The Journey of Digital Health to Date

Brian E. Chapman, PhD

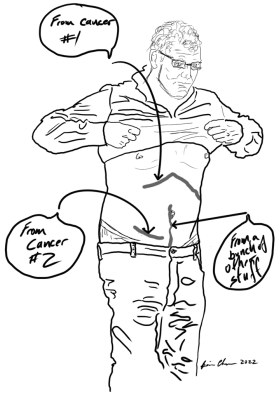
2024-10-11

Ethos: What are my credentials?

- PhD in medical informatics
- 30 years of professional experience of working on, collaborating with, and teaching about AI in healthcare
  - Primarily in medical imaging and natural language processing

Ethos: What are my credentials?

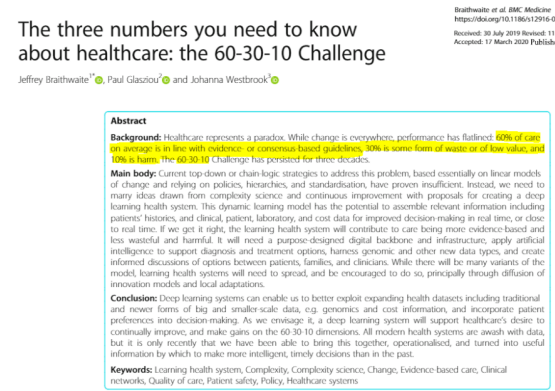
- Long-term patient
  - 4-time cancer survivor
  - Two childhood cancers (1976, 1983)
  - Two adult cancers
  - 12+ surgeries
  - 4 emergencies
  - Advanced peritonitis
  - Gangrenous strangulated bowel
  - Many resulting chronic issues!



My “mobile medical record”

Pathos: Why digital health?

Pathos: Healthcare has delivery challenges (Braithwaite, Glasziou, and Westbrook 2020)



Braithwaite *et al. BMC Medicine* (2020) 18:102
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The three numbers you need to know about healthcare: the 60-30-10 Challenge

Jeffrey Braithwaite[1*], Paul Glasziou[2] and Johanna Westbrook[3]

Abstract

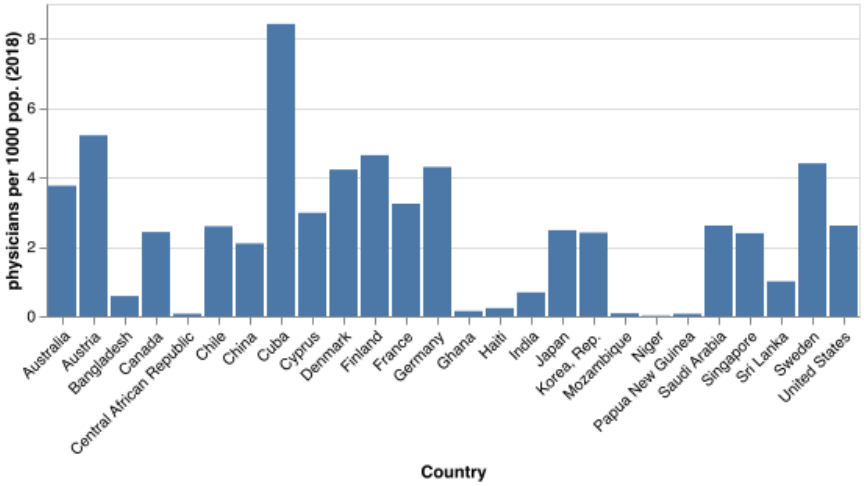
Background: Healthcare represents a paradox. While change is everywhere, performance has flatlined: 60% of care on average is in line with evidence- or consensus based guidelines, 30% is some form of waste or of low value, and 10% is harm. The 60-30-10 Challenge has persisted for three decades.

Main body: Current top-down or chain-logic strategies to address this problem, based essentially on linear models of change and relying on policies, hierarchies, and standardisation, have proven insufficient. Instead, we need to marry ideas drawn from complexity science and continuous improvement with proposals for creating a deep learning health system. This dynamic learning model has the potential to assemble relevant information including patients' histories, and clinical, patient, laboratory, and cost data for improved decision-making in real time, or close to real time. If we get it right, the learning health system will contribute to care being more evidence-based and less wasteful and harmful. It will need a purpose-designed digital backbone and infrastructure, apply artificial intelligence to support diagnosis and treatment options, harness genomic and other new data types, and create informed discussions of options between patients, families, and clinicians. While there will be many variants of the model, learning health systems will need to spread, and be encouraged to do so, principally through diffusion of innovation models and local adaptations.

