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ORIGINAL PAPER

Can machines think? The controversy that led to the Turing test

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Abstract

Turing's much debated test has turned 70 and is still fairly controversial. His 1950 paper is seen as a complex and multilayered text, and key questions about it remain largely unanswered. Why did Turing select learning from experience as the best approach to achieve machine intelligence? Why did he spend several years working with chess playing as a task to illustrate and test for machine intelligence only to trade it out for conversational question-answering in 1950? Why did Turing refer to gender imitation in a test for machine intelligence? In this article, I shall address these questions by unveiling social, historical and epistemological roots of the so-called Turing test. I will draw attention to a historical fact that has been only scarcely observed in the secondary literature thus far, namely that Turing's 1950 test emerged out of a controversy over the cognitive capabilities of digital computers, most notably out of debates with physicist and computer pioneer Douglas Hartree, chemist and philosopher Michael Polanyi, and neurosurgeon Geoffrey Jefferson. Seen in its historical context, Turing's 1950 paper can be understood as essentially a reply to a series of challenges posed to him by these thinkers arguing against his view that machines can think. Turing did propose gender learning and imitation as one of his various imitation tests for machine intelligence, and I argue here that this was done in response to Jefferson's suggestion that gendered behavior is causally related to the physiology of sex hormones.

Keywords Alan Turing · The imitation game · The Turing test · Mind–machine controversy · History and philosophy of artificial intelligence · AI and society

1 Introduction

Robin Gandy (1919–1995) was one of Turing's best friends and his only doctoral student. He received Turing's mathematical books and papers when Turing died in 1954 and in 1963, took over the task from Max Newman of editing Turing's papers for publication (Moschovakis and Yates 1996). Regarding Turing's purpose in writing his 1950 paper and sending it for publication, Gandy offered a testimony previously mentioned by Jack Copeland in 2004 (p. 433) and by Margaret Boden in (2006) (p. 1351), which has not yet been fully appreciated:

> (Turing's 1950 paper) was intended not so much as a penetrating contribution to philosophy but as propaganda. Turing thought the time had come for philosophers and mathematicians and scientists to take seriously the fact that computers were not merely calculating engines but were capable of behaviour which must be accounted as intelligent; he sought to persuade people that this was so. He wrote this paper unlike his mathematical papers quickly and with enjoyment. I can remember him reading aloud to me some of the passages always with a smile, sometimes with a giggle (Gandy 1996, p. 125).

I shall refer to this as Gandy's anecdote on the purpose of the Turing test. I think it is intriguing, for one thing, because it diverges from the widely shared view of Turing's paper as proposing a decisive experiment for machine intelligence. However, more than that, it suggests that Turing was engaged in a dialog with 'philosophers and mathematicians and scientists' on the capabilities of digital computers. But what debate was this? Who were these interlocutors that Turing sought to persuade? While the Turing test is widely known in philosophy, there have not yet been any detailed historical studies of the origins and context of Turing's (1950) paper, beyond remarks made by biographers. I shall gather a mass of available sources that, although mostly

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known to Turing scholars, have not yet been tied together and fairly appreciated for the role they can play in sharpening our interpretation of Turing's 1950 proposal.

2 The purpose of the Turing test in the secondary literature thus far

Seventy years have passed since Turing's famous 1950 proposal of an imitation game or test for machine intelligence, and interpretations of it still vary substantially. I shall offer an overview of representative classes of the interpretations of Turing's test. My goal is not to engage with them in detail but only to position them with respect to Gandy's anecdote and the purpose of the Turing test.

First, interpreters disagree on whether Turing proposed a definite experiment to determine machine intelligence. On the one hand, philosophers such as Daniel Dennett (2006 [1984]), James Moor (2001) and Jack Copeland (2000) all provided support for viewing Turing's test as just such an experiment. Dennett wrote that 'the Turing test, conceived as he conceived it, is (as he thought) plenty strong enough as a test of thinking', and added, 'I defy anyone to improve upon it' (2006 [1984], p. 297). This group of interpreters saw in Turing's (1950) paper an epic test for machines seen as a species in opposition to the human species and have generally neglected to consider any gender dimension to the test. They did not acknowledge the presence of the gendered *machine-imitates-woman* and *machine-imitates-man* variants of the imitation game.[1] Rather, they suggested one could read 'man' in Turing's second variant as masculine generics. They argued that by considering all primary sources and not only Turing's 1950 text, one must concede that Turing proposed not a gender but a species test. (One of my contentions is that Turing did propose gender learning and imitation as one of his various historical tests for machine intelligence). Those philosophers insisted that the construed *machine-imitates-human* test is the best experiment to decide whether machines have already achieved human-level intelligence. Dennett seems to have reconsidered his position to some extent after his experience with the Loebner Prize Competition, which he referred to in (1997) as 'a fascinating *social* experiment' (my emphasis). He then wrote that the Turing test 'requires too much Disney and not enough science' and complained that '[t]he Turing Test is too difficult for the real world'. On the other hand, scientists such as Hayes and Ford (1995), and Drew McDermott (2014), although less certain about what Turing tried to do in his paper, tried to take his 1950 proposal of a definite experiment for machine intelligence seriously but found no scientific substance in it. Additionally, based on the working assumption that Turing would have proposed a decisive experiment for machine intelligence, this group of readers complained about the quality of Turing's experimental description and design, be it for a gender or a species test. McDermott wrote that '[c]onsidering the importance [that] Turing's Imitation Game has assumed in the philosophy-of-mind literature of the last 50 years, it is a pity he was not clearer about what the game was exactly' (*ibid.*).

Furthermore, there are those who have suggested a deflationary view of Turing's 1950 proposal, if not rejecting altogether that Turing's test addresses an empirical question. Whitby acknowledged in (1996) the role played by Turing's proposal in the early 1950s to inspire or drive research. However, he claimed that soon after, it became a distraction because Turing's test measures the human reaction to a performative machine, which is not a problem in artificial intelligence research. Like Gandy in his anecdote, Marvin Minsky saw 'the Turing test [as] a joke, sort of'; he believed that Turing suggested his test 'as one way to evaluate a machine but he had never intended it as the way to decide whether a machine was really intelligent'.[2] Noam Chomsky wrote in (1995) that the question '"Can machines think?" is not a question of fact' but one of language, and that Turing himself observed that the question is 'too meaningless to deserve discussion' (p. 9).

