understand, model and replicate intelligence and cognitive processes by invoking computational, mathematical, logical, mechanical and biological principles and devices (Frankish & Ramsey, 2017). More specifically, it is the study of the synthesis and analysis of computational agents that exhibit intelligent behaviour (Poole & Mackworth, 2010). In the field of AI research, an intelligent agent is something that acts in an environment where those actions are appropriate for its circumstances and its goals. In other words, the agent is able to adapt to changing environments and changing goals, learn from experience, and make appropriate choices given its perceptual and computational limitations (ibid.).

The modern field of *artificial intelligence* research was born in 1956 at the Dartmouth Workshop where the term was coined and was initially conceived as a project that might take a few decades to conclude (Frankish & Ramsay, 2014). However, until recently progress in AI research has not lived up to the enthusiastic predictions of its initial supporters. This was particularly true with respect to the claims made by pioneers in AI research around the development of artificial general intelligence. For example, "...machines will be capable, within twenty years, of doing any work that a man can do" (Simon, 1965) and "In...3 to 8 years, we will have a machine with the general intelligence of an average human being" (Minsky, 1970), have turned out to be completely wrong. While we are still not much closer to a generally intelligent machine, there are three main characteristics of modern AI research that demonstrate how and why the development of AI-based systems has seen significant growth over the past ten years (Susskind & Susskind, 2015).

The first is the ubiquity of cheap computation. The second is the availability of massive data sets that are necessary for machine learning algorithms to be trained on. The third is the development of improved programming techniques and more sophisticated algorithms (Brynjolfsson & McAfee, 2014). The combination of these three characteristics have led to an increase in the ability of AI-based algorithms to reach conclusions in uncertain contexts that, in many ways, outperform what is possible by human beings. In addition, it is not only the computational power of machines that is noteworthy but the increased power and sensitivity of the associated hardware that makes the AI of today qualitatively different than what was possible in the past. Better and cheaper sensors, fast networks, smaller gyroscopes, and the global positioning system (GPS) enable AI-based systems to perceive their physical environment, locate themselves on earth, connect to and establish relationships with other connected devices, and understand their own position in space. AI-based technologies are not only smarter than they were even five years ago but are embodied and able to move and learn in the real world. Intelligent machines are therefore no longer constrained to solving theoretical problems in academic research labs but are doing real work in the real world.

Today, AI-based research has led to the use of expert systems that guide clinical decision-making, computer vision algorithms that outperform human beings in the analysis of CT and MRI scans, better diagnostics and prediction of patient outcomes, and enhanced administration and planning in health systems (Harwich & Laycock, 2018). In addition, AI research is achieving important advances in the areas of information retrieval and retention, problem-solving and reasoning, image recognition, planning, and physical manipulation (Frankish & Ramsey, 2017). It is worth noting that, broadly speaking, these are also core aspects of physiotherapy practice. It seems reasonable to suggest therefore, that much of physiotherapy practice may become increasingly vulnerable to automation by AI-based systems. The aim of this paper is to explore the potential impact of AI-based technologies in clinical practice and the subsequent ways in which physiotherapy education might change in order to graduate professionals who are fit for practice in a 21st century health system.

## Artificial intelligence in clinical practice

Health and education systems are increasingly recognised as complex adaptive systems, characterised by high levels of uncertainty and constant change as a result of rich, non-linear interactions that cannot all be tracked (Fraser & Greenhalgh, 2001); Bleakley, 2010). This means that complex systems are inherently ambiguous and uncertain and that they lack predictable outcomes or clear boundaries. Over time these systems become more complex, making it difficult - or impossible - for individuals or even single disciplines to work effectively within them (Frenk, et al., 2010). The emergence of AI-based technologies will play an essential role in augmenting our cognitive capacities so that we are able to function effectively in increasingly complex systems. However, there are some important ways in which this will require future health professionals to change some of our more fundamental concepts around clinical practice (Wartman & Combs, 2017).