Conclusion: Deep learning systems can enable us to better exploit expanding health datasets including traditional and newer forms of big and smaller-scale data, e.g. genomics and cost information, and incorporate patient preferences into decision-making. As we envisage it, a deep learning system will support healthcare's desire to continually improve, and make gains on the 60-30-10 dimensions. All modern health systems are awash with data, but it is only recently that we have been able to bring this together, operationalised, and turned into useful information by which to make more intelligent, timely decisions than in the past.

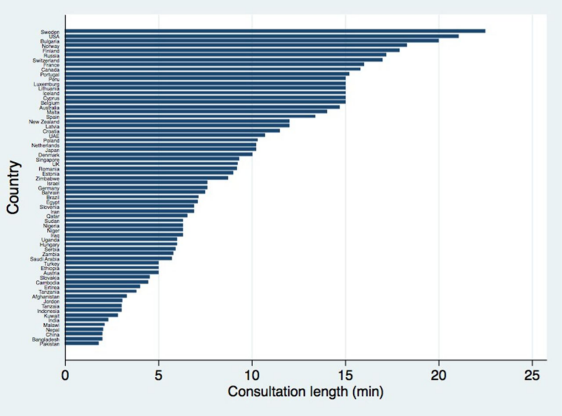
Keywords: Learning health system, Complexity, Complexity science, Change, Evidence-based care, Clinical networks, Quality of care, Patient safety, Policy, Healthcare systems

Pathos: Healthcare has delivery challenges [1]

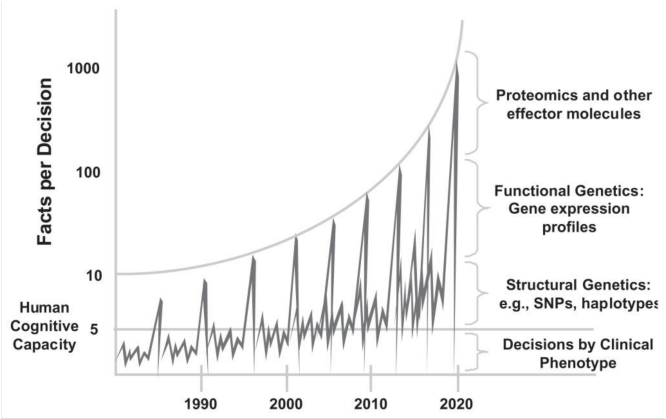


[1] World Bank

Pathos: Healthcare occurs in time-constrained settings (2017) (Irving et al. 2017)



Pathos: An overwhelming amount of information (Medicine et al. 2008)



Logos: Digital Health, a Brief History

- Digital health is many things
  - wearables, telehealth, EMRs, remote monitoring,...
- But due to time constraints, I will limit my discussion to facilitating decision making
  - Artificial Intelligence (AI)
- Medical informatics, e-Health, Digital Health, Artificial Intelligence, Cybernetics, Complex Information Processsing
  - **Labels are mostly created for marketing!**

3 July 1959, Volume 130, Number 3366 SCIENCE

Reasoning Foundations of Medical Diagnosis

Symbolic logic, probability, and value theory aid our understanding of how physicians reason.

Robert S. Ledley and Lee B. Lusted

The purpose of this article is to analyze the complicated reasoning processes inherent in medical diagnosis. The importance of this problem has received

fitted into a definite disease category, or that it may be one of several possible diseases, or else that its exact nature cannot be determined." This, obviously, is a

ance are the ones who do remember and consider the most possibilities."

Computers are especially suited to help the physician collect and process clinical information and remind him of diagnoses which he may have overlooked. In many cases computers may be as simple as a set of hand-sorted cards, whereas in other cases the use of a large-scale digital electronic computer may be indicated. There are other ways in which computers may serve the physician, and some of these are suggested in this paper. For example, medical students might find the computer an important aid in learning the methods of differential diagnosis. But to use the computer thus we must understand how the physician makes a medical diagnosis. This, then, brings us to the subject of our investigation: the reasoning foundations of medical diagnosis and treatment.

