THE IMPACT OF AUTOMATION ON HUMAN ACTIVITY AND ACCESSIBILITY FOR INDIVIDUALS WITH DISABILITIES

A Research Paper submitted to the Department of Engineering and Society
Presented to the Faculty of the School of Engineering and Applied Science
University of Virginia • Charlottesville, Virginia
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science, School of Engineering

By

Bryam Ayvar

April 27, 2023

On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

ADVISOR
Catherine D. Baritaud, Department of Engineering and Society

DEVELOPMENT OF AN AUTONOMOUS CHESS BOARD FOR HANDICAPPED USERS AND GADGET HOBBYISTS

Throughout history, there has been a continual drive towards automating tasks to enhance efficiency, decrease costs, and promote safety in the workplace (Yi & Hiroatsu, 2022). In medical and manufacturing industries alone, automation has proven to decrease errors and costs by 88% and 16%, respectively (Holland & Davies, 2020), while increasing the efficiency and throughput of a specific task. Furthermore, recent emerging technologies, such as Artificial Intelligence (AI), the Internet-of-Things (IoT), and Smart Sensors are allowing much more complex tasks to reach full-automation, such as cooking and driving. Nonetheless, concerns about the potential negative impacts of technology on self-sufficiency and overreliance on machines for routine tasks have arisen (Autor, 2015; Jeremic & Stankovic, 2017). The relationship between automation and human development needs to be further analyzed to understand the impact it can have on humanity and how we can safely use it.

Automation creates user abstractions which promote social inclusion of an artifact. Automating a task simplifies the complexity of a traditional manual method, thus opening more doors for any user to achieve the task. For example, a fully self-driving car offers the abstraction of simply inputting the destination to replace the tedious task of manually driving. Thus, an ideal self-driving car would allow for anyone to drive, including blind and other handicapped. However, this assistance can also have destructive effects for users over-rely on automation. There have been harmful alarming trends that revolve around automation, such as Tesla owners falling asleep under the wheel and airline pilots training failing to teach how to fly a plane without auto-pilot (Kolodny & Wayland, 2019; Arakawa & Oi, 2016).

The research paper focuses on investigating how we can maximize the benefits of automation for human development. Through the analysis of specific case studies, the paper evaluates the advantages and disadvantages that automation has posed on humanity. By analyzing the moderately-coupled technical portion of the project, ReChess, the paper explores the advantages of automation usage. ReChess provides a simplified solution for rearranging a chessboard with just the push of a button. Applying the Social Construction Of Technology (Bijker & Pinch, 1984) into this case study, the paper seeks to better understand how automation can be practically applied to specific social groups, such as individuals with disabilities, and identifies the importance of incorporating inclusivity and accessibility considerations into the development process. The Social Construction Of Technology (SCOT) framework also gives a deep insight into how societal and cultural factors influence design and implementation, and how these technologies can be made more inclusive and accessible for individuals with disabilities. Then, automation is a key tool that is able to break barriers between an artifact and smaller social groups.

On the other hand, an over-reliance and misuse of automation can also be detrimental to its users. By means of examination of additional case studies, the article demonstrates the need for developers to consider the product's user base more carefully and highlights the importance of considering social groups when developing automated technology. The findings demonstrate that in order to maximize the benefits of automation, developers should consider the artifact's user base more carefully, the government should provide adequate guidelines regarding automation, and the users should make an effort to follow the standardized usage for automated technologies.

THE RISKS AND CHALLENGES ASSOCIATED WITH AUTOMATION

THE LEVELS OF AUTOMATION

Automobiles are on their way to become self-driving, and there are well-understood levels of automation that have now become popular in the auto-industry. According to the Society of Automotive Engineers (SAE), driving automation is split into 0 - 5 levels with level 0 (L0) representing a fully manual vehicle and level 5 (L5) representing a fully autonomous vehicle. According to experts, Tesla's self-driving research and development endeavors currently fall within the L3-L4 range, with some experts opining that achieving L5 autonomy is either an impossibility or considerably distant (Stayton & Stilgoe, 2020). Alex Lyashok (2017), the ex-CEO of WorkFusion, a company which specializes in researching and automating processes with intelligent bots and analytics, generalized the SAE levels of automations for a general technological device in his article, *6 Levels of Automation (Remastered)*. These levels theoretically apply to any technological device that is attempting to achieve automation for a particular task.

