A pioneering use of early computers in weather and mortality research: Ellsworth Huntington's work with New York life insurance companies in the 1920s

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ABSTRACT

Geographers are familiar with Ellsworth Huntington's influential, yet frequently derided claims about climatic determinism, eugenics and the progress of civilization. His work on weather and mortality in New York City, a study conducted under the auspices of the National Research Council and the extensive collaboration of New York based life insurance companies, offers a different insight into Huntington's approach. While the results of this 1920s research project had a limited impact on the field, the work that produced it represents one of the earliest examples of using computing technology in the atmospheric sciences. Drawing on archival research at Yale University and the National Academy of Sciences, the paper argues that not only can Huntington be considered pioneering in his use of early computers, the use of such machines constrained the research in important ways. The limited funding and processing capabilities of early computers, standardised punch card designs, necessary labor and staff time, and clerks' learned practices, all came to define the research project. This demonstrates that early computers did not simply enable more efficient numerical analysis of geographical problems, but rather they were part of socio-technical configurations that were co-emergent from the situated development of technologies within user communities.

KEYWORDS

Huntington, history of atmospheric sciences, computing, life insurance, socio-technical configurations

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Many geographers may be familiar with the name Ellsworth Huntington, a controversial figure in the history of the discipline most familiar for his support of climatic determinism and views on eugenics. Born in 1876 as the third child of a religious minister, Huntington travelled as a missionary to Turkey in 1897, a trip that seems to have inspired a life-long interest in understanding the relations between environments and civilization (Martin 1973). Studying at Harvard under William Morris Davis for his Bachelors and Masters degrees, Huntington travelled widely, producing his first major publication *The Pulse of Asia* (Huntington 1907). He submitted a hurried PhD dissertation from this travel experience alongside a series of articles, passing the preliminary examination but failing the final examination in 1907 (Martin 1973). That same year he moved to Yale University as an instructor, a university with which he maintained an affiliation for the rest of his life.

Huntington had a strong affiliation with the Association of American Geographers, being a founding member, presenting regularly at the annual conference and becoming president in 1923 (Martin 2015). His always provisional contractual situation at Yale, however, meant that he lived a precarious academic life, having to publish textbooks, write radio scripts and engage in other commercial activities to supplement his meagre Yale salary. He was rejected for Professorship in 1912 and was never given a tenured position. When he returned to Yale in 1919 after a brief war stint at the National Research Council he held the position of Research Associate, though he continued to give classes too (Martin 1973). Despite this, he managed to pay a secretary to maintain his correspondence and he frequently self-funded research costs and overseas travel.

He was a prolific writer, but of most significance for this paper is his work on climate and civilization, most fully developed in his multiple edition *Civilization and Climate* first published in 1915 (Huntington 1915). This work explored how weather shaped individual lives, wellbeing and productivity, as well as on a grander scale how climates shaped the emergence of world civilizations. He studied productivity in factories, results in exam halls and compiled a hierarchy of the quality of different civilizations based on a questionnaire to just over 200 'experts' mostly in Europe and the United States. The book was the epitome of Huntington's work – sometimes speculative and methodologically lacking in rigour, but with what appeared to be brilliant conclusions and the big ideas that Huntington so cherished. He was well aware that climate did not determine alone and felt that culture and heredity played important roles too, ones that he tackled in subsequent work and which drew him into debates on eugenics (Martin 1973).

Huntington is most frequently remembered for being a leading geographical promoter of determinism who “cast a long shadow over the field [of climate studies]” (Fleming 1998, 106; Livingstone 2012) with consequences for the reputation of geography and ‘unscientific’ climatology (Koelsch 1996; Schulten 2001). His biographer concluded that “Probably no twentieth-century American geographer stood forward so prominently as the representative of the aggregate knowledge of his age” (Martin 1973, 253). While his work was widely critiqued at the time (Fleming 1998), his ideas continue to have resonance in contemporary climate change debates (Livingstone 2020; McGregor 2004; Randalls 2017).

This paper explores a less well-known part of Huntington’s oeuvre, work that he co-ordinated and led on the relationship between weather and mortality in New York City. This project is worthy of exploration in particular for its methodology and approach rather than its results. Two primary claims will be advanced. First, that Huntington worked with life insurance companies in New York City from 1921 using their sorters and tabulators in a pioneering use of early computing technologies in the atmospheric sciences that has gone unrecognized in histories of the subject. Second, that the materiality of these technologies, combined with costs and staff practices, both enabled and constrained what Huntington and his collaborators could achieve in the research. Early computers were integrated in new socio-technical configurations that were negotiated and often fragile achievements.

To establish these claims, the paper draws on histories of geography, atmospheric sciences, life insurance and computing, combined with archival research at Yale University (the Ellsworth Huntington papers) and the National Academy of Sciences in Washington D.C. (The Committee on Atmosphere and Man papers). The paper proceeds by establishing the relevance of understanding socio-technical configurations in research projects as provisional achievements, before describing the establishment of Huntington's New York City project and his rationale for engaging life insurers as research partners. The paper then sets out three ways in which these socio-technical configurations enabled and constrained the research: limited funding, the technological capacities of machines, and clerk practices. Finally, the paper explores the analysis and publications from the research, before concluding by situating the work within the broader historical context of early computing use in the atmospheric sciences.

Technological matters in history

Geography has paid increasing attention to the materiality of objects, actors and networks through which ideas, imaginations and practices are produced. Whether referring to papers, computers or pipelines, technical devices have been seen as integral to the human lifeworld (Barry 2013), a point that is reflected in the language of various theoretical traditions from socio-technical systems and knowledge infrastructure, to actor network theory and assemblage thinking (Barry 2013; Edwards 2010; Dittmer 2017).