There is an encyclopedic account of Turing's test construed as a concept in analytic philosophy (Oppy and Dowe 2021 [2003]). A comprehensive survey on the so-called 'Turing test' in the philosophy of mind and in artificial intelligence research was conducted by Saygin et al. (2000). They are focused on the secondary literature and not on historiographies of Turing's proposal.

Additionally, in the face of the sheer heterogeneity in the secondary literature on the Turing test, one may note that there is still much room in Turing scholarship for the historical study of Turing's 1950 proposal.

3 Core events of 1949, the crucial year

In June (Hartree 1949), a computer pioneer, distinguished physicist, and then University of Cambridge professor Douglas Hartree published *Calculating Instruments and Machines*. He argued that the new electronic computing machines could do a lot but should still be seen as nothing but calculation engines. On June 9th, distinguished

[1] These appear, respectively, in (Turing 1950, pp. 433–4, and p. 442).

[2] Cf. 'Marvin Minsky on AI: the Turing test is a joke!', Interview to the Singularity Weblog, available at: <http://www.singularityweblog.com/marvin-minsky/>, from 23′35" to 24′45". Accessed 1 July 2021.

neurosurgeon and then University of Manchester professor Geoffrey Jefferson had given his Lister Oration in London along the same lines and pushed it further. He outlined hard requirements for the thesis that 'machine equals brain' be accepted (Jefferson 1949). Essentially, Jefferson argued, to be attributed the capability of thinking, a machine should be able to write a sonnet and feel its significance. Jefferson's memorial was covered by *The Times*; the next day, when asked by a reporter for a reply, Turing made a witty and sharp rebuttal. This exchange between Turing and Jefferson appeared in *The Times* (see §7). It would have an actual impact on Turing's views from October to December 1949 after two editions of a seminar titled 'Mind and computing machine', in the Department of Philosophy at their university. These seminars were cochaired by distinguished chemist and University of Manchester professor of social studies Michael Polanyi, who also engaged in the mind–machine controversy with Turing. These three conservative thinkers, then all endowed with fellowships by the Royal Society and university professorships more prestigious than Turing's, who was then Reader at the University of Manchester's Department of Mathematics, tried to establish boundaries for Turing's views on machine intelligence. From June to December 1949, Turing considered their challenges, which must have led to his famous 1950 paper, as we shall see. While these events are mostly known to Turing scholars, to the best of my knowledge, no previous scholar has established their significance for the character of Turing's 1950 proposal.

4 The mind–machine controversy in England, 1946–1950

Turing's dialog with Hartree is observable through direct citations from 1950 to 1951, which addressed the possibility of learning machines.[3] However, to my knowledge, the influence of Hartree's opposition on Turing has barely been noted thus far. Andrew Hodges offered in (2009) an account of Turing's test and argued for the Turing–Polanyi connection, writing that Polanyi 'encouraged [Turing] to publish his views' (p. 13). In the most comprehensive biography on Turing, Hodges provided several valuable primary and secondary sources (2012 [1983]). Nevertheless, Hodges often struggles to understand Turing's text due to his favoring of, in my view, his own essayistic drives. For instance, he wrote that Turing's 'sexual guessing game' was 'in fact a red herring, and one of the few passages of the paper that was not expressed with perfect lucidity' (p. 415). Jonathan Swinton's (2019) biography provided plenty of valuable new sources. Regarding Turing's test, Swinton emphasized the Turing-Jefferson connection. He argued that 'it was Jefferson's obtuseness that provoked Turing into developing this vivid image [the Turing test]' (p. 93). Swinton did not comment on why he thought so. In (2013), Turing scholar Diane Proudfoot provided an interpretation of Turing's 1950 proposal centered on a specific aspect of Turing's concept of machine intelligence, namely, Turing's 1948 observation that 'the idea of "intelligence" is itself emotional' (p. 411). More broadly, Proudfoot concurred with Copeland's (2000) defense of the test as a decisive experiment for artificial intelligence. I shall also refer later to Darren Abramson's (2011) location of material evidence that Turing read and annotated Jefferson's (1949) citations of René Descartes. My contention here is that we can connect specific findings such as this to build a more comprehensive, overarching interpretation of Turing's 1950 test that is historically grounded and also helps explain some of the tensions in existing interpretations. This gap in the secondary literature can be illustrated by the general obliviousness regarding Gandy's anecdote but also by key exegetical and historical questions that appear to still be largely unanswered:

- Why did Turing choose learning from experience as the best approach to achieve machine intelligence? In what context did he make this decision? Can we trace its intellectual history?
- If Turing was decided on conversational performance as the best intellectual task to illustrate, develop and test machine intelligence, why did he work for several years from his wartime service in 1941 to his 1950 paper with chess-playing as such a task, having even reconsidered it at the end of his 1950 paper?
- If Turing truly favored a species test for machine intelligence over a gender test in his 1950 paper, why did he refer to gender imitation so vigorously in the same source?

Developing an account of key events in 1949 in the following sections enables me to offer relatively succinct answers to these questions. An extended account can be found elsewhere (Gonçalves 2021). I suggest that Turing's (1950) proposal can be best understood against the background of the mind–machine controversy, notably involving Hartree, Polanyi and Jefferson in England from 1946 to 1950. Ultimately, this is the debate that led Turing to propose his famous imitation game or test for machine intelligence, and it explains Robin Gandy's anecdote.

[3] Cf. (Turing 1950, p. 450); and (Turing 2004c [1951], pp. 482–6, p. 485).

5 Turing's exchanges with Douglas Hartree

Douglas Hartree (1897–1958), F.R.S. since 1932 and Plummer Professor of Mathematical Physics and member of the Cavendish Laboratory at the University of Cambridge since October 1946 (Darwin 1958), had given a 'short series of lectures' in the early fall of 1948 at the University of Illinois. His related *Calculating Instruments and Machines* came out around June 1949. In the preface (p. v), which dates to May 1949, Hartree cited the Manchester 'Baby' computer which had recently been 'put into operation'. (Earlier, in February 1946, Hartree had played a key role in the Royal Society granting Newman's Computing Machine Laboratory in Manchester funding; see Rope (2010)). He kept pushing his public criticism of the term 'electronic brain', as he had been doing ever since his note in *The Times* in early November 1946. It was after Hartree's (1949) book was published that Turing began citing and discussing 'Lady Lovelace's objection' (1950), or 'Lady Lovelace's dictum' (2004 [1951]). Hartree drew attention to Lady Lovelace's views in the following way:

> Some of her comments sound remarkably modern. One is very appropriate to a discussion there was in England which arose from a tendency, even in the more responsible press, to use the term "electronic brain" for equipment such as electronic calculating machines, automatic pilots for aircraft, etc. I considered it necessary to protest against this usage [Hartree, D. R. The Times (London), Nov. 7, 1946], as the term would suggest to the layman that equipment of this kind could "think for itself," whereas this is just what it cannot do; all the thinking has to be done beforehand by the designer and by the operator who provides the operating instructions for the particular problem; all the machine can do is to follow these instructions exactly, and this is true even though they involve the faculty of "judgment." I found afterwards that over a hundred years ago Lady Lovelace had put the point firmly and concisely (C, p. 44): "The Analytical Engine has no pretensions whatever to originate anything. It can do whatever we know how to order it to perform" (her italics) (Hartree 1949, p. 70).