With the rise of the computer age, high levels of automation have been becoming possible (L3 & L4), even for extremely complex tasks, such as driving a car or playing chess. Nonetheless, there is limited understanding on how automation can impact the development of human beings, particularly specific social groups such as the handicapped and the youth. This research paper aims to shine light on the extent automation can impact human development and these social groups.

Figure 1 displays the levels of autonomous technology and offers a brief overview of them.

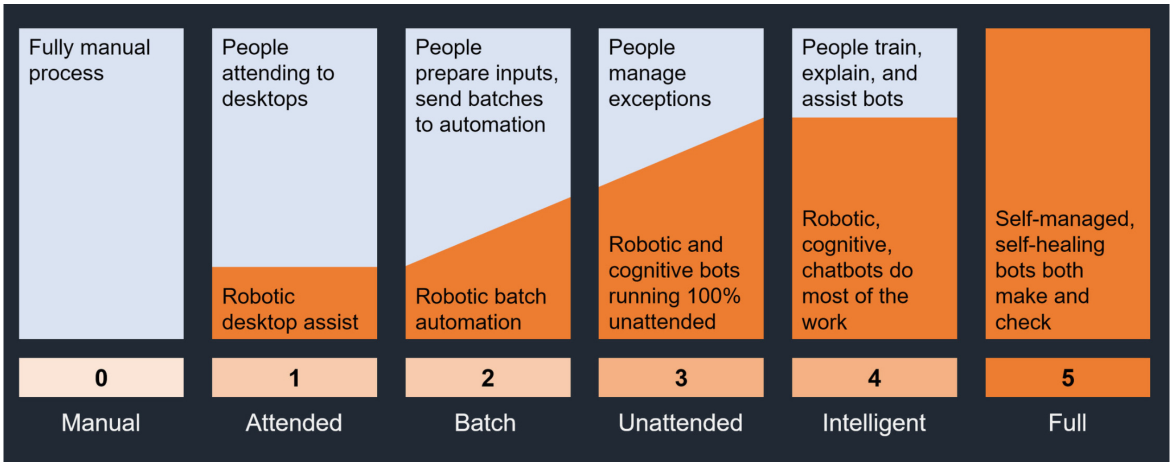

Figure 1: The levels of technological automation according to the IEEE. Level 0 represents a manual process while level 5 represents a fully automated process. (Stayton & Stilgoe, 2020)

IMPACT OF AUTOMATION ON VARIOUS STAKEHOLDERS

The rapid advancement of technology has led to a significant increase in advanced (L3-L4) automation in the modern-day workplace, resulting in increased efficiency, decreased costs, and improved safety (Yi & Hiroatsu, 2022). While certain groups in society, such as individuals with disabilities, have benefitted from these efforts, there have also been detrimental effects on humanity. In particular, there is a growing concern that reliance on technology has led to a decrease in self-sufficiency and an overreliance on machines to complete routine tasks. Throughout this section of the research paper, different case studies regarding automation will be examined and evaluated to conclude the extent of efficacy of automation.

Breaking Barriers: Automation Opening New Doors for Social Inclusion

The obstacles that alienate users from artifacts are primarily established during the initial stages of development (Petralia, Balland, & Morrison, 2017). This can result in the exclusion of unaccounted users from being able to interact with the device. Although changes can enhance accessibility and attractiveness of the device to larger audiences, smaller social groups are always marginalized because of implementation difficulties, such as those with disabilities. However, the advent of the new technological era has presented opportunities for social inclusion through automation, which leverages advanced engineering to address the needs of disabled communities by incorporating inputs such as voice commands and smart sensors, and outputs such as automatic movement and visual imagery. Automation has provided a gateway for social inclusion.

Social Construction of Technology: ReChess and Inclusion

The barriers posed to the users of a device are primarily established during the early stages of development (Petralia, Balland, & Morrison, 2017), and chess is no exception. Chess has multiple cognitive benefits for everyone, such as increased memory, critical thinking, and concentration skills (Marjoram, 1987), yet traditional chess is not fully playable for all of its users. An analysis of chess through a Social Construction of Technology (SCOT) lens is required to understand the social groups pertinent to each specific feature of modern chess (Bijker & Pinch, 1984). Further, the result can determine where ReChess and handicapped fall in its development.

