

beyond our biochemical vibrations, biometric algorithms might not make very good artists. But nor do most humans. In order to enter the art market and displace many human composers and performers, algorithms won't have to begin by straightaway surpassing Tchaikovsky. It will be enough if they outperform Britney Spears.

New jobs?

The loss of many traditional jobs in everything from art to health-care will partly be offset by the creation of new human jobs. GPs who focus on diagnosing known diseases and administering familiar treatments will probably be replaced by AI doctors. But precisely because of that, there will be much more money to pay human doctors and lab assistants to do groundbreaking research and develop new medicines or surgical procedures.¹²

AI might help create new human jobs in another way. Instead of humans competing with AI, they could focus on servicing and leveraging AI. For example, the replacement of human pilots by drones has eliminated some jobs but created many new opportunities in maintenance, remote control, data analysis and cyber security. The US armed forces need thirty people to operate every unmanned Predator or Reaper drone flying over Syria, while analysing the resulting harvest of information occupies at least eighty people more. In 2015 the US Air Force lacked sufficient trained humans to fill all these positions, and therefore faced an ironic crisis in manning its unmanned aircraft.¹³

If so, the job market of 2050 might well be characterised by human-AI cooperation rather than competition. In fields ranging from policing to banking, teams of humans-plus-AIs could outperform both humans and computers. After IBM's chess

program Deep Blue beat Garry Kasparov in 1997, humans did not stop playing chess. Rather, thanks to AI trainers human chess masters became better than ever, and at least for a while human-AI teams known as 'centaurs' outperformed both humans and computers in chess. AI might similarly help groom the best detectives, bankers and soldiers in history.¹⁴

The problem with all such new jobs, however, is that they will probably demand high levels of expertise, and will therefore not solve the problems of unemployed unskilled labourers. Creating new human jobs might prove easier than retraining humans to actually fill these jobs. During previous waves of automation, people could usually switch from one routine low-skill job to another. In 1920 a farm worker laid off due to the mechanisation of agriculture could find a new job in a factory producing tractors. In 1980 an unemployed factory worker could start working as a cashier in a supermarket. Such occupational changes were feasible, because the move from the farm to the factory and from the factory to the supermarket required only limited retraining.

But in 2050, a cashier or textile worker losing their job to a robot will hardly be able to start working as a cancer researcher, as a drone operator or as part of a human-AI banking team. They will not have the necessary skills. In the First World War it made sense to send millions of raw conscripts to charge machine guns and die in their thousands. Their individual skills mattered little. Today, despite the shortage of drone operators and data analysts, the US Air Force is unwilling to fill the gaps with Walmart drop-outs. You wouldn't like an inexperienced recruit to mistake an Afghan wedding party for a high-level Taliban conference.

Consequently, despite the appearance of many new human jobs, we might nevertheless witness the rise of a new 'useless' class. We might actually get the worst of both worlds,

suffering simultaneously from high unemployment and a shortage of skilled labour. Many people might share the fate not of nineteenth-century wagon drivers – who switched to driving taxis – but of nineteenth-century horses, who were increasingly pushed out of the job market altogether.¹⁵

In addition, no remaining human job will ever be safe from the threat of future automation, because machine learning and robotics will continue to improve. A forty-year-old unemployed Walmart cashier who by dint of superhuman efforts manages to reinvent herself as a drone pilot might have to reinvent herself again ten years later, because by then the flying of drones may also have been automated. This volatility will also make it more difficult to organise unions or secure labour rights. Already today, many new jobs in advanced economies involve unprotected temporary work, freelancing and one-time gigs.¹⁶ How do you unionise a profession that mushrooms and disappears within a decade?

Similarly, human-computer centaur teams are likely to be characterised by a constant tug of war between the humans and the computers, instead of settling down to a lifelong partnership. Teams made exclusively of humans – such as Sherlock Holmes and Dr Watson – usually develop permanent hierarchies and routines that last decades. But a human detective who teams up with IBM's Watson computer system (which became famous after winning the US TV quiz show *Jeopardy!* in 2011) will find that every routine is an invitation for disruption, and every hierarchy an invitation for revolution. Yesterday's sidekick might morph into tomorrow's superintendent, and all protocols and manuals will have to be rewritten every year.¹⁷

A closer look at the world of chess might indicate where things are heading in the long run. It is true that for several years after Deep Blue defeated Kasparov, human-computer cooperation

flourished in chess. Yet in recent years computers have become so good at playing chess that their human collaborators lost their value, and might soon become utterly irrelevant.

On 7 December 2017 a critical milestone was reached, not when a computer defeated a human at chess – that's old news – but when Google's AlphaZero program defeated the Stockfish 8 program. Stockfish 8 was the world's computer chess champion for 2016. It had access to centuries of accumulated human experience in chess, as well as to decades of computer experience. It was able to calculate 70 million chess positions per second. In contrast, AlphaZero performed only 80,000 such calculations per second, and its human creators never taught it any chess strategies – not even standard openings. Rather, AlphaZero used the latest machine-learning principles to self-learn chess by playing against itself. Nevertheless, out of a hundred games the novice AlphaZero played against Stockfish, AlphaZero won twenty-eight and tied seventy-two. It didn't lose even once. Since AlphaZero learned nothing from any human, many of its winning moves and strategies seemed unconventional to human eyes. They may well be considered creative, if not downright genius.

Can you guess how long it took AlphaZero to learn chess from scratch, prepare for the match against Stockfish, and develop its genius instincts? Four hours. That's not a typo. For centuries, chess was considered one of the crowning glories of human intelligence. AlphaZero went from utter ignorance to creative mastery in four hours, without the help of any human guide.¹⁸

AlphaZero is not the only imaginative software out there. Many programs now routinely outperform human chess players not just in brute calculation, but even in 'creativity'. In human-only chess tournaments, judges are constantly on the lookout for players who try to cheat by secretly getting help from computers.