Hartree further resumed this passage in a way that conceded a window for research on machine learning:

> This does not imply that it may not be possible to construct electronic equipment which will "think for itself," or in which, in biological terms, one could set up a conditioned reflex, which would serve as a basis for "learning." Whether this is possible in principle or not is a stimulating and exciting question suggested by some of these recent developments [...]. But it did not seem that the machines constructed or projected at the time had this property (Hartree 1949, p. 70).

This passage would be quoted and discussed by Turing (1950) at length in (pp. 450, 454, 459). However, Turing expressed his intent to pursue machine learning beyond 'reflexes' and 'the action of the lower centres' of the brain at least as early as his *c.* November (Turing 1946) letter to Ross Ashby. In fact, Hartree's (1949) writing was, in part, a reply to Turing.

In November 1946, Hartree was interviewed alongside Turing about the machine (or 'brain') under construction at the National Physical Laboratory near London, the so-called Automatic Computing Engine (ACE). After the Second World War, Turing was hired to lead the design of the ACE as an implementation of his 1936 concept of the universal machine (Womersley 1946), while Hartree collaborated with Maurice Wilkes on the EDSAC machine at the University of Cambridge (Rope 2010). On 7 November, *The Daily Telegraph* reported an account based on their interviews with its headline centered on Hartree's views.[4] Hartree is reported to have said, 'The implications of the machine are so vast that we cannot conceive how they will affect our civilisation'. While Hartree meant the practical applications of scientific computing, Turing represented a different understanding of the potential implications of computing, as the reporter noted: 'Dr Turing, who conceived the idea of [ACE], said that he foresaw the time, possibly in 30 years, when it would be as easy to ask the machine a question as to ask a man'. The contrast between Hartree's view and Turing's view was marked. Hartree is also reported to have said in that 1946 interview, in line with his later citations of Lady Lovelace, that 'the machine would always require a great deal of thought on the part of the operator'. He denied 'any notion that [ACE] could ever be a complete substitute for the human brain'. This was postwar Britain, and Hartree saw a connection between the possibility of machine thinking and authoritarian regimes. He added, 'The fashion which [has] sprung up in the last 20 years to decry human reason is a path which leads straight to Nazism.'

Turing did not seem to have paid attention to Hartree's Nazi reference. However, he must have felt compelled to respond to what we can describe as the Lovelace–Hartree thesis, for soon after their early November 1946 interviews, during his February 1947 lecture on the ACE to the London Mathematical Society, Turing had already defined his line of response. He accepted the premise of the thesis and questioned its conclusion:

[4] *The Daily Telegraph,* ' "ACE" will speed jet flying', 7 November 1946.

> It has been said that computing machines can only carry out the processes that they are instructed to do. This is certainly true in the sense that if they do something other than what they were instructed then they have just made some mistake. It is also true that the intention in constructing these machines in the first instance is to treat them as slaves, giving them only jobs which have been thought out in detail, jobs such that the user of the machine fully understands what in principle is going on all the time. Up till the present machines have only been used in this way. But is it necessary that they should always be used in such a manner? (Turing 2004a [1947], pp. 392–3)

Turing observed that the objection raised by the Lovelace–Hartree thesis was strong and could only be met if machines were made to learn for themselves by experience, with no need to be redesigned. He said, 'What we want is a machine that can learn from experience,' continuing on to say that '[t]he possibility of letting the machine alter its own instructions provides the mechanism for this' (2004a [1947], p. 393). Therefore, when Hartree wrote the above passage in 1949 denying that 'the machines constructed or projected at the time had this property' (of learning to think for themselves), he was already responding to Turing's February 1947 comment. He may also have been responding to Norbert Wiener's *Cybernetics* (1965 [1948]), which was published soon after in October 1948. Wiener reported (p. 23) that he met Turing in the spring of 1947. Among his other various mentions of Turing, Wiener referred to Turing's results from his (1937) paper to conclude that 'the logic of the machine resembles human logic, and, following Turing, we may employ it to throw light on human logic' (pp. 125–6). Following that passage, Wiener suggested a positive answer to the possibility of the machine having even 'a more eminently human characteristic,' namely, 'the ability to learn.' In doing so, Wiener publicly stated that he shared Turing's nonobvious view that machines could be made to learn for themselves. Indeed, Wiener's *Cybernetics* did not pass unnoticed in Britain, as we shall also see shortly by looking at Jefferson's participation in the mind–machine controversy.

Turing's iconic section on 'learning machines' is a high point in his 1950 paper, constituting one quarter of it. This section presents his 'positive' views on machine intelligence. We have just seen that it had a historical grounding in his dialog with Douglas Hartree, which started in early November 1946. Moreover, a detailed chronology of Turing's concept of machine intelligence shows no reference to any notion of (machine) 'learning' by Turing prior to early November 1946,[5] when he was interviewed by *The Daily Telegraph* alongside Hartree. He had been talking about machine intelligence in general (with no mention of learning) since at least December 1945.[6] The historical record thus suggests that Hartree's point (essentially the Lovelace–Hartree thesis) helped influence the formation of Turing's concept of machine intelligence in terms of learning from experience.