Chess was born in India, and it was originally known as Chaturanga, which translated to "four-divisions", in relation to four divisions of the military ("History of chess", September 7, 2022). Originally, there were six pieces: foot-soldier, elephant, horse, chariot, minister, and king ("History of chess", September 7, 2022). Chess then moved from India to Persia, where there were major changes to the pieces. Most notably, the elephant piece was replaced by a bishop ("Bishop(chess)", October 13, 2022). This modification was done because some users were unfamiliar with elephants and educators wanted to introduce the idea of social groups with the game of chess (McClain, November 17, 2011). This change meant that there were some cultural influences on the development of the game even this early on. Nearing the 15th century, due to the rise of female monarchs, the game of chess replaced the advisor piece with a new piece, the queen, and additionally, she was given the amalgamated powers of the rook and the bishop (McCrary, 2021). As chess became more popular, every-day players had the problem of pawns being too slow, the king being too weak, and artists wanting more bold and dramatic plays to be added ("Promotion (chess)", 2022). These social groups propelled the addition of special moves, such as castling, en-passant, and pawn-to-queen upgrading. Finally, one of the most recent features added to chess was simply standardization, and it was introduced by chess theorists, programmers, and chess organizations, who needed a game to study, program, and host games of chess, respectively (Newborn, 1975). Figure 2 describes the major social groups that had an effect on a feature of the game of chess as discussed before, in the form of a Social Construction Of Technology graph (Bijker & Pinch, 1984).

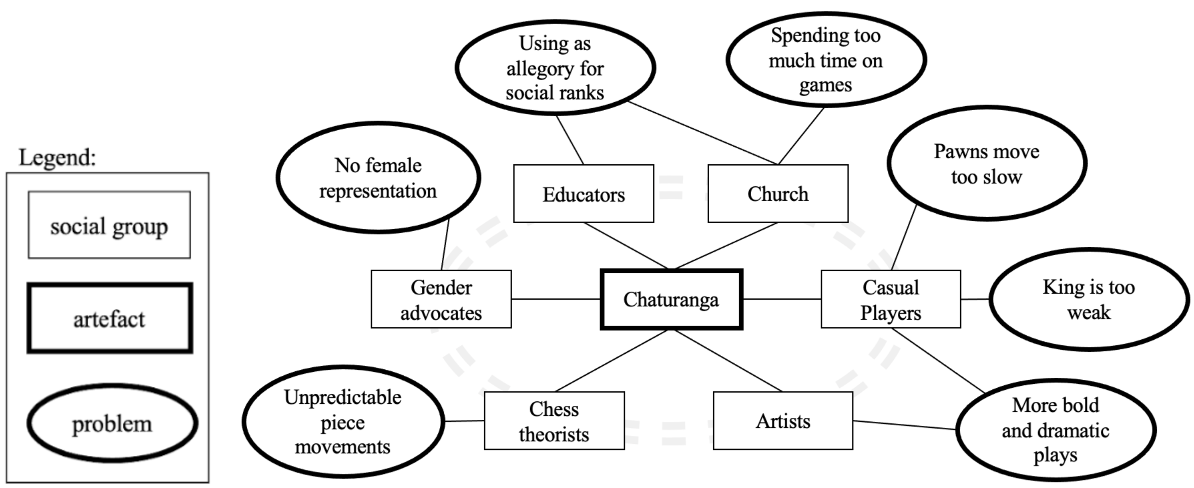

Figure 2: Social-construct graph of the original game of chess, Chaturanga. Depictions of the major social group's effect on a feature of the game of chess as discussed (Ayvar, 2022).

As chess moved from culture to culture, the values that a certain group carried were embedded in the game, either due to events at certain points in time, such as the rise in female monarchy, or the uniqueness of a particular culture, such as the Persians (Golladay, 1996). The new pieces and their movements reflected the problems contemporary social groups had with the game. Each addition to the game served as a new, marketable feature to attract more players to become familiar with the game, ultimately proliferating and increasing the popularity of the game.

The main pattern that can be seen from the evolution of chess is the fact that larger social groups have a greater influence than smaller ones. From the analysis of the history of chess, we can see that religion, government, and human expression (art) steered the major changes in the game, whereas smaller social groups, such as handicapped users have been left to feel marginalized. Engineers may not always design assistive technologies for individuals with disabilities due to a variety of reasons. These may include the need for specialized knowledge and expertise that not all engineers possess (Harniss et al., 2015), financial constraints that make investing in research and development of assistive technologies less attractive to companies (National Institute of Disability), and a potential lack of awareness or understanding of the unique needs and capabilities of individuals with disabilities among engineers and designers (Newell & Gregor, 2007). While always catering for a larger market is advantageous for the development of the technology, this leaves less popular social groups to be marginalized and unable to benefit from the changes.