Firstly, patient management will be based on the interpretation of massive aggregates of data that are collected from multiple sources and applications, many of which will be patient-controlled. We can already see this with wearable - and soon, ingestible - technology that moves with patients providing a continuous flow of information on a wide variety of health-related metrics at a scale that health professionals have never had to work with before (Susskind & Susskind, 2015). The exponential growth of these interconnected medical devices continuously generate a volume of data that simply cannot be analysed, interpreted, or even understood by human beings alone as they exceed the capacity of our cognitive ability (Obermeyer & Lee, 2017; Wartman & Combs, 2017; Claiborne, 2018). Clinicians will therefore need to incorporate AI-enhanced analysis of large patient data sets into their clinical decision making, where the data resides in multiple locations and across a variety of service providers, all interacting in ways that are too complex for individuals to track, or for single disciplines to manage.

Following from this, a second characteristic of 21st century health systems is that care will be provided by newly-constituted care teams where patients interact with providers across a wide range of professions, some of which are themselves only beginning to emerge. For example, patients may work directly with data scientists who will help them analyse and interpret the enormous amounts of personal and health-related data that they gather themselves (Topol, 2015). Thus, the role of the patient will change as they become true participants in clinical decision-making, possibly even becoming team-leaders as they delegate responsibility for various aspects of their care to different providers, as and when *they* deem it is necessary. Thus, the nature of the professional role may need to be re-evaluated as specialised knowledge becomes increasingly available outside of the disciplines. This will lead to decision-making that is distributed across different providers and services, some human and some machine, with the patient in control (Topol, 2015; Susskind & Susskind, 2017).

Finally, these interactions will take place in both physical and digital environments and will therefore be distributed in both time and space. As clinical encounters move into digital and online spaces, the vast number of interactions between patients, their data, and distributed care teams will need to be mediated by AI-based systems that manage and plan interactions based on the patient's self-identified goals. Professional scopes of practice may need to be revised as certain cognitive and physical tasks, previously the explicit domain of discipline-based professionals, become distributed between diverse care providers with differing levels of expertise. In these new health care teams clinicians will need to learn how to fluidly pass control of patient care between themselves, other team members (which may include data scientists and software developers, for example) and smart machines (Wartman & Combs, 2017). Success will increasingly be premised on a teams' ability to recognise the collective intelligence of the system or network, rather than privileging the expertise of an individual or single profession.

It seems clear that 21st century healthcare will be characterised by a move from producing information, to analysing and interpreting it on a massive scale and across distributed platforms. Clinical practice will therefore be enacted in data-rich systems where information flows will include high volumes of data that are generated from multiple sources of differing quality and validity (Wartman & Combs, 2017). It is in this context that the clinician will need to learn how to position themselves as they work alongside intelligent machines, not only because AI will augment our physical and cognitive abilities but because it will soon be impossible to function at all without them. As machines gain preeminence in the retention, access, and analysis of information it has never been more important for clinicians to recognise the caring aspects of the profession (Claiborne, 2018). Future clinicians will need to focus their attention and efforts on a more patient-centered, higher quality of care (Panagiotis, 2017) and discard the paternalism that continues to characterise clinical practice today. We will need to come to terms with the fact that 21st century health systems will be patient-driven and that care teams will be loosely connected, cross-disciplinary, and will include smart machines imbued with artificial intelligence.

Preparing graduates for clinical practice in the 21st century will not come through iterative changes to our current clinical and educational paradigms but rather through fundamental reforms to how we think about professional practice (Susskind & Susskind, 2017). We would do well to think carefully about whether physiotherapy is an art practice or a technical craft remembering that, for much of our professional history, it has been viewed as the former (Nicholls, 2018). But if the nature of future practice is such that the technical components of the discipline are outsourced to intelligent machines, we may find ourselves in the position of being well-trained, competent, and irrelevant. We should ask how to adapt physiotherapy education so as to deepen and strengthen the human-based components that are difficult for AI-based systems to replicate, as well as to integrate the technological and data literacies that are needed in order to understand and work with smart machines.