6 Turing's exchanges with Michael Polanyi

Hungarian born Michael Polanyi (1913–1976) left Nazi Germany in 1933 for England and became FRS in 1944 (cf. Wigner and Hodgkin 1977). In 1948, while associated with the Department of Philosophy and with some support from Professor of Philosophy Dorothy Emmet, he was granted a position as the new chair of Social Studies at the University of Manchester. Emmet was an Alfred Whitehead scholar (cf. Swinton 2019, pp. 87–90). Emmet and Polanyi were interested in the postwar public discussion about science and society and paid attention to the debate around the new computing machines or 'electronic brains.' Therefore, they invited Turing, Newman, Jefferson and others to a seminar on 'the mind and the computing machine,' held on 27 October 1949 in the Philosophy Department. This would indeed be a crucial event. We know of it mostly from the minute notes that survived (Turing et al. 2005 [1949]). I will cover what I see as Polanyi's key interventions that challenged Turing.

The seminar was held in two sessions. The first session was led by Polanyi, who read a text entitled 'Can the mind be represented by a machine? Notes for discussion on 27th October 1949,' which he had prepared and circulated to Newman and Turing several weeks before the meeting.[7] Essentially, Polanyi claimed that humans can solve problems that machines cannot. He supported his argument using Gödel's incompleteness theorems. In what survived from the first session of the seminar, we can read the following:

> NEWMAN TO POLANYI: The Gödel extra-system instances are produced according to a definite rule, and so can be produced by a machine. The mind/machine problem cannot be solved logically; it must rest on a

[5] Cf. (Gonçalves 2021, APPENDIX A—Machine intelligence in Turing's thought (1936–1952)).

[6] See Turing's (2005 [1945]) formulation of problem 10 where he asked the question, 'Can the machine play chess?', in his technical report to the National Physical Laboratory (p. 389).

[7] At the Polanyi Archive at the University of Chicago, Polanyi scholar Paul Blum found a printed copy of that text containing a few critical annotations by hand, which may indeed have been made by Turing. See (Blum 2000, p. 52).

> belief that a machine cannot do anything radically new, to be worked on experimentally. The interesting thing to ask is whether a machine could produce the original Gödel paper, which seems to require an original set of syntheses.
> TURING: emphasises the importance of the universal machine, capable of turning itself into any other machine.
> POLANYI: emphasises the Semantic Function, as outside the formalisable system (Turing et al. 2005 [1949]).

This suggests that Newman, like Turing, believed that 'the mind/machine problem' can be decided only empirically. Moreover, Newman shifted the discussion around Polanyi's Gödelian argument to the Lovelace–Hartree thesis. Therefore, Turing and Newman seem to have tried to extract some philosophical substance from Polanyi's point. Specifically, Newman cast the problem of 'produc[ing] the original Gödel paper' as an example of Lady Lovelace's objection, that is, it attends to the question of whether a machine can 'do anything radically new'. Indeed, this connection had been suggested by Turing himself ever since his February 1947 lecture on the ACE. Using the concept of machine learning, Turing responded to both the (then yet unnamed) objection from Lady Lovelace (2004a [1947] pp. 392–3) and to the mathematical objection based on Gödel's argument (pp. 393–4).

Polanyi's appeal to a 'semantic function' would extend into the second session of the seminar, chaired by Dorothy Emmet, and lead to new exchanges with Turing. At some point, we see that Turing is reported to have presented a distinction to Polanyi, who replied as follows:

> TURING: declares he will try to get back to the point: he was thinking of the kind of machine which takes problems as objectives, and the rules by which it deals with the problems are different from the objective. Cf. Polanyi's distinction between mechanically following rules about which you know nothing, and rules about which you know.
> POLANYI: tries to identify rules of the logical system with the rules which determine our own behaviour, and these are quite different things (Turing et al. 2005 [1949]).

Here lies the motivation for Turing's (1950) formulation and rebuttal of 'the argument from informality of behaviour' (p. 451). Now, writing 9 years after the October 1949 seminar in Manchester, Polanyi gave this even more valuable piece of historical information:

> A. M. Turing has shown [Polanyi's note: in a communication to a Symposium held on "Mind and Machine" at Manchester University in October 1949. This is foreshadowed in 'Systems of Logic based on Ordinals', Proc. London Maths. Soc., Series 2, 45, 1938–9, pp. 161–228.] that it is possible to devise a machine which will both construct and assert as new axioms an indefinite sequence of Gödelian sentences. Any heuristic process of a routine character—for which in the deductive sciences the Gödelian process is an example—could likewise be carried out automatically. A routine game of chess can be played automatically by a machine, and indeed, all arts can be performed automatically to the extent to which the rules of the art can be specified (Polanyi 1974 [1958], p. 261).

Polanyi thus provides a key historical fact, namely, as of late October 1949, Turing was still referring to the game of chess as an intellectual task to illustrate and test for machine intelligence. However, as we combine what Polanyi is reported to have said in the notes of the 1949 seminar with what he wrote years later in 1958 (see both quotations above), we observe that Polanyi himself replied to Turing by classifying chess as an art that 'can be performed automatically' because its rules 'can be specified'. Therefore, in October 1949, Turing saw that his reference to machine chess was unimpressive to philosophers.

It turns out that in his 'Intelligent machinery' report written in the summer of 1948, Turing discussed a tradeoff between the most convenient and most impressive intellectual fields:

> Of the above possible fields [including "various games e.g. chess"] the learning of languages would be the most impressive, since it is the most human of these activities. This field seems however to depend rather too much on sense organs and locomotion to be feasible (Turing 2004b [1948], p. 421).

Indeed, Turing presented at the end of his 1948 report an imitation test for machine intelligence based on the game of chess. Therefore, after considering the strengths and weaknesses of various intellectual tasks and fields to illustrate, develop and test machine intelligence, he chose chess-playing. Indeed, this choice stemmed from his experiences as early as his wartime service in 1941 (Copeland and Prinz 2017, p. 329) and lasted at least until late 1945 (cf. note 9 above). Furthermore, it remained part of his schema as late as his February 1947 lecture (2004a [1947], p. 393) and his summer 1948 report cited above, surviving at least until the Manchester seminar in October 1949, as related by Polanyi. However, Turing would later have second thoughts about this. In his seminal paper written in early (Turing 1950), he replaced chess, his well-established task, with conversational question-answering or a *viva voce* test (within the field of the learning of languages). We can now revisit the question: why did he make this move?

My suggested answer is as follows. As we have seen from his exchanges with Polanyi, he saw that chess-playing would not suit his goal, which, according to Robin Gandy, was to persuade 'philosophers and mathematicians and scientists to take seriously the fact that computers were not merely calculating engines but were capable of behavior which must be accounted as intelligent'.