Figure 2 (p. 6) fails to showcase this phenomenon, as it is missing an essential component, the weights of the stakeholder graph. The weight of a path in the graph can be a representation of cost/reward for the artifact itself or a developer to meet the requirements of a social group.

Figure 3 depicts the proposed update to the social construct graph of Chaturanga, including weights connecting each social group, representing incentives that the designer or artifact may be persuaded to follow. Impaired users, shown in red, are often unaccounted for in this representation because they pose the least benefits for the designer or artifact.

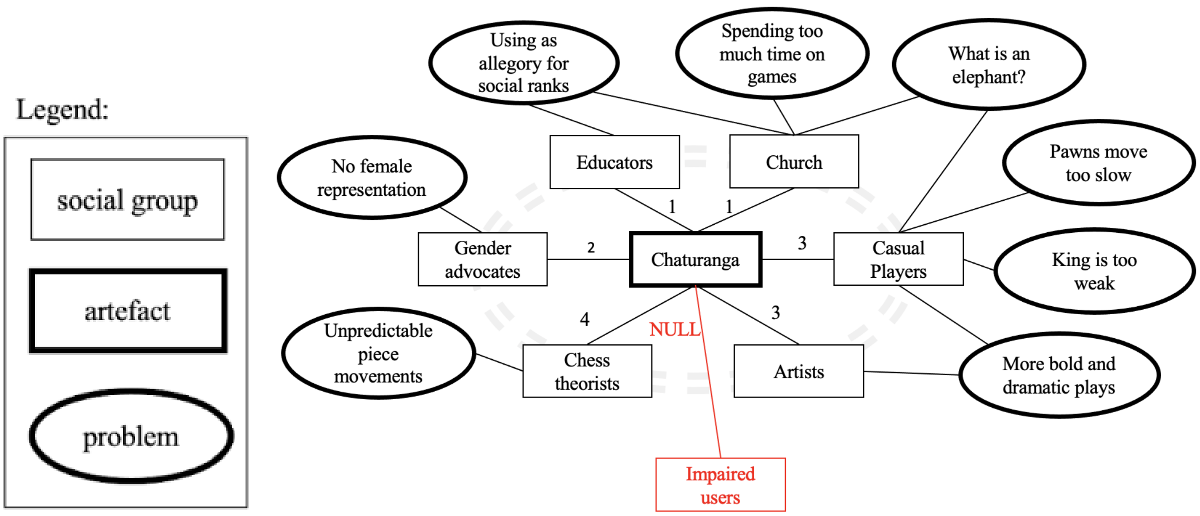

Figure 3: Updated social construct graph of the game of Chaturanga. Weights represent incentives that the artifact may benefit from catering to a specific social group (Ayvar, 2022).

The new technological era has equipped us with tools, such as automation, to fulfill the demands of very specific social groups, such as the handicapped and chess (Foley & Ferri, 2012). For chess, the embodiment of this new stage is the technical project, ReChess. Advancement in engineering allows us to take inputs such as voice commands, capacitive touch buttons, and smart multiple types of sensors; and outputs such as automatic movement, sound, and visual imagery. This allows engineers to be able to account for members of society who do not have the required senses to interact with a device, such as playing a game of chess (Heron, 2018). The technical aspect of this project solves some of the problems that handicapped social groups face when playing chess, such as recognizing a piece without seeing it, and moving a piece without lifting it.

Social Inclusion in Automated Design: CNC Machining

A first-hand example in which a member of the handicapped community has been held back because of technological accessibility involves CO_2 car design and Computer Numerical Control (CNC) Machining. According to an article published in *CNC Router Educational Success Stories*, CNC machining and computer graphics enabled a child who suffered from cerebral palsy to design a fully functioning and award winning CO_2 car in a Florida Middle School (Lintz, 2004). At first, the handicapped child only watched his professor and classmates design and make CO_2 cars, but he was never physically able to make one because of his condition. Through computer design and CNC machining (a form of automated manufacturing), the child was able to make his own CO_2 car, which won multiple local competitions. Ever since, the handicapped child has been actively participating in making CO_2 cars for his school. The hidden ability of this user highlights the necessity for developers to examine their product's user base more carefully. According to Burgstahler (2003), early access to electronic and information technology has the potential to promote positive academic and career outcomes for students with disabilities (p.1). Thus, engineers and inventors must start considering whether the devices they design can be easily accessible for smaller social groups, such as the handicapped (Titchkosky, 2003). Although automation has proven to be a link for accessibility to people with disabilities, it can also pose a threat to safety and life skills in some cases.