Understanding assemblages as practices that intervene in the world through their admixture of materials, cultures and technologies, has prompted an examination of the contingent yet often enduring materialities that shape socio-technical configurations (Dittmer 2017; de Goede 2012). If early actor-network theory sometimes appeared too neat once the black box or settlement of a fact had been achieved, assemblage thinking retains more ambiguity and multiplicity in what is assembled, where and when, and the enduring work that has to be undertaken to maintain the assemblage (Anderson and McFarlane 2011). Assemblages are produced, therefore, through emergent, but always fragile and provisional associating of actors (human and non-human).

Assemblage theory encourages focus on the socio-materiality of the things that are being assembled, even if they might seem banal. For instance, the preservation of the archive and the materiality of the papers contained therein, came to matter to the design of the British Foreign Office building (Dittmer 2017). Documents, as physical objects, came to shape and re-shape bureaucratic institutions in Islamabad as particular organizational systems or graphical designs, for instance, became adopted or required within governmental institutions (Hull 2003). The materiality of paper and designs, therefore, was consequential for ways of governmental knowing and acting.

In the same way, histories of computing have reflected on the contingent pathways through which computing technologies have enacted new and re-shaped existing social, institutional and technological configurations. Computers enabled the production of new ways of governmental working and action in the United Kingdom, for instance, while those governmental practices became increasingly tied to these technologies to enable decision-making (Agar 2016). Computing formats and programming forced the processing of information in particular ways, even as they opened up the possibilities for quicker and more efficient interventions by users. As new socio-material assemblages formed with and through computers, new systemic dependencies were established. Economic geographers, for instance, made ambitious claims about the ability to number society with the advent of faster computers in the post-World War II period, but a co-dependency was created and computational demands for new form of mapmaking or analysis often outstripped computing capabilities (Barnes 1998; Barnes and Wilson 2014).

A parallel example can be found in the atmospheric sciences. Prior to the late 1940s, human computing placed limits on the possibilities of grand numerical analyses with Lewis Richardson's famous ideal of a forecast factory needing 64,000 staff to process weather data fast enough to keep up with the weather conditions, let alone forecast future weather (Edwards 2010). Emerging machine computers were far more efficient, but even as processing power rapidly increased in the subsequent decades, processing limitations continued to remain significant for the kinds of meteorological forecasting and climate modelling exercises that could be undertaken (Edwards 2010).

Computing technologies and infrastructure did not simply determine a singular, universal future, therefore, but rather they were and always are socio-technical configurations with fragilities and limits that require continual work to maintain. Even the history of probably the most well-known computing company, I.B.M., demonstrates a number of precarious moments in which I.B.M. had to re-establish itself at the intersection of emerging technologies and customer needs in order to maintain its position as a central node in the computer-society infrastructure (Cortada 2019). The computer had to be *made* to work within existing configurations even as computers played a role in re-shaping them. Enrolling computers as allies required a translation of interests (Latour 1987), but the outcomes were always provisional. The reach of their network was generated through new ways of doing things.

New technologies sometimes failed to re-configure assemblages too. The failure to enroll sufficient allies to strengthen the network (Latour 1987) had consequential effects on the historical development of particular technologies. Technologies assembled in one configuration might be stabilized at the expense of alternative configurations and become difficult to change (Bijker 1995), while others were never successfully stabilized at all. Peters' (2017) history of the Soviet Internet, is a good example, showing that a networked infrastructure could have been made otherwise, formulated with a design of socialist utopian values. The Soviet Internet, however, failed through the challenge of reconciling technological capabilities with political desires. Such technological failures become moments in which the interlocking machinic and political values are exposed, particularly when blame is apportioned for their failings (Jones-Imhotep 2017; Latour 1996).

A settlement is never fully achieved. The assemblage is always provisional, emergent through socio-material arrangements in which new forms of paperwork, process, machine or technical capability challenge existing norms, habits and practices. Equally, those same norms shaped reactions to and interventions into how such new forms and machines might be adopted, used or rejected. Before turning to the details of the socio-technical assemblage, it is important to first situate the actors in the network pulled together by the weather and mortality research, particularly the life insurers and their machines.

Building a research project and team

Geographers had explored the connections between weather, climate and disease throughout the nineteenth century, debating whether climate was determinant on mortality or increasingly by the early twentieth century, whether improvements in hygiene and development would limit the impacts of climate (Livingstone 2002). Huntington first engaged in detailed correspondence with New York-based life insurance companies in 1914 regarding their mortality statistics for policyholders travelling to and residing in different climates, whether overseas or in the southern United States. In 1919, he further engaged with life insurers about plans to study the influenza epidemic of 1918, expanding this to a broader analysis of weather and mortality. Huntington feared that medical scientists would not support him in this endeavour given initial reactions (Christian 1920) so he turned to the more active interest shown by life insurers. For example, Edwin Kopf, assistant statistician at Metropolitan Life and chair of the “American Public Health Association Committee on Statistical Study of the Influenza Epidemic,” sought Huntington’s advice in August 1919 with regard to such a study (Kopf 1919) reporting back in 1920 with the initial results that suggested strong correlations between mean temperature, humidity and influenza rates (Kopf 1920). This study provided a concise example of the kind of work Huntington wished to establish. He hoped that statistics would demonstrate the cost to society of weather and climate’s impacts on health (Huntington 1921a).