At the end of his 1950 paper Turing reconsidered this stance:

> We may hope that machines will eventually compete with men in all purely intellectual fields. But which are the best ones to start with? Even this is a difficult decision. Many people think that a very abstract activity, like the playing of chess, would be best. It can also be maintained that it is best to provide the machine with the best sense organs that money can buy, and then teach it to understand and speak English. This process could follow the normal teaching of a child. Things would be pointed out and named, etc. Again I do not know what the right answer is, but I think both approaches should be tried (Turing 1950, p. 460).

Indeed, Turing was not quite sure. As he had already suggested in the summer of 1948, he was hesitant regarding the cost of providing 'child machines' with 'sense organs and locomotion' so that they could learn a language. Clearly, chess was more convenient for use in initial experiments in the early 1950s, while conversational question-answering was still an imaginary experiment, though preferable for persuasion about human intelligence. In further discussions with essentially the same interlocutors, Turing reiterated his proposal of various forms of *viva voce* examination to test for machine intelligence in (Turing 2004c [1951], p. 484) and 1952 (Turing et al. 2004 [1952], p. 495); in turn, from 1952 to 1953, he reconsidered the virtues of chess yet again (Turing 2004d [1953], p. 569).

Indeed, Turing did not claim one single, and special form of (species) test to be a decisive experiment for human-level machine intelligence. Rather, he acknowledged the existence of several 'imitation tests'.[8] In short, I suggest, Turing felt compelled to drop the game of chess as his chosen task for illustrating, developing and testing machine intelligence. He did that, if for no other reason, under the influence of Polanyi's criticism that chess was an art that 'can be performed automatically' because its rules 'can be specified.'

Thus far, we have seen that in his 1950 paper, Turing responded to criticisms from Hartree (November 1946 and June 1949) and Polanyi (October 1949). In particular, we have seen that Turing left chess as sort of a second option to embody an intelligence test after Polanyi's criticism arose. It turns out that his positive adoption of linguistic performance instead of chess-playing also has historical roots, namely, in his exchanges with Jefferson in the same period (late 1949) as we shall now see. Jefferson indeed became Turing's primary antagonist.

7 Turing's exchanges with Geoffrey Jefferson

Geoffrey Jefferson (1886–1961), then Professor of Neurosurgery at the University of Manchester and Fellow of the Royal Society since 1947 (cf. Walshe 1961), read on 9 June 1949 in London his Lister Oration, which was published 2 weeks later in the *British Medical Journal* (1949). Jefferson issued criteria and demands to 'agree that machine equals brain' (p. 1110). He entitled his lecture 'The mind of mechanical man' in response to Norbert Wiener's 1948 *Cybernetics* and to the several digital computing projects in the UK and the US; notably, the project Turing was engaged in, which was hosted at the University of Manchester. A reporter from *The Times* covered Jefferson's memorial and emphasized one of Jefferson's strongest observations, which was quoted the next day (10 June 1949) under the headline 'No mind for mechanical man':[9]

> [N]ot until a machine can write a sonnet or a concerto because of thoughts and emotions felt, and not by the chance fall of symbols, could we agree that machine equals brain—that is, not only write it but know that it had written it. No mechanism could feel (and not merely artificially signal, an easy contrivance) pleasure at its successes, grief when its valves fuse, be warmed by flattery, be made miserable by its mistakes, be charmed by sex, be angry or miserable when it cannot get what it wants. (cf. also Jefferson 1949, p. 1110)

The reporter from *The Times* asked the Computing Laboratory at the University of Manchester for a reply to Jefferson's claims. Once asked,[10] Turing made a witty and sharp rebuttal. On the next day (11 June 1949), he was quoted in the newspaper under headline 'Calculus to Sonnet:'

> Mr. Turing said yesterday: "This is only a foretaste of what is to come, and only the shadow of what is going to be. We have to have some experience with the machine before we really know its capabilities. It may take years before we settle down to the new pos-

[8] '[If] the machine was being put through one of my imitation tests, it would have to do quite a bit of acting…' (Turing et al. 2004 [1952], p. 503).

[9] *The London Times,* 'No mind for mechanical man', 10 June 1949, p. 2.

[10] Cf. an excerpt of the letter from Lyn Irvine (wife of Turing's colleague and then director the University of Manchester Computing Laboratory Max Newman) to Antoinette Esher on 24 June 1949, as quoted by their son William in (Newman 2012).

> sibilities, but I do not see why it should not enter any one of the fields normally covered by the human intellect, and eventually compete on equal terms". "I do not think you can even draw the line about sonnets, though the comparison is perhaps a little bit unfair because a sonnet written by a machine will be better appreciated by another machine". Mr. Turing added that the University was really interested in the investigation of the possibilities of machines for their own sake. Their research would be directed to finding the degree of intellectual activity of which a machine was capable, and to what extent it could think for itself. News of the experiments was disclosed by Professor Jefferson in the Lister Oration reported in The Times yesterday.[11]

Two weeks later, when Jefferson's Lister Oration appeared in the BMJ (25 June), Turing was included in a warning note from the editorial that opened the edition:

> Mr. A. W. Turing [sic], who is one of the mathematicians in charge of the Manchester "mechanical brain," said in an interview with The Times (June 11) that he did not exclude the possibility that a machine might produce a sonnet, though it might require another machine to appreciate it. Probably he did not mean this to be taken too seriously [...] (BMJ 1949, p. 1129).

Turing would push back in 1950. It turns out that a sonnet-writing machine is just what he presented in his 1950 paper. This is evidence that not only Polanyi's negative point about chess but also Jefferson's positive demand for sonnets influenced Turing in shifting from chess to conversation for testing machine intelligence. Turing quoted Jefferson's demands and addressed Jefferson directly:

> I am sure that Professor Jefferson does not wish to adopt the extreme [...] point of view. Probably he would be quite willing to accept the imitation game as a test. The game (with the player B omitted) is frequently used in practice under the name of viva voce to discover whether some one really understands something or has 'learnt it parrot fashion' (Turing 1950, p. 446).

Jefferson's Lister Oration, in fact, posed a bold critique of the Turing–Wiener analogy between the new electronic computing machines and the human brain. He spoke out against the idea that machines could think and even tied it to 'political' and 'religious' issues. He urged that 'the concept of thinking like machines lends itself to certain political dogmas inimical to man's happiness [and] erodes religious beliefs that have been mainstays of social conduct' (1949, p. 1107).

[11] *The London Times,* 'Calculus to sonnet', 11 June 1949, p. 4.