## Physiotherapy education in the intelligence age

Education has always been one way for human beings to adapt to social and economic disruption; this is how we upgrade ourselves. But as machines get smarter - and the pace of change accelerates - the relative value of a professional degree is reduced (Susskind & Susskind, 2015). Accordingly, the ability to access professional education continuously throughout our working lives will become increasingly important. We should stop thinking of physiotherapy education as a time-limited degree programme that people graduate from once in their lives and reconsider it as a platform for lifelong learning that provides learners with customisable modules they can access when they need to (Aoun, 2016). This will be critical as more people return to higher education during their careers, driven by the need to stay ahead of technological change. In addition, it will not be enough to focus only on training future healthcare professionals, as the pace of AI implementation in health systems will rapidly outpace the retirement of practising clinicians. In other words, we face a situation in which current physiotherapists may find themselves unable to practice effectively as they struggle to communicate and collaborate with AI-based systems. Neglecting professional development may have been less serious in times of incremental change but in an era of profound transformation that requires the retraining of many thousands of clinicians, it will be problematic (Hodges, 2018). It is therefore essential that we develop improved systems for continuing professional development that not only aim to provide current practitioners with the knowledge and skills necessary for clinical practice in an intelligence age but to cultivate a mindset of flexibility that enables them to adapt to a rapidly changing workplace (Susskind & Susskind, 2015). As a side note it is by no means self-evident that this curriculum will be housed within an accredited higher education institution. In fact, as specialised knowledge is democratised and available outside discipline-specific programmes it seems more likely that continuing education will be provided elsewhere (ibid.).

This is likely to present a significant problem for physiotherapy training. It should not be controversial to suggest that the profession is traditionally conservative and that undergraduate education continues to privilege the accumulation of knowledge and skills rather than the agency that students need to navigate uncertain and changing futures (Barradell, 2017). The current, largely memorisation-based programme must transition to one that integrates three fundamental literacies across the core physiotherapy curriculum; data literacy, technological literacy, and human literacy (Aoun, 2017). As clinicians become single nodes (and possibly not even the most important nodes) within information networks, they will need data literacy to read, analyse, interpret and make use of vast data sets. As they find themselves having to work more collaboratively with AI-based systems, they will need the technological literacy that enables them to understand the vocabulary of computer science and engineering that enables them to communicate with machines. Failing that, we may find that clinicians will simply be messengers and technicians carrying out the instructions provided by algorithms. Finally, as machines take over the computation and reasoning tasks previously performed by human beings clinicians will need the human literacy that is beyond the reach of machine learning algorithms, helping them to develop skills in empathy, teamwork, creativity, design, ethics, and entrepreneurship (ibid.).

The integration of these literacies within and across the core curriculum will help future therapists develop the creative mindset and mental flexibility to invent, discover and produce the original ideas that are necessary to supplement the computation and reasoning abilities of artificial intelligence (Aoun, 2017). A curriculum that is integrated in this way will help future clinicians learn to collaborate with high-performing algorithms while at the same time accentuating our uniquely human strengths. In contrast, a curriculum that is driven by content is oriented to the present and not the future, leaving little room for imagination, professional artistry and capability (Barradell, 2017). We will therefore need to reevaluate certain taken-for-granted assumptions about what we consider to be core to the curriculum. Will we continue teaching students to interpret X-rays when algorithms are already better at image recognition? Will students need to know about disease progression when expert systems have the sum total of all human knowledge embedded within them? Should students learn research skills when search, filtering, aggregation and synthesis algorithms do a better job of summarising a body of work? Or, will students need to know how to interpret algorithmic decisions and more importantly, know when to ignore them? These are only a few examples of the kinds of questions that physiotherapy educators might consider as we move into AI-supported health systems.

It may be necessary for professional programmes to integrate data science, deep learning, and behavioral science into their undergraduate curricula in order that health professionals are able to develop, evaluate, and apply algorithms in clinical practice (Obermeyer & Lee, 2017; Hodges, 2018). Without this integration we may find that we have generations of health professionals and educators who are unable to speak the language of 21st century healthcare. In addition, we should consider moving away from the simple transfer of knowledge and skills that characterise many curricula and instead aim to build students' capacity for creative problem-solving and ideation. In short, we will need to develop creativity capacity and personal human connection instead of routine cognitive skills. Physiotherapy educators must strive to provide the things that smart machines cannot; depth of disciplinary expertise and practice wisdom, personal learning pathways, and an emotional connection to students as part of a relationship-centred approach to teaching and learning. While AI-based systems may ultimately take over the mundane tasks of *managing* the learning process, educators will still need to help students identify meaningful goals, address the emotional aspects of learning, and develop closer relationships with students in order to better support and motivate them.