Finding an institutional home for such work would provide logistical and financial support, as well as lend a sense of credibility. Huntington turned to the National Research Council (N.R.C.), which had undergone a major re-organization in 1919. Huntington became a member of the Division of Geology and Geography for a 3-year term, but it was not this Division that proved consequential for the project (Huntington 1922a). In 1921 Huntington helped establish a new Committee within the Division of Biology and Agriculture initially titled “The relation of air to health” and subsequently re-named “The Committee on the Atmosphere and Man” (National Research Council 1921).[1] He envisaged being chairman of the committee as time-consuming but likely to aid Yale’s prestige as a centre (Martin 197, 162) and he sought “men of unusually high achievement and wide reputation” to be members (Huntington 1921b).

The preliminary committee established in April 1921 included eminent physiologists and biologists such as Huntington’s colleague at Yale, Yandell Henderson, and Raymond Pearl from Johns Hopkins; representatives from government and industry such as Joseph Schereschewsky from the U.S. Public Health Service; several insurance representatives; and the Weather Bureau’s Charles Marvin, who corresponded with Huntington about the value of producing a meteorological book demonstrating the weather’s relevance to health and activity

(Huntington 1921c). The committee had several additional projects in mind including a study of industrial efficiency, factory settings and atmospheric conditions, as well as further work on the influenza epidemic (National Research Council 1921).

Following the Committee meeting in October 1921, a new sub-committee on the "Relation of the Atmosphere to Mortality in New York City" worked without further wider consultation (National Research Council 1921). The sub-committee met in November and agreed that research would compare deaths from all causes, specific children's diseases, and temperature and humidity, as well as changes thereof, using statistical methods that conformed to "best modern practise in two distinct respects, namely in actuarial methods and in the newly developed methods of biological correlation" (Huntington 1921c). The study would use data for New York City from 1883-1888, supplemented with three more recent years from the Department of Health in New York City (1916, 1917 and 1921). Life insurers would be deeply involved from data processing to tabulation and analysis, while quick initial results would convince actors of the project's merits (Huntington 1921d).

Life insurance and computing in the early twentieth century

Life insurance companies were attractive research partners, not least due to their ability to process large datasets using early computing technologies. They first used tabulators in 1890, the same year as more famously the U.S. Census was tabulated by Herman Hollerith (Yates 1993). Insurance was an information intensive business. Sorting and tabulating machines enabled insurers to more quickly and easily sort through their insurance policies and to tabulate results that might indicate mortality patterns that should be considered in the pricing of policies. Business needs drove insurers to innovate and push innovation too. In 1895, the Prudential's actuary John K. Gore developed a different sorting system (Campbell-Kelly

1992) that was considered so much more efficient than Hollerith's machine that the Actuarial Society of America adopted Gore's technology for a significant study of mortality in 1902 despite the fact that the smaller card size meant less data could be processed (Yates 1993). Hollerith responded with a new sorter that quickly displaced Gore's equipment, although the Prudential maintained the Gore sorter until the early 1930s (Yates 1993).

From 1910 the insurers pushed Hollerith to develop better printing capability from his machines. In 1915, J. Roydon Pierce, the Hollerith company's printer, worked with Metropolitan Life to make a new custom printer that would be suitable for the life insurers. Many insurers, however, had adopted the alternative technology of the Powers printing tabulator produced by Hollerith's largest rival, Remington Rand, and it was only the introduction of a new Hollerith printing tabulator in the early 1920s that likely prevented most of the life insurance business leaching to Remington Rand (Yates 1993). Insurance companies therefore were in a stronger position than most other organisations by the 1920s to both work with technological innovators to develop better machines equipped for their requirements and to use those machines to tabulate and print vast quantities of numbers in a variety of forms and reports from agents' books to actuarial studies (Yates 1993).

These machines were vital for the ability to quickly process data and provide analysis for the Committee on the Atmosphere and Man, but the use of such equipment would have to be negotiated through the insurance companies. While differentiated in their response, insurers were interested in substantive explanations of mortality. Five major New York-based life insurance companies in the early twentieth century were initially involved. Three had limited contributions. The Equitable promised $1000 to the committee, while Mutual Life promised help with tabulation, though this was not followed up (National Research Council 1922). The Prudential planned greater involvement through their statistician Frederick Hoffman who agreed to become a committee member. Hoffman wanted to see more comprehensive investigations of weather and health, planning to take regular personal bodily measurements during a trip to the Amazon in summer 1921 (Hoffman 1921), but his departure from the Prudential in 1922 prematurely ended the working relationship with the committee.

New York Life played a more significant role through the work of Arthur Hunter, an actuary who, while he expressed some doubts about the ability to find direct connections between weather and mortality given other intervening factors (Hunter 1921a), had access to the latest technologies. Hunter had helped enable and promote New York Life to switch from manual to Hollerith punched card systems and innovated a new system that introduced duplication of records to ease the sorting of cards for studies (Yates 1993). Hunter, with his employers, offered the technical capability and knowledge to facilitate an efficient processing of data.

Of most long-lasting significance, however, was Metropolitan Life and particularly the influence and work of the biologist Louis I. Dublin and his assistants. Initially Dublin had been hired by Mutual Life in 1908 to explore the health effects of being overweight, but he was poached the following year by Metropolitan Life to work on their own health and welfare projects (Bouk 2015). Dublin, and his employers, viewed welfare work as an important component of life insurance, arguing that the extension of lives would return value through premiums, a position that the Prudential's staff (including Hoffman) widely critiqued (Bouk 2015). Edwin W. Kopf, employed by Metropolitan Life as an assistant statistician under Dublin, had explored sickness statistics in his early career and likewise saw the value of a reform oriented insurance. Alfred J. Lotka, hired in 1924 to supervise mathematical research, became a prominent demographer who published extensively, sometimes with Dublin, on the value of life and population dynamics (Bouk 2015). The company's promotion of statistical research to support welfare work and understandings of population mortality (including questions about eugenics) was central to their engagement with Huntington's work.