The influence of Jefferson's text on Turing's 1950 paper is material and substantial. While this general point will not be surprising to Turing scholars, Jefferson's influence on Turing's paper is yet to be fully appreciated.

Very recent evidence suggests that another edition of the seminar took place in December 1949. Jonathan Swinton located a Christmas Eve postcard sent to cybernetician Warren McCulloch, then in Chicago, by a Jules Bogue, an industrialist in the chemical sector and a neighbor of Max Newman, who found his way into the meeting:

> I wish you [McCulloch] had been with us a few days ago we had an amusing evening discussion with Thuring [sic], Wiliams [sic], Max Newman, Polanyi, Jefferson, JZ Young and myself. An electronic analyser and a digital computer (universal type) might have sorted the arguments out a bit.[12]

Some chaos was noted in the arguments during the discussion in December 1949, which may explain Turing's desire to propose the imitation game 'as a basis for discussion' (1950, p. 445).

Now, I have observed that this finding of Swinton's correlates with what Jefferson related in a letter after Turing's death. Jefferson described an event when Turing would have come to his house to talk to Professor J.Z. Young and himself over dinner after a meeting in the Philosophy Department. The key information that Jefferson gave was that after midnight, Turing went to ride home on his bicycle 'through the same winter's rain' (Irvine 2012 [1959], p. xx). Therefore, if we take Jefferson's word at face value, that meeting cannot have been the seminar held on 27 October 1949 (in the fall) and must have taken place in late December (in the winter) near Christmas Eve. In fact, given that the minute notes of the October 1949 edition (Turing et al. 2005 [1949]) do not show any exchange between Jefferson and Turing, it must have been at this December meeting (extending late into the night at Jefferson's house) that they had their most lively exchanges; this must have been when Jefferson drew Turing's attention to his Lister Oration.

We know that Turing possessed and annotated an offprint of Jefferson's Lister Oration at the time he was writing his own work in January 1950.The offprint was delivered to the King's College Archive at the University of Cambridge after Turing's death, and the Archive's catalog entry describes it as having 'annotations by AMT (Alan Turing)'.[13] Darren

[12] Jules Yule Bogue to Warren McCulloch, *c*. December 1949, Christmas greetings letter found and transcribed by Jonathan Swinton; original in Warren McCulloch archive, MIT American Philosophical Society; facsimile at <http://www.manturing.net/manufacturing-blog/2019/6/3/manchester-minds-and-mit-ones>, accessed 1 July 2021.

[13] Entry AMT/B/44 of the King's College Archive catalog.

Abramson drew attention to that in 2011 (p. 548). He reports having located two heavy markings in the offprint, which gives material evidence that Turing read and annotated Jefferson's 1949 text. Turing marked two passages in pencil: Jefferson's demands that appeared in *The Times,* as we have seen above, and Jefferson's exposition of René Descartes's 1637 *Discourse on Method*, Part V (cf. Jefferson 1949, p. 1106). The latter presented the sensible image proposed by Descartes of a *viva voce* examination to distinguish human beings from machines and other animals regardless of how good their imitation of human behavior might look at first glance. Toward the end of his oration, Jefferson returned to Descartes to suggest speech as the most distinctive intellectual faculty of 'man' as opposed to 'the highest animal' (p. 1109) and further required that thinking machines should be able to write a sonnet 'because of thoughts and emotions felt' (p. 1110). Therefore, by imagining a machine being questioned about a sonnet composed by itself in his imitation game or test (1950, p. 446), Turing addressed both of Jefferson's demands—writing a sonnet and passing a *viva voce* test about it—at once.

Now, Jefferson made another move that to my knowledge has never been observed in the secondary literature and yet is crucial for understanding Turing's test. Jefferson offered a second image to Turing, and this one was no less striking than the other image. Jefferson referred to 'sex hormones' as a distinctive feature of the behavior of 'animals' and 'men,' as opposed to 'modern automata' (1949, p. 1107). As part of this connection, he referred to the iconic electromechanical tortoises of Grey Walter:

> [It] should be possible to construct a simple animal such as a tortoise (as Grey Walter ingeniously proposed) that would show by its movements that it disliked bright lights, cold, and damp, and be apparently frightened by loud noises, moving towards or away from such stimuli as its receptors were capable of responding to. In a favourable situation the behaviour of such a toy could appear to be very lifelike—so much so that a good demonstrator might cause the credulous to exclaim "This is indeed a tortoise." I imagine, however, that another tortoise would quickly find it a puzzling companion and a disappointing mate (Jefferson 1949, p. 1107).

Jefferson further remarked that 'neither animals nor men can be explained by studying nervous mechanics in isolation, so complicated are they by endocrines, so coloured is thought by emotion.' He then stated that '[s]ex hormones introduce peculiarities of behaviour often as inexplicable as they are impressive' (*ibid.*). In short, Jefferson suggested that machines could not exhibit enough peculiarities of behavior to be able to imitate the actions of animals or 'men' because they have no sex hormones. A machine would give itself away and be found to be 'a puzzling companion and a disappointing mate.' Jefferson thus suggested that the physiology of sex hormones is causally related to interesting behavior, meaning gendered behavior.

In Jefferson's passage quoted by *The Times* in June 1949, he notably argues that machines should be able to have emotional reactions in general and be capable of being 'charmed by sex' in particular if they can be said to think. In his 1950 paper, Turing addressed this in his discussion of objection (5) 'Arguments from various disabilities' (p. 447). Among other nonobvious things, he considered the ability to 'fall in love' and 'make someone fall in love with it' as within the reach of machines. Although Turing did not address Jefferson's tortoise challenge directly, one may note that for a machine to not be a puzzling companion and a disappointing mate in the sense of Jefferson, it must be able to learn and imitate gender. Turing addressed the tortoise challenge more subtly, one might say, in the very design of his imitation game. He modified the *viva voce* examination proposed by Descartes in (1985 [1637]) in a few key aspects. In Descartes's test, there were only two participants: the one contestant entity—an animal or machine—and the human interrogator questioning it. Turing, having introduced an arrangement for blind communication to control for bias, introduced another arrangement for a third player, player B, who is supposed "to help the interrogator" in making the right decision. Player B is meant to be gendered and to sit side by side with player A, that is, to serve as a baseline model of its gender performance in the unrestricted conversation conducted by the examiner. Now, let us recall Jefferson's argument about the influence of sex hormones in the production of peculiarities of behavior in "animals" and "men". Jefferson presented the image of an electromechanical tortoise that is put side by side with an actual tortoise. Suppose by analogy that we consider, as Jefferson suggested in the title of his Lister Oration, a "mechanical man" side by side with an actual woman or man. Turing's question is thus posed: without being able to see, touch or hear the two, would one be able to tell them apart? Or would the machine, as predicted by Jefferson in his critique of Walter's electromechanical tortoise, be quickly found to be "a puzzling companion and a disappointing mate"? If the thesis that sex hormones are crucial to produce interesting behavior was also at stake, then Descartes's language test by itself, even if fixed by Turing's arrangement for blind communication, would fall short at satisfying one of Jefferson's conditions for machine intelligence. It would have to be extended along the lines of Turing's imitation game. If player A can imitate the required gender sufficiently well, then it will showcase not only human intelligence in general but also the 'peculiarities of behaviour' that according to Jefferson would be rendered by specific (male/female) 'sex hormones'.