## Conclusion

Artificially intelligent systems are driving changes in the health system that will have profound effects on how health care is enacted in the 21st century. These disruptive changes will force all healthcare professions to reevaluate how fit for purpose they are in an intelligence age that is characterised by smart machines, massive data sets of vast complexity, and fundamentally different relationships with patients and algorithms. We should probably take seriously the notion that the health professions of yesterday can - and maybe should - be at least partially replaced by more appropriate alternatives, including AI-based systems and cheaper alternatives. Intelligent algorithms are already smarter than us within certain narrow domains and successful clinical practice in the future will require that we understand how to interpret the advice of machines, when to hand over control to them, and when to ignore them.

The physiotherapy curriculum should adapt in order to integrate data, technological, and human literacy across all that is considered to be core to the profession, as clinicians who are unable to communicate with AI-based technology are likely to become increasingly irrelevant. Educators should acknowledge that the curriculum must serve people for the duration of their careers and not only offer time-limited undergraduate and postgraduate degrees. Clinicians will need to access the curriculum several times over the course of a career as they work to stay ahead of the changes in practice wrought by an increasingly competent variety of intelligent algorithms. We would do well to focus on adapting physiotherapy education and clinical practice for a radically different future, one in which we learn how to excel at the things that computers find difficult to replicate. Human connection will be key to success in an intelligence age and we must take every opportunity to enhance our capacity to care for each other, to learn effectively over the course of our lives, and to develop creative solutions for the problems that matter to us.

## References

Aoun, J. (2016). Higher education for the AI age: Let's think about it before the machines do it for us. The Washington Post, 27 October..

Aoun, J. (2017). Robot proof: Higher Education in the Age of Artificial Intelligence. MIT Press.

Barradell, S. (2017). Moving forth: Imagining physiotherapy education differently. Physiotherapy Theory and Practice, 33(6), 439–447.

Bleakley, A. (2010). Blunting Occam's razor: Aligning medical education with studies of complexity. Journal of Evaluation in Clinical Practice, 16(4):849-855.

Brynjolfsson, E. & McAfee, A. (2014). The second machine-age: Work, progress, and prosperity in a time of brilliant technologies. W.W. Norton & Company, New York.

Claiborne, J.S. (2018). Anticipating and Training the Physician of the Future. Academic Medicine. Preprint.

Frankish, K. & Ramsey, W.M. (2014). The Cambridge Handbook of Artificial Intelligence. Cambridge University Press, University Printing House, Cambridge, CB2 8BS, United Kingdom.

Fraser, S.W. & Greenhalgh, T. (2001). Coping with complexity: Educating for capability. BMJ, 323(7316):799-803.

Frenk, J., Chen, L., Bhutta, Z.A., et al. (2001). Health professionals for a new century: Transforming education to strengthen health systems in an interdependent world. Lancet, 376(9756):1923-1958.

Gottfredson, L.S. (1997). Mainstream science on intelligence. Intelligence, 24(1):13-23.

Harwich, E., & Laycock, K. (2018). Thinking on its own: AI in the NHS. The Reform Research Trust, Charity no. 1103739.

Hodges, B.D. (2018). Learning from Dorothy Vaughan: Artificial Intelligence and the Health Professions. Medical Education 52 (1): 11–13.

Minsky, M., in Darrach, B. (1970). Meet Shaky, the first electronic person. Life Magazine, November.

Morris, I. (2010). Why the West rules - for now. The patterns of history and what they reveal about the future. Profile books, 3A Exmouth House, Pine Street, London, EC1R 0JH.

Nicholls, D. (2018). What's the difference between a technician and an artist? Critical Physiotherapy Network, 9th May.

Obermeyer, Z. & Thomas, H.L. (2017). Lost in Thought - The Limits of the Human Mind and the Future of Medicine. New England Journal of Medicine, 1209–11.

Panagiotis, K. (2017). Man Versus Machine: The Future of Medicine. Academic Medicine 92 (5): 578.

Simon, H. (1965). The Shape of Automation for Men and Management (1st edition). Harper & Row.

Susskind, R. & Susskind, D. (2015). The Future of the Professions: How Technology will Transform the Work of Human Experts. Oxford University Press, Great Clarendon Street, Oxford, OX2 6DP, United Kingdom.

Topol, E. (2015). The patient will see you now: The future of medicine is in your hands. Basic Books, 250 West 57th Street, New York, NY 10107.

Wartman, S.A. & Combs, C.D. (2017). Medical Education Must Move from the Information Age to the Age of Artificial Intelligence. Academic Medicine. Preprint.

Winston, P. (1992). Artificial intelligence (3rd edition). Pearson.

## Peer review reports

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