From Auto-Pilot to Auto-Destruction: How Over-Reliance on Technology Poses Risks to Safety and Life Skills

Although the advent of automation has undoubtedly brought significant benefits to people with disabilities, it has also sparked concerns regarding the potential for individuals to become overly dependent on technology (Dzindolet et al., 2003). The implications of such reliance are alarming, particularly when it comes to the erosion of critical life skills and the potential for harm. This phenomenon is especially relevant in the context of automation, where users may become excessively reliant on technology, leading to neglect of their duties. This section delves into the issue of over-reliance on automation, exploring the risks it poses to safety and critical life skills. Specifically, we will examine two examples of these risks: Tesla drivers sleeping under the wheel and millennials lacking essential life skills.

Over-Reliance on Automation: Air France Flight 447 & Tesla Owners Sleeping Under the Wheel

The increasing use of automation in vehicles has brought about various safety concerns that have prompted debates about the role of humans in driving and flying. While automation has the potential to enhance safety on the road and the air, it is not without risks.

One notable example is Air France Flight 447, scheduled to fly from Rio de Janeiro, Brazil, to Paris, France, but crashed in the Atlantic in 2009 due to problems with the autopilot and speed readings (Gilbert, 2012). The plane model, Airbus A330, was one of the world's greatest airplanes and had the latest technologies at the time (Learmount, 2016). The plane's autopilot turned off in the middle of the flight because of inconsistent speed readings, as the pitot-tube data-system had frozen (Oliver et al., 2017). Furthermore, the pilots failed to recognize the situation and correct their control inputs accordingly, causing the aircraft to be put outside its flight envelope. The pilots mistakenly thought that they were on an over-speed condition, when in fact, it was the opposite. The French Civil Aviation Safety Investigation Authority (BEA 2012) concluded that the pilot training regime was too narrow and prescriptive for modern airline flying and does not take into account the high levels of automation that today's pilots take for granted. The pilots were simply unprepared to recover from a stall at high altitudes and were too dependent on the auto-pilot system. The combined failure of the autopilot system and the pilot's overreliance on flight automation showcases the need to further assess the relationship between users and automation.

Another example of destructive automation in vehicles is the alarming trend of Tesla drivers falling asleep at the wheel while using the auto-pilot feature (Arakawa & Oi, 2016). This reckless behavior not only puts the driver's life at risk but also endangers the safety of other road users. Furthermore, studies have shown that drivers tend to over-rely on automation, which can lead to complacency and delayed responses to critical situations. As such, there is a pressing need for regulators and automakers to develop robust safety protocols that ensure that drivers remain alert and engaged when using automated driving features. Only by doing so can we realize the full potential of automation in enhancing safety on our roads while minimizing risks.

Destructive Automation: Millennials Lacking Important Life Skills

According to a number of studies conducted by Ordnance Survey, a national mapping agency in the United Kingdom, some essential skills that were once common have become less prevalent among newer generations due to their over-reliance on technology. These skills include reading paper maps for navigation, writing grammatically correct sentences, and having adequate penmanship. The study revealed that 53% of millennials admitted that they would struggle to find their way somewhere without their mobile phone (Hughes, 2019).

Furthermore, another survey conducted by Wake Forest University and Penn State University investigated a negative relationship between text message usage and grammar scores of sixth, seventh, and eighth-grade students (Cingel & Sundar, 2012). The study involved 228 participants and aimed to determine whether there was a link between the use of tech speak in text messages and the scores on the grammar assessment test. The results show broad support for a general negative relationship between the use of tech speak in text messages and scores on a grammar assessment. This has important implications for Social Cognitive Theory and Low-Road/High-Road Theory of Transfer of Learning, suggesting that excessive use of text messaging in day-to-day communication can harm students' grammar and writing skills.