Now, as a homosexual man, Turing must have been sure that gendered behavior was not causally determined by male/female sex hormones and then it could be learned and imitated. Therefore, in a subtle rebuttal to Jefferson, Turing may have tried to show that machines could learn and imitate whatever gender they are taught. It is astounding to observe that Turing designed his imitation game in early 1950 to challenge Jefferson's thesis, and 2 years later he was imposed a pseudo-therapy based on sex hormones to convert his homosexual behavior by the British State. Turing was not converted (cf. Hodges 2012 [1983], §8). In fact, Turing's sexuality can be understood as proof that Jefferson was wrong.

8 Conclusion

Turing's proposal of a test for machine intelligence is still fairly controversial. His seminal 1950 paper is often said to be accessible to general readership and yet is also considered complex, multilayered and too ambiguous for scientific and philosophical interpretation—if not even contradictory. In this article, I have drawn attention to the mind–machine controversy in England (1946–1950), which led Turing to propose his famous imitation game or test for machine intelligence. I have provided original answers to key exegetical and historical questions that have not been suitably addressed thus far.

Indeed, Turing spent several years—from *c.* 1941 to late 1949—working with chess-playing as a task to illustrate, develop and test for machine intelligence. At least since his indirect dialog with Hartree about the cognitive capabilities and limitations of the ACE in late 1946, Turing had been thinking of making a machine to play chess by learning from experience. His goal was to establish a concept of machine intelligence that would not fall prey to the Lovelace–Hartree thesis. Learning from experience was Turing's answer to Hartree's criticism, and it could be illustrated quite well in the game of chess. However, in October 1949, his argument based on chess received criticism from Polanyi, who was unimpressed and argued that chess was an art that 'can be performed automatically,' for its rules 'can be specified.' Not less importantly, late that year, Jefferson drew Turing's attention to his Lister Oration. In his oration, Jefferson shed light on Descartes's proposal of a *viva voce* examination to distinguish humans from machines and other animals and pointed out speech as the highest form of human intelligence. Jefferson's emphasis on speech was such that the climax of his Lister Oration was to require that thinking machines be able to write a sonnet. He further required that linguistic performance be tied to emotions. Additionally, in his oration, Jefferson pointed to Grey Walter's iconic electromechanical tortoises and suggested that machines could not exhibit enough peculiarities of behavior to be able to imitate the actions of animals or 'men' because they have no sex hormones. A machine would give itself away and be found to be 'a puzzling companion and a disappointing mate.' In doing so, Jefferson suggested that the physiology of sex hormones is causally related to gendered behavior. Turing challenged Jefferson's position through an irreverent adaptation of Descartes's test. I suggest that Turing's dialog with Jefferson's Lister Oration provides evidence that Turing did propose gender learning and imitation as one of his various historical tests for machine intelligence,[14] and this was done in response to Jefferson.

In sum, I have explained Robin Gandy's anecdote on the purpose of the Turing test and singled out Turing's most notable interlocutors—the 'philosophers and mathematicians and scientists' that Turing 'sought to persuade' about the cognitive capabilities of digital computers. Turing's direct and indirect discussion with these three thinkers—Hartree, Polanyi and Jefferson—I hold, is key for any exegesis of Turing's (1950) paper and to an understanding of the conceptual problems he tried to solve with his proposal of the imitation game, which became widely known as his test for machine intelligence.

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References

Abramson D (2011) Descartes' influence on Turing. Stud Hist Philos Sci Part A 42(4):544–551. https://doi.org/10.1016/j.shpsa.2011.09.004

Blum PR (2000) Michael Polanyi: can the mind be represented by a machine? Documents of the discussion in 1949. Polanyiana 1(1–2):35–60

BMJ (1949) Mind, machine, and man. Br Med J (editorial) 1(4616):1129–1130

Boden M (2006) Mind as machine: a history of cognitive science, vols 1 and 2. Oxford University Press, Oxford

Chomsky N (1995) Language and nature. Mind. https://doi.org/10.1093/mind/104.413.1

Copeland BJ (2000) The Turing test. Mind Mach 10(4):519–539. https://doi.org/10.1023/A:1011285919106

Copeland BJ (2004) The essential Turing: the ideas that gave birth to the computer age. Oxford University Press, Oxford

[14] As mentioned, Turing made explicit reference to '[his] imitation tests'. See note 8 above.

Copeland BJ, Prinz D (2017) Computer chess: the first moments. In: Copeland BJ (ed) The Turing guide, chapter 31. Oxford University Press, Oxford, pp 327–346

Darwin CC (1958) Douglas Rayner Hartree, 1897–1958. Biogr Mem Fellows R Soc 4:102–116. https://doi.org/10.1098/rsbm.1958.0010

Dennett D (1997) Untitled postscript to can machines think? In: Teuscher C (ed) Alan Turing: life and legacy of a great thinker. Springer, Berlin, pp 314–316

Dennett D (2006 [1984]) Can machines think? In: Teuscher C (ed) Alan Turing: life and legacy of a great thinker. Springer, Berlin, pp 295–316 (**Reprinted with added 1985 and 1997 postscripts 'Eyes, ears, hands and history' and no title, from M. G. Shafto (ed.), How we know, San Francisco: Harper & Row, 1984, pp. 121–145**)

Descartes R (1985 [1637]) Discourse and essays. In: Cottingham J, Stoothoff R, Murdoch D (eds) The philosophical writings of Descartes, vol 1. Cambridge University Press, Cambridge, pp 111–151