In sum, the Committee on the Atmosphere and Man incorporated insurance men that were eminent within their businesses and who had access to the latest computing technologies that would enable large datasets to be quickly processed. These men were engaged in their own internal debates about the purpose of insurance and, also, eugenics. Working with insurers and their machines, however, had particular consequences in enabling and constraining the research Huntington envisaged.

Researching weather and mortality

In December 1921, Huntington agreed a plan of work for the mortality study with Hunter, the actuary, undertaking the punching of the cards with his colleague Gerhard, and Dublin, the statistician, the tabulation, using the requisite technologies at their companies. The botanist and biometrician J. Arthur Harris of the Carnegie Institution was to advise on the mathematical analysis. At an early stage, Huntington recognized the pragmatic compromises that would ensue: "My one desire is that we should make our project as thorough as possible and yet not go beyond what either the insurance men or we ourselves can handle" (Huntington 1921e). There were three important aspects that shaped the production of the work: financial constraints, technological capabilities and clerical practices.

Financial constraints

A considerable constraint on the project was the cost and labor involved in using punch cards, sorters and tabulators, particularly given the scale of the dataset. Indeed Huntington noted that if four million entries needed to be tabulated, it would take eleven years work with two clerks on average entering 11,000 entries a day to complete the dataset, followed by a "simply impossible" timescale for the mathematical work that would need to follow

(Huntington 1921f). Punch card systems did not completely minimize labor costs as the data punching was time-consuming. Even though the insurers had the relevant machines, they were not cheap to run, costing up to $360 to run a machine each year (Kistermann 2005).

One immediate challenge was Huntington's ambition to include changes in temperature and humidity as well as the daily average. These needed to be calculated before being punched on the card, something Harris considered to involve significant extra labor given the greater challenges of subtractions compared to additions, especially with signs involved (Anon undated a).[2] Seasons would need to be sacrificed as a specific entry on the card due to the time taken to produce and check temperature changes, even if summation machines were used.

The costs of such work presented a considerable challenge. Huntington tried to strengthen his position by alluding to the voluntary work the scientists would undertake for the project while the "chief beneficiaries" would be the life insurers (Huntington 1921c). But this was never a formal agreement. In writing to Huntington on 17 December 1921, Hunter asked how he intended to pay for the work of creating the punch cards, pointing out that while they agreed that clerk time would be spared when possible to conduct the study, "no promise was made or implied to meet other expenses" (Hunter 1921b). Huntington had assumed otherwise, though he recognized that nothing had been formalized (Huntington 1921g). He hoped that since other committee members were self-funding this work and he was personally spending $50—60 a month on stenography, that Hunter might be able to carry the cost temporarily until funds arrived or the business could be convinced of the value of the work "from a purely business point of view" (ibid). The challenge for New York Life, however, was that unlike Metropolitan Life they did not anticipate any direct benefits of welfare work paying them in "dollars and cents" as they did not possess industrial life insurance policies (Hunter 1921c). While Dublin might make a social welfare case for the project, Hunter could not and he was unwilling to ask the company to pay for the cards (ibid). Consequently, the cards would have to be standardized and involve no specialized requests. As Harris summarised after discussing with Gerhard: “the requisition for a special set of cards would make trouble with a purchasing department which would not understand why special cards were required for the normal business of the company” (Harris 1921a). The lack of funds to support the project meant the research had to have the appearance of normal business labor.

Huntington pressed ahead with the research, hoping that once investigations were underway, “the insurance people will become more interested” (Huntington 1922b). In January 1922, Hunter confirmed that the plate was being produced, though Gerhard’s enquiry with Harris as to the suitability of the option of using a cheaper rubber plate further hints at the attention to cost saving (Hunter 1922a; Harris 1922a).[3] The design involved using just one plate with different colored cards for the different data series (Figure 1). 2,200 cards of each color had been ordered and data sheets prepared (Harris 1922a) and work was well underway when the N.R.C. Committee awarded $2,000 for the project (Moore 1922). $200 was for any cards and blank forms which insurance companies did not supply, $100 expenses for Hunter, and $1,700 for clerical assistance to work up correlation coefficients and prepare results for publication (National Research Council 1922).