These findings highlight the importance of balancing technology with traditional methods of communication and learning. As technology becomes more integrated into our daily lives, it is crucial to ensure that we are not sacrificing essential skills and abilities in the process. By promoting the use of both traditional and modern communication methods, we can encourage students to be proficient in both and create a more well-rounded learning experience. Additionally, educators and parents should consider incorporating activities that foster traditional skills, such as map-reading and handwriting, into the curriculum to help students maintain these important abilities.

THE FUTURE OF ETHICAL AUTOMATION

In order to maximize the potential benefits and minimize the drawbacks of autonomous artifacts in the context of human development, stakeholders must understand the socio-technical aspects regarding automated technology (Wastell & White, 2014). Stakeholders must consider factors such as user practices, possible audience, and robustness of the system. Users can become more aware of the consequences of using autonomous devices and be incentivized to use them responsibly to limit over-reliance on technology.

Furthermore, there exists an opportunity for the government to intervene by implementing standards and regulations that benefit users and restrict the amount of automation that certain fields can use. For example, the government could require manufacturers of autonomous products to provide clear and accurate information on the limitations and capabilities of their devices. Regulations could be put in place to ensure that these devices are tested thoroughly to avoid safety hazards and malfunctions. Additionally, proper training for high-level automation must be standardized, such as to avoid the Air-France Flight 447 disaster (Learmount, 2016).

Another way to promote responsible usage of autonomous products is for developers to make better design decisions. For instance, developers could incorporate a form of restriction in their products to allow users to regulate the high amount of automation. This approach is evident in Tesla's "keep your hands on the wheel" mode (Kolodny & Wayland, 2019), which requires drivers to maintain control of the vehicle despite its autonomous capabilities. By implementing this kind of feature, developers can mitigate the harmful effects of fully automating a product while still providing the benefits of automation.

While some would argue that automation should follow a free path, as it is merely a tool, past events have shown that high levels of automation can have detrimental effects for users.

Automation opens doors for social inclusivity, acting as a sturdy bridge between a problem and a unique social group, but it also has risks regarding safety. The government, development, and users have a role to play in ensuring that autonomous products are safe and user-friendly, and measures such as implementing standards and providing guidelines can help achieve the true power of autonomous technologies.

REFERENCES

Arakawa, T., & Oi, K. (2016). Verification of autonomous vehicle over-reliance. Retrieved March 21, 2023, from the Research Gate website: https://www.researchgate.net/profile/Toshiya-Arakawa

Autor, D. (2015). Why are there still so many jobs? The history and future of workplace automation. *Journal of Economic Perspectives, 29*(3), 3-30

Ayvar, B. (2022). Social-construct graph of the original game of chess, Chaturanga. [Figure 4]. Prospectus (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.

Ayvar, B. (2022). Updated social construct graph of the game of Chaturanga. [Figure 5]. Prospectus (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.

Bijker, W. E., & Pinch, T. J. (1984). The social construction of facts and artifacts. *Social Studies of Science, 14*, 399–441. https://doi.org/10.1177/030631284014003004

Bishop(chess). (2022, October 13). In *Wikipedia*. https://en.wikipedia.org/wiki/Bishop_(chess)

Burgstahler, S. (2003). The role of technology in preparing youth with disabilities for postsecondary education and employment. *Journal of Special Education Technology*, *18*(4), 7–19.

Cingel, D. P., & Sundar, S. S. (2012). Texting, techspeak, and tweens: The relationship between text messaging and English grammar skills. *New Media & Society*, *14*(8), 1304–1320. https://doi.org/10.1177/1461444812442927

Dzindolet, M. T., Peterson, S. A., Pomranky, R. A., Pierce, L. G., & Beck, H. P. (2003). The role of trust in automation reliance. *International Journal of Human-Computer Studies*, *58*(6), 697–718. https://doi.org/10.1016/s1071-5819(03)00038-7

Foley, A., & Ferri, B. A. (2012). Technology for people, not disabilities: Ensuring access and inclusion. *Journal of Research in Special Educational Needs*, *12*(4), 192–200.