Medical diagnosis involves processes that can be systematically analyzed, as

Two significant early digital health papers

Vol. 177, No. 3

A Mathematical Approach to Medical Diagnosis

Application to Congenital Heart Disease

Homer R. Warner, M.D., Ph.D., Alan F. Toronto, M.D., L. George Veasey, M.D., and Robert Stephenson, Ph.D., Salt Lake City

JAMA 1961
Computerized (probabilistic) medical knowledge

Vol. 278 No. 11

SPECIAL ARTICLE

MEDICAL RECORDS THAT GUIDE AND TEACH

LAWRENCE L. WEED, M.D.*

THE beginning clinical clerk, the house officer and the practicing physician are all confronted with conditions that are frustrating in every phase of medical action. The purpose of this article is to acceptance and use of paramedical personnel and a more positive attitude about the computer in medicine. Eventually, for every physician all three areas will be an obligatory part of his professional envi-

NEJM 1968
Rational data collection and organization

Three flavors of medical decision support (AI)

- Probability (1960s, and 1990s): **The Best!**
  - Represent knowledge as as probabilities and use Bayes' theorem to make inferences
- Logic/Expert Systems (1970s-1980s): **The Most!**
  - Represent knowledge as computable rules and relationships
- Machine Learning (2000 present): **All the rage!**
  - Learn implicit or explicit relationships between data (input) and classifications, predictions, etc. (output)
  - LLMs (ChatGPT, Claude, Llama3, etc.)

Probabilistic AI

- Probabilities are great
  - Optimal way of reasoning under uncertainty
- Probabilities are challenging
  - You need **a lot** of them
  - How do you calculate the probabilities?
  - Judea Pearl: Bayesian Networks (DAG) 1980s

Early Expert System AI in Healthcare: MYCIN (1973)

"An artificial intelligence program to advise physicians regarding antimicrobial therapy" (Shortliffe et al. 1973)

- Exploration of heuristics
  - How to pragmatically represent uncertainty?
  - How do real humans, as opposed to "rational actors", make decisions?

Early Expert System AI in Healthcare: MYCIN

"Our goal is to build a program that can assist working scientists with reasoning problems. You wouldn't expect a tool to have all of the power of a working scientist, **but you would hope that you could design a smart system to provide some of the solutions to subproblems.**" (D. 1977)

Experts Argue Whether Computers Could Reason, and if They Should

By LEE DEMBART

Can machines think? Should they? The computer world is in the midst of a fundamental dispute over those questions because an eminent computer scientist wrote a book arguing that machines could never be made to reason like people and, what was more, should not be.

Twenty years ago, in the infancy of the computer revolution, before problems began cropping up, the public was told that computers would be smarter than brains. Computer chess champions and machine translation, for example, were just around the corner. So far, neither has been accomplished successfully, and neither is likely to be any time soon.

Nor have computers had much success in making decisions that require judgment. They can rattle off the Manhattan telephone directory unerringly time after time, which no human can do, but they cannot begin to distinguish one face from another, as babies can.

Computer scientists have always said, "Give us more time. The problem is more complex than we thought." Then one of them, Joseph Welzenbaum, a professor of computer science at the Massachusetts Institute of Technology, wrote a book saying that the project was fundamentally unsound and dangerous to pursue, partly, he said, because the computers' and humans' ways of thought would always be alien, and because knowledge might become limited to what a computer could undertand.

The elders of the artificial intelligence community reacted with outrage. Even those who agreed with his premises criticized the book as being too harsh in tone, too personal in its attacks. Computer journals have bristled over the last year with reviews, comments and replies provoked by Professor Weizenbaum's book, "Computer Power and Human Reason" (W. H. Freeman & Co., 1976). Now the controversy has spilled into the prestigious publication Science,

Continued on Page 34, Column 3

erals of his intention to back Mr. Cuomo all the way in an apparent effort to strengthen Mr. Cuomo's bid for the Liberal Party's nomination.

Titular Head Turns Elsewhere

If Mr. Cuomo wins the Liberal nomination but loses that of his own party, it would mean that the Governor would be supporting the Liberal candidate for Mayor rather than the Democratic one.