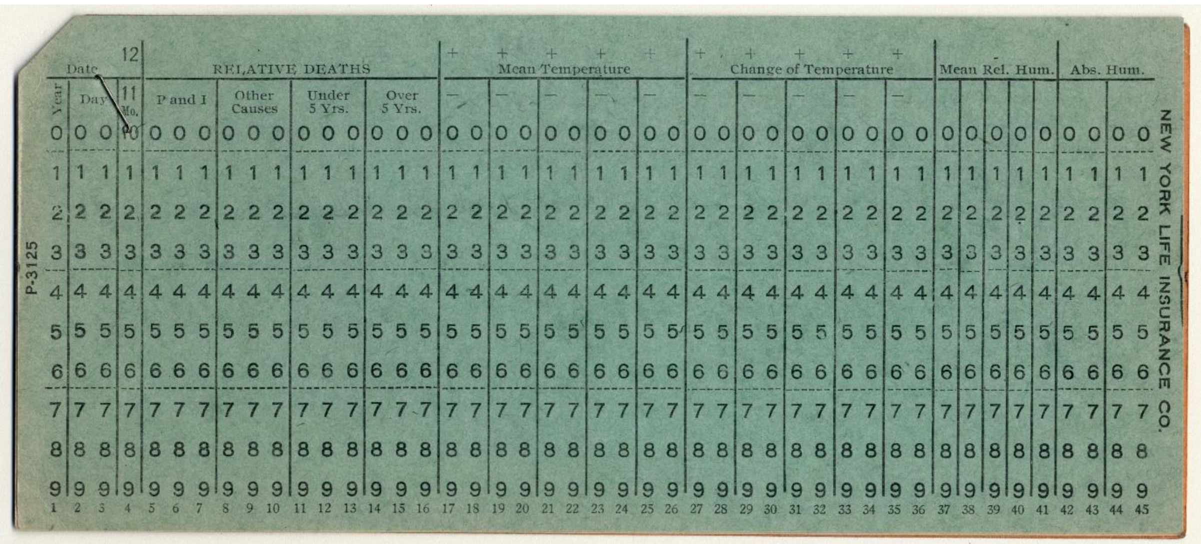

Figure 1. The final punch cards produced by New York Life Insurance for the project (image produced by © Yale University archives)

This was insufficient to cover all the costs. Indeed, Huntington had applied for more from the National Industrial Conference Board, but was informed that they would only advance up to $5,000 if matching funds were supplied by the insurers (Huntington 1922c). Hunter's (1922b) reply was negative, Dublin's (1922a) non-committal, and Harris advised Huntington that in his feeling "I think we have gotten our last support from the two insurance companies until we can get the mortality tabulations completed and show what they are worth" (Harris 1922b). While the Equitable promised $1,000 with a particular interest in influenza mortality, this was the only committed cash, and while Huntington tried to argue that the *hypothesized* cost of the New York, Mutual and Metropolitan's clerical and computation work brought the total up to $5,000, he was unsuccessful (Huntington 1922d). They would have to make do with $2,000.

The limited budget had further consequences for the scope of the research. Harris and Huntington had hoped to access New York data that differentiated mortality in terms of whether parents were of native or foreign stock, a question that was of considerable interest to life insurers at the time, including Dublin who had recently worked on immigrant stock (Harris 1922c).[4] According to Harris, however, the Commissioner in the Department of Health had problems with this enquiry and, without funds, they would be unable to personally employ people to undertake the tabulations (Harris 1922d).

The labor and costs of assembling a research project reliant on the goodwill and technologies of the life insurance companies restricted the overall scope of the research. While this large dataset would have undoubtedly been challenging for human computers, early technical machines and the institutional infrastructure surrounding their use, resulted in an uneasy coexistence between scientific ideals, the practicalities of cost and time, and the necessity for quick results. The lack of funds enhanced the physical constraints that the computing systems themselves placed on the project.

Technological capabilities

These technological capabilities were central to the planning of the project through both summation machines and punch cards, sorters and tabulators. In a series of memorandums in December 1921, concerns were raised about the interoperability of research data and computing machines (Anon undated a, b, c). The preparation of data and initial analyses of results needed to be planned in advance to ensure punch cards and data were produced in usable ways.

The punch card design needed to reflect the machine design. As previously noted, Hunter had influenced New York Life to switch to Hollerith systems in the 1910s and Metropolitan Life had invested in printing machines to work with Hollerith systems. Hollerith punch cards had a standard size format of ten rows and forty-five columns, which remained standard until the late 1920s not least as it enabled the machine's automated card feeding system (Norberg 1990; Yates 1993). Given the inability to make special requests and the limitations to the number of cards in terms of labor processing time, Huntington's ideals would have to conform accordingly. Machine limits would shape research design, but not uniformly.

In some cases, card re-design circumvented machine limitations. The limit of ten rows had little consequence to the research given that the data series comprised of just nine years (1883-1888 and 1916-1917 and 1921). The column limit was initially more problematic, however, and Huntington appeared to have to make some difficult trade-offs. In writing to

Harris in December 1921, Huntington (1921e) confirmed that a two week period would capture the full cycle of diseases like pneumonia, but he hoped that ten days of data could cover that cycle. He was advised there would be insufficient columns for this given Hunter's insistence that two columns were needed for each rubric of death (ibid). In recalculating the available space, taking away the year, month, day, and with four rubrics of death, there would be only twenty-nine columns left and if full expressions of temperature and humidity were given, there would be space for just seven days. He "hate[d] to skip" so many days, but saw no alternative than to only include days 0, 1, 2, 4, 7, 10 and 15 (ibid). In subsequent correspondence, however, they developed an alternative replicable card design enabling multiple iterations of the cards to be produced as time and resources permitted (Anon undated b, c). One card plate would be used with different series running on different colors of card, saving a great deal of expense and enabling up to five days before death to be used per card (Harris 1922e). With three runs of cards, fifteen days could be captured in full.

Humidity was a more troubling problem, however, and Huntington admitted that his ideal of including both relative and absolute humidity in full would lead to the need for 1.5 million spaces. "The upshot of it all seems to be that we have got to group our data" (Huntington 1921h). Groups needed careful working out to ensure the maximum of ten groups (for ten rows) were analytically useful (Huntington 1922e). Accordingly on the final card, relative humidity received one column per day (marked by ten groups), compared to temperature's two (full expression). Huntington also wanted changes of temperature to be included on the cards and convinced Hunter of the value of this, initially expecting this to require a separate set of punch cards, but subsequently with the re-working of the layout, these were incorporated into the main card design (Huntington 1921e). The design of the punch cards to fit the machine's standard size was a negotiated process in which scientific ambition had to confront practical realities of both labor and machine resource capacities.