French Civil Aviation Safety Investigation Authority. (2012). *Air France flight AF 447 Rio de Janeiro-Paris final report.* https://bea.aero/docspa/ 2009/f-cp090601.en/pdf/ f-cp090601.en.pdf

Gilbert, D. (2012). AF447 pilot: “Damn it, we’re going to crash”. *CNN World*. https://www.cnn.com/2011/10/14/world/americas/af447-transcript/index.html

Gregor, P., Sloan, D., & Newell, A. F. (2005). Disability and technology: Building barriers or creating opportunities? *Advances in Computers*, 283–346. https://doi.org/10.1016/s0065-2458(04)64007-1

Harniss, M., Samant Raja, D., & Matter, R. (2015). Assistive technology access and service delivery in resource-limited environments: Introduction to a special issue of disability and rehabilitation: Assistive technology. *Disability and Rehabilitation: Assistive Technology*, *10*(4), 267–270. https://doi.org/10.3109/17483107.2015.1039607

Heron, M. J., et al., (2018). Eighteen months of meeple like us: An exploration into the state of Board Game Accessibility. *The Computer Games Journal*, *7*(2), 75–95. https://doi.org/10.1007/s40869-018-0056-9

History of chess. (2022, September 7). In *Wikipedia*. https://en.wikipedia.org/wiki/History_of_chess

Holland, I., & Davies, J. A. (2020). Automation in the Life Science Research Laboratory. *Frontiers in Bioengineering and Biotechnology*, *8*. https://doi.org/10.3389/fbioe.2020.571777

Hughes, A. (2019). Millions of millennials have never read a paper map, study claims. Retrieved March 22, 2023, from the Independent website: https://www.independent.co.uk/news/uk/home-news/map-reading-millennials-smartphones-ordnance-survey-a8932976.html

Jeremic, V., & Stankovic, J. (2017). Impact of automation on employment in the developed countries. *Journal of Economic Development, Environment and People, 6*(1), 44-57.

Kolodny, L., & Wayland, M. (2019). Watch Tesla drivers apparently asleep at the wheel, renewing autopilot safety questions. *CNBC*. https://www.cnbc.com/2019/09/09/watch-tesla-drivers-apparently-asleep-at-the-wheel-renewing-safety-questions.html

Learmount, D. (2016). MS804; did the crew report smoke to Egyptian ATC? Retrieved March 21, 2023, from the Leamount website: https://davidlearmount.com/tag/air-france-447

Lintz, J. (2004). CNC Technology brings out hidden talents in disabled children. *Tech Directions*, *64*(4), 19 - 21.

Lyashok, A. (2017). 6 levels of automation (Remastered). In *Linkedin*. https://www.linkedin.com/pulse/6-levels-automation-remastered-alex-lyashok/

Marjoram, D. T. E. (1987). Chess and gifted children. *Gifted Education International*, *5*(1), 48–51. https://doi.org/10.1177/026142948700500112

McClain, D.L. (2011, November 17). Elephants and bishops. *The New York Times*. Retrieved from https://www.nytimes.com/2011/11/18/arts/elephants-and-bishops.html

McCrary, J. (2021, July 2). The evolution of Modern Chess Rules: Enter the queen and bishop. Retrieved October 24, 2022, from US Chess website: https://new.uschess.org/news/evolution-modern-chess-rules-enter-queen-and-bishop

Newborn, M. (1975). The history and basic ideas of computer chess. *Computer Chess*, 5–29.

Oliver, N., et al., (2017). The tragic crash of flight AF447 shows the unlikely but catastrophic consequences of automation. In *Harvard Business Review*. https://hbr.org/2017/09/the-tragic-crash-of-flight-af447-shows-the-unlikely-but-catastrophic-consequences-of-automation

Petralia, S., Balland, P.A. & Morrison, A. (2017). Climbing the ladder of technological development. *Research Policy*, *46*(5), 956–969. https://doi.org/10.1016/j.respol.2017.03.012

Promotion (chess). (2022, October 29). In *Wikipedia*. https://en.wikipedia.org/wiki/Promotion_(chess)

Stayton, E., & Stilgoe, J. (2020). It's time to rethink levels of automation for self-driving vehicles. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3579386

Titchkosky, T. (2003). Governing embodiment: Technologies of constituting citizens with disabilities. *Canadian Journal of Sociology / Cahiers Canadiens De Sociologie*, *28*(4), 517.

Wastell, D., & White, S. (2014). Making sense of complex electronic records: Socio-technical design in social care. *Applied Ergonomics*, *45*(2), 143–149. https://doi.org/10.1016/j.apergo.2013.02.002

Yi, L., & Hiroatsu, F. (2022). Incentives for innovation in robotics and automated construction: Based on a tripartite evolutionary game analysis. *Sustainability*, *14*(4), 2475. https://doi.org/10.3390/su14042475