Gandy R (1996) Human versus mechanical intelligence. In: Millican P, Clark A (eds) Machines and thought: the legacy of Alan Turing, vol 1. Oxford University Press, Oxford

Gonçalves B (2021) Machines will think: structure and interpretation of Alan Turing's imitation game. Doctoral Dissertation, Faculty of Philosophy, Languages and Human Sciences, University of São Paulo, São Paulo. https://doi.org/10.11606/T.8.2021.tde-10062021-173217

Hartree DR (1949) Calculating instruments and machines. University of Illinois Press, Urbana

Hayes P, Ford K (1995) Turing test considered harmful. In: Proceedings of the 14th international joint conference on artificial intelligence, pp 972–7

Hodges A (2009) Alan Turing and the Turing test. In: Epstein R, Roberts G, Beber G (eds) Parsing the Turing test: philosophical and methodological issues in the quest for the thinking computer, chapter 2. Springer, Berlin, pp 13–22

Hodges A (2012 [1983]) Alan Turing: the enigma, the centenary edition. Princeton University Press, Princeton

Irvine L (2012 [1959]) Foreword to the first edition. In: Turing S (ed) Alan M. Turing, centenary edition. Cambridge University Press, Cambridge

Jefferson G (1949) The mind of mechanical man. BMJ 1(4616):1105–1110. https://doi.org/10.1136/bmj.1.4616.1105

McDermott D (2014) What was Alan Turing's imitation game? In: The critique, as part of an issue on Turing's imitation game. http://www.thecritique.com/articles/what-was-alan-turings-imitation-game/. Accessed 1 July 2021

Moor J (2001) The status and future of the Turing test. Mind Mach 11(1):77–93. https://doi.org/10.1023/A:1011218925467

Moschovakis Y, Yates M (1996) In memoriam: Robin Oliver Gandy 1919–1995. Bull Symb Log 2(3):367–368. https://doi.org/10.1017/S1079898600007873

Newman W (2012) Alan Turing remembered: a unique firsthand account of formative experiences with Alan Turing. Commun ACM 55(12):39–40. https://doi.org/10.1145/2380656.2380682

Oppy G, Dowe D (2021 [2003]) The Turing test. In: Stanford Encyclopedia of Philosophy, first published 9 April 2003, substantive revision 18 August 2020. http://plato.stanford.edu/entries/turing-test/. Accessed 1 July 2021

Polanyi M (1974 [1958]) Personal knowledge: towards a post-critical philosophy, 2nd edn. University of Chicago Press, Chicago

Proudfoot D (2013) Rethinking Turing's test. J Philos 110(7):391–411

Rope C (2010) Pioneer profiles: Douglas Hartree. Comput Resurrect 49. http://www.cs.man.ac.uk/CCS/res/res49.htm#d. Accessed 1 July 2021

Saygin AP, Cicekli I, Akman V (2000) Turing test: 50 years later. Mind Mach 10(4):463–518. https://doi.org/10.1023/A:1011288000451

Swinton J (2019) Alan Turing's Manchester. Infang Publishing, Manchester

Turing AM (1937) On computable numbers with an application to the entscheidungsproblem. Proc London Math Soc s2–42(1):230–265. https://doi.org/10.1112/plms/s2-42.1.230

Turing AM (1946) Alan Turing to Ross Ashby. In: W. Ross Ashby Digital Archive, c. November 1946; also at Woodger Papers (catalogue reference M11/99). Facsimile available at: http://www.rossashby.info/letters/turing.html. Accessed 1 July 2021

Turing AM (1950) Computing machinery and intelligence. Mind 59(236):433–460. https://doi.org/10.1093/mind/LIX.236.433

Turing AM (2004a [1947]) Lecture on the automatic computing engine. In: Copeland BJ (ed) The essential Turing: the ideas that gave birth to the computer age, chapter 9. Oxford University Press, Oxford, pp 378–394

Turing AM (2004b [1948]) Intelligent machinery. In: Copeland BJ (ed) The essential Turing: the ideas that gave birth to the computer age, chapter 10. Oxford University Press, Oxford, pp 410–432

Turing AM (2004c [1951]) Can digital computers think? In: Copeland BJ (ed) The essential Turing: the ideas that gave birth to the computer age, chapter 13. Oxford University Press, Oxford

Turing AM (2004d [1953]) Chess. In: Copeland BJ (ed) The essential Turing: the ideas that gave birth to the computer age, chapter 16. Oxford University Press, Oxford, pp 569–575

Turing AM (2005 [1945]) Proposed electronic calculator. In: Copeland BJ (ed) Alan Turing's automatic computing engine: the master codebreaker's struggle to build the modern computer, chapter 20. Oxford University Press, Oxford, pp 369–454. https://doi.org/10.1093/acprof:oso/9780198565932.003.0021

Turing AM, Braithwaite R, Jefferson G, Newman M (2004 [1952]) Can automatic calculating machines be said to think? In: Copeland BJ (ed) The essential Turing: the ideas that gave birth to the computer age. Oxford University Press, Oxford, pp 494–506

Turing AM et al (2005 [1949]) Rough draft of the discussion on the mind and the computing machine, held on Thursday, 27th October, 1949. In: The Philosophy Seminar. The Rutherford Journal 1 (December). http://rutherfordjournal.org/article010111.html. Facsimile at: www.alanturing.net/philosophy_seminar_oct1949/. Accessed 1 July 2021

Walshe FMR (1961) Geoffrey Jefferson, 1886–1961. Biogr Mem Fellows R Soc 7:127–135. https://doi.org/10.1098/rsbm.1961.0010

Whitby B (1996) The Turing test: AI's biggest blind alley? In: Millican P, Clark A (eds) Machines and thought: the legacy of Alan Turing, vol 1. Oxford University Press, Oxford

Wiener N (1965 [1948]) Cybernetics: or control and communication in the animal and the machine, 2nd edn. MIT Press, Cambridge

Wigner EP, Hodgkin RA (1977) Michael Polanyi, 12 March 1891–22 february 1976. Biogr Mem Fellows R Soc 23:412–448. https://doi.org/10.1098/rsbm.1977.0016

Womersley JR (1946) A.C.E. Project—origin and early history. In: National Physical Laboratory, 26 November 1946, Public Record Office, Kew, Richmond, Surrey (document reference DSIR 10/385); a digital facsimile is in The Turing Archive for the History of Computing. http://www.AlanTuring.net/ace_early_history. Accessed 1 July 2021