A final facet of the punch card design worth noting is that they contained four causes of death. One rationale for this was the anticipated processing of the results on a summation machine. A few options were mentioned (the oft-favoured German Brunsviga, the more limited American Monroe, and the slower Swiss Millionaire), but the final choice would be determined by availability (Anon undated d; Comrie 1946). They planned to use a four dial machine, which would enable a fast running of simultaneous calculations just twice, allowing a total of two series of cards with four causes of death on each (Anon undated b). Again a trade-off was made. For skilled comptometers to produce this manually would have taken much greater effort and time, but designing the cards for an efficient running of a four-dial summation machine limited the research to multiples of four causes of death. This limitation clearly left an impression on Huntington, who was less familiar with them than Harris and the insurers: “what you say about the summation machine is very important. I am not familiar with the machine and want to see one” (Huntington 1921e).

Planning for the analysis was crucial in the design of the punch cards and this incorporated the scope of the summation machines as well as the sorters. The capacity of the machines, but especially when combined with the financial limitations of the project, influenced the layout of the punch cards and constrained the quantity of data that could be explored. Huntington’s ambitions to explore a variety of atmospheric conditions became limited to average temperature, change in temperature and grouped relative humidity for five days per card, and only two days for absolute humidity. Other potentially significant data were rendered invisible in the process. There is one further more-than-scientific aspect that shaped the design of the punch cards namely the practices of the life insurance clerks.

Clerical practices

Working with life insurers that were of eminent professional standing in population studies, epidemiology and statistics, undoubtedly enhanced the rigor and credibility of the research. They also, however, had to rely on the clerks of the companies who would operate the punching machines. While this had less influence on the scope of the project, clerk practices were interwoven with the design of the punch cards, because the positioning and understanding of the cards for a human operator was critical. Conforming to normal working practices would reduce the possibilities of errors in the punching process.

Huntington was confident in the ability of punch card operators to learn new procedures, remarking to Harris that: "… after a girl has done a hundred or so cards she learns the divisions and thereafter makes them automatically" (Huntington 1921e). Notwithstanding, he was forced to surrender to the power of the operators. Before they were approved, Harris asked Gerhard to get some of New York Life's clerks and machine operators to provide feedback on the cards practicability and any potential for streamlining (Harris 1921a). It would be an interwoven technological and social configuration that would make the machines work for the research.

The placement of dates and months was one concern. While Huntington had originally proposed month then date, Harris insisted that it would have to be the other way round so as "not to confuse the card punchers, who treat the months in this way, both in the Health Department and in the Insurance Companies" (Harris 1921b). The month being too close to the left-hand side of the punch card would also have resulted in risks of errors, because the Hollerith ten row punch cards were adapted by insurers to squeeze the eleventh and twelfth punch spots above the zero. If the month column was too near the left edge of the card it risked the twelfth being tight to the top left corner and keeping the corner undamaged was critical to prevent alignment issues. Harris noted that the "point is theoretically unimportant, but practically essential” (Harris 1921b). Clerk customs with machine experience would shape the design.

Clerks also needed to be able to quickly understand the terminology on the cards. Headings needed to be sufficiently detailed to guide punching, while concise enough to fit within printing limits (Harris 1921b). While mortality data were familiar to the insurance clerks, meteorological data were certainly not. Relative humidity had to be grouped to save card space and absolute humidity had to be calculated. Huntington hoped to use the Weather Bureau’s relevant tables for this, but in Harris’ view, the data were too complex and required considerable work to create the absolute humidity values, reckoning that clerks “would have difficulties in using the Weather Bureau tables which require interpolation” (Harris 1922f). While Huntington was sanguine about the challenges, unfamiliar data interpolation slowed processing time and absolute humidity calculations had to be rationed (Huntington 1922e).

To enable computer processing, therefore, required accurate data and punching, and this was facilitated by operating within the existing norms and practices of the clerks and operators. Computers did not displace the work of social conventions; rather these conventions were written into the socio-technical configuration in which computers were *made* to work. Machines would follow clerk’s behavioural norms.

In synthesis, the research emerged within a socio-technical configuration made up of clerical practices, resource constraints and machine limits. Some like clerk habitual norms were more readily resolved in practice, but others like the machine limits of sorters and tabulators were more significant for the research design (especially the set number of columns on a punch card). This was all magnified by funding constraints that limited the total number of cards that could be used, particularly as the work needed to be passed off as ‘normal’ business activity for insurers. It was this *socio*-technical configuration that came to shape the research, limiting the number of causes of death and number of days, preventing full statements of relative humidity, and removing the possibility of including other meteorological or demographic data. These constraints furthered doubts about whether, analytically, the chosen factors represented primary causation or merely spurious correlations.

Analysis and publications

Once Gerhard had completed the cards in early June 1922, they were forwarded to Dublin to work on tabulating the results. Dublin's initial tabulations were enthusiastically received by Huntington in September who suggested that "already they show a good deal that is suggestive," for instance the implication that wetter days had lower death rates than drier ones (Huntington 1922f). Dublin sent further tabulations in October particularly related to the rise and falls of temperatures in different seasons. Progress with these initial analyses, however, was slower than anticipated. A central contributing factor was Harris' resignation from the Committee on Atmosphere and Man in November 1922, in which he cited personal and institutional challenges, as well as his consideration that the cause of Science would be better advanced elsewhere (Harris 1922h).[5] His role in liaising between New York Life, Metropolitan Life and Huntington, and his advice on correlation analysis, was lost.

Initial analysis of the 1883-1888 data was also undertaken by a female graduate student at Yale, Miss Margaret Justin, whose work was formally supervised by Dublin and Professor Charles-Edward Amory Winslow, who had founded the Yale Department of Public Health in 1915 (Viseltear 1982). Significant input was provided by Huntington, indeed Dublin asked him to meet her to help her define her study given the pressing time-scale of PhD completion and the lack of clerical assistance he could provide (Dublin 1922b). Justin produced the most extensive initial analysis of the data in her PhD entitled *Correlation of weather and mortality* *as shown by the mortality statistics of New York City, 1883-1888* (Justin 1923). Successfully completed in 1923, the work was never formally published, a fact that did not impede her future academic career as she immediately moved to a new role as Dean of the College of Home Economics at Kansas State Agricultural College (Kansas State University), where a hall, named in her honour, opened in 1960 (Moxley 2015).

A couple of initial publications followed. A short article was published in February 1923 in *The Statistical Bulletin of Metropolitan Life* under the title "Temperature and mortality in New York City" (Metropolitan Life Insurance Company 1923). Huntington himself published a short synthesis of the initial findings as a new chapter nine in the third edition of *Civilization and Climate* in 1924 (Huntington 1924). The Committee, however, were convinced that further analysis of the data would yield more significant findings, and after a hiatus, this work was taken up again from 1925 primarily by Dublin, Kopf and the newly-arrived Lotka at Metropolitan Life.

In Huntington's annual reports of the Committee's work for the Division of Biology and Agriculture he continually re-iterated that progress was being made but that there were delays and it was slower than expected (National Research Council 1924, 1925, 1927). Partly Huntington was to blame being absent travelling and with his attention diverted to other projects. Indeed, Yandall Henderson wrote to the head of the Division to complain that "the reason why this Committee has accomplished nothing lies chiefly in the carelessness of the Chairman" (Henderson, 1924). Staff sickness and competing work priorities at Metropolitan Life slowed progress too (National Research Council 1927).

In March 1927, Kopf informed Huntington that the material was sufficiently developed to permit analysis of mortality in relation to weather conditions, separating seasons to differentiate the effects of temperature at different times of year (Lotka 1927a). Eight climographs and further tabulations for pneumonia were dispatched to Huntington in May (Lotka 1927b), who recommended possible comparative work and techniques for smoothing data (Huntington 1927a). A central challenge was how to present the findings in a way that did not look contrived. In fact, Lotka anticipated possible critiques about the choice of days, for instance, sending a couple of 'nonsense' climographs for Huntington's amusement. Ironically while the climograph correlating deaths with weather conditions six months prior did indeed look nonsensical, the second showing death rates compared to weather a year before appeared "not quite so lawless" (Lotka 1927c). While Huntington remarked that the similarity of weather patterns each year might explain such results (Huntington 1927b), Lotka was uncomfortable with this response. It might problematize *any* significance that could be claimed about the causal influence of weather. Why would days one-to-three before death matter as compared to, say, days thirteen-fifteen, if day 365 was statistically relevant (Lotka 1927d)? Spurious correlations were a real analytical risk.

Lotka's concerns were heightened when he sent Huntington further climographs in October that appeared to have little weight, hoping that Huntington's ability to "dig up relations between the figures which may escape the eyes of one less steeped in the subject" might provide insights (Lotka 1927e). The final climographs were despatched to Huntington in June 1928 (Lotka 1928a) who responded with great enthusiasm that the results justified the whole expense of the research (Huntington 1928a). Lotka hoped an initial report could be quickly produced as he was "anxious to give visible evidence of the results of our rather prolonged labors on the project" (Lotka 1928b). Huntington completed the first draft of this in September, writing of his admiration for the quality of the figures and his astonishment at the value of this study in showing the relevance of inter-diurnal temperature changes and humidity (Huntington 1928b). Connecting this work to his broader interest in climate and civilization, he suggested that these results indicated that the "most stimulating kind of climate may be found in regions where the mean temperature is far removed from the ideal" as it seemed to be the changing conditions of winds and storms that encouraged healthiness (ibid). The manuscript was circulated to Committee members before then being submitted to the Chairman of the N.R.C. in 1929. With the report concluded, the Committee on Atmosphere and Man was dissolved, while Huntington received $150 appropriation for securing the manuscript's approval (Woodruff 1929; National Research Council 1929).

The N.R.C. published *Weather and Health: A study of daily mortality in New York City* in 1930 (Huntington 1930a). Huntington noted the positive review of the work in *Geographic Review* (Huntington 1930b) and press articles, one example most likely from the *Washington Evening Star* entitled "Data on death and weather show white man's ideal day" (Ackerman 2002; Anon 1930) and the relevance of the work in light of draft material that had emanated from Clarence Mills at Cincinnati (Huntington 1930b; see also Livingstone 2020). While the N.R.C. Bulletin was not widely cited, Huntington used the work as an example of the need for strict statistical reasoning, developed with eminent statisticians such as those in Metropolitan Life, chastising the physician William F. Petersen for basing his theory on individual cases in a manuscript draft in 1936 (Huntington 1936). Huntington maintained correspondence with Dublin and Lotka for the remainder of his career often reminding them of the relevance of weather conditions (for example Huntington 1933). Emphasizing the atmosphere's role in shaping health and civilization remained central to Huntington's geographical enquiry and interventions.

Conclusions

In conclusion, it is important to justify the initial claim that Huntington's work with the Committee was pioneering in its use of computing technologies in the atmospheric sciences.

Conventionally, the dating of the first practical use of punch cards in meteorology is to Leo Wenzel Pollak's work in Czechia in 1927 (Coen 2018; Edwards 2010; Kistermann 1999). Pollak was inspired by the use of such systems within American businesses (Kistermann 1999) and he was keen to assess climatic periodicities through the collation of a wide range of meteorological data. He distributed hand punches to Czech weather station observers and promoted a unified international observation system that he envisaged might lead to a World Climatological Office (Edwards 2010). His interest went beyond data collation and he "patented a calculating machine adapted to the needs of climatologists, geophysicists and astronomers" (Coen 2018, 349). Undoubtedly Pollak was an important innovator.[6]

He was not alone, however, in the use of early computing technology. The U.K. Meteorological Office had started using a Hollerith sorting and tabulating machine in 1920, initially as a trial led by C.S. Durst and particularly for maritime observations from ship logs (George 1945; Pollak 1946). In 1922 the Meteorological Office worked with Dutch counterparts who extracted data from Hollerith cards to compute averages (George 1945) and subsequently adopted a similar system to the British (Pollak 1946).

Huntington's work places him at least contemporary with these and may precede them in terms of exploring correlations. His aim, however, was not to explain climatic patterns and periodicity, but to explore societal impacts. Perhaps that partly explains why historians of the atmospheric sciences have neglected his contribution. Equally, however, while Huntington's letters conveyed enthusiasm for the processing of datasets using machines that he did not fully understand, there is no sense that he saw his work as pioneering in any way. His publications (e.g. Huntington 1924) obscured the methodology. Add to that the fact that Huntington was a geographer with a reputation for speculative arguments and grand but unsupported claims, and it is perhaps not surprising that this work has remained relatively hidden in histories that focus more on his civilizational-scale climatic determinism. The weather and mortality project offers a rather different insight into his oeuvre, suggesting a much greater ambition for statistical rigor than is often associated with his work. That said, his penchant for digging up correlations, warranted or not, was undiminished.

Research on Huntington's big ideas can be usefully extended by drawing on geographical scholarship that increasingly emphasizes materiality. Exploring the socio-technical configurations within the weather and mortality project has demonstrated that, from punch cards to calculators, technical devices played an important role in shaping the research. While the work did not re-shape a field, it nonetheless demonstrates the challenges and struggles involved in the use of early computing technology for geographical research. Computing technology did not simply sweep through science in a triumphalist narrative of progress. Early computers and the challenges of their operation, constrained as much as enabled new research opportunities. Computers made sorting, tabulating and calculating more efficient, *as long as* the data were presented in the right layout and format. The Hollerith punch card design placed limits on a project without sufficient income to cover the costs of additional expensive printing plates or staff time. The researchers simply could not incorporate a full range of mortality or weather data. Paying attention to materiality (from technologies to costs) demonstrates the contingencies within research projects that could have been otherwise. By looking more closely in archives at *how* research is made, histories of geography might reveal further surprises, making visible things that had fallen out of view and that might challenge *de novo* accounts of computing or technically-driven disciplinary progress (Barnes and Wilson 2014).

Huntington was an innovator, but only as part of a network. He could not undertake this work or access the relevant technologies without the support of the life insurance companies. They were already pushing the boundaries of computing technologies at this time and to access the latest machines required negotiation and alignment of interests. Keeping the insurers invested in the project was always a central concern and led to the desire to produce quick initial results to generate enthusiasm. The insurers could require the research to be adapted to their norms in part because of the relatively weak position that the scientists were in. In the end, it was really only Dublin, Kopf and Lotka in Metropolitan Life that maintained their engagement in the work, probably in part due to that company's appetite for engaging in welfare work and strong personal connections. Huntington always found it hard to maintain his allies in a Committee that drifted whenever he was away travelling or otherwise engaged. As such, funding, machine capacities and operators norms all came to define the socio-technical configuration of the research project as much as the scientists.

That Huntington had flaws is unquestionable (his views on eugenics should not be overlooked), but establishing and maintaining this complex assemblage of actors from the human scientists, insurers, statisticians and punch card operators with their differing interests, through to the capacities and designs of the non-human punch card sorters, tabulators and summation machines might be considered an achievement. It was always a provisional and fragile achievement, particularly in the context of limited funding, and in the end a great deal of effort was expended for somewhat limited results. Nonetheless, this experimental project in the 1920s perhaps surprisingly reveals that one of geography's caricatured villains should equally be regarded as something of a pioneer.

NOTES

1. The Division of Biology and Agriculture were interested in biological correlation, had formed a Eugenics Committee in 1920 and had a working relationship with the Ecological Society of America, for whom Huntington was appointed as their representative in the Division in 1921.

2. These undated, unsigned documents are cited as Anon, undated, for consistency with the records at Yale University, They were produced or compiled by Harris and received by Huntington 7 December 1921.

3. It is unclear whether a rubber or regular plate was selected.

4. This went beyond a neutral technical issue as eugenics arguments supported both the Johnson-Reed Immigration Act of 1924 that blocked migration from Asia and the restrictive insurance practices for African Americans (Bouk 2015).

5. The Department of Genetics had previously tried to limit Harris' involvement in this Committee work, feeling it did not fit their remit (Harris 1922g).

6. There is no evidence that Huntington directly corresponded with Pollak.

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