When Mr. Badne was asked about the Carey move, disclosed in The New York Times yesterday, he said it was difficult to believe "the titular head of the Democratic Party would support a candidate of another party rather than his own, especially after all his pretensions about the importance of an open primary."

"Apparently the Liberal Party is more important to him than the Democratic

Continued on Page 23, Column 1

Casinos Bring Atlantic City Woes

By MARTIN WALDRON

Special to The New York Times

ATLANTIC CITY, May 7—Fires, the condemnation of slum housing and the destruction of small hotels are driving out many elderly and poor as this seaside resort begins to experience sociological consequences in a prelude to the opening of gambling casinos.

Under a measure in the New Jersey Legislature, casines could be opened only in large hotels. State and city officials hope to rebuild the deteriorating city, once the nation's premier convention center, by attracting $500 million worth of these new facilities.

Hotels and other businesses may be

Front P

SHOW SU

erected in an area now by slum housing, much of sought by speculators.

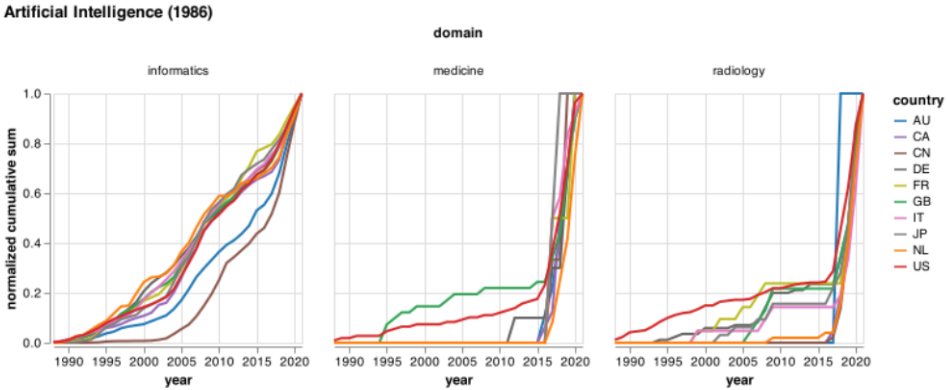
City officials deny tha policy to try to drive the poor from Atlan tic City. A third of the city's 40,000 per manent residents are on welfare, with unemployment over 20 percent.

About 10,000 of these—mostly black and Hispanic residents—live in the are expected to be in demand soon for th construction of casinos, restaurants an parking facilities.

In all, some 700 to 1,000 people have

Continued on Page 36, Column 3

Deep Learning, Generative AI, and Medicine

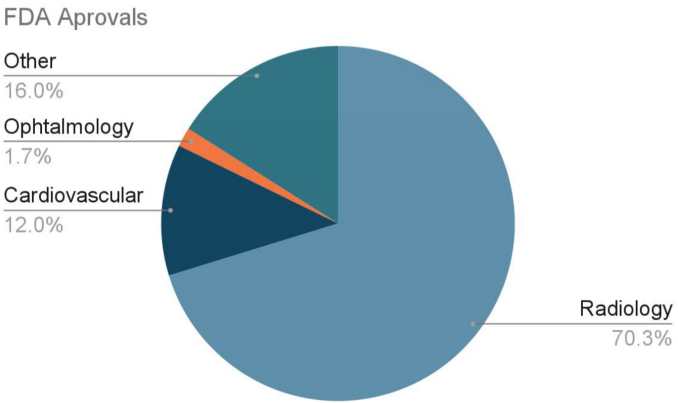


What is driving this publication acceleration?

- Hardware
- Algorithms
- **Availability of data!**

Implications of data-driven AI

The most FDA (USA) approved "AI" tools are in imaging (FDA 2022)



Why might imaging applications be so common?

- Do radiologist need extra help (relative to their peer clinicians)?
- Or is it about the availability of the data?
- **Application development might be driven more by data than need**

Early Reactions to Early AI (in Healthcare)

"Experts Argue Whether Computers Could reason, and if They Should"

Warner: "Old cardiologists just couldn't believe that a computer could do something better than a human." (Quoted in (McGrayne 2011))

"The most profoundly depressing of all ideas about the future of the human species is the concept of artificial intelligence." (Lewis Thomas, M.D., NEJM February 28, 1980 ("Artificial Intelligence" 1980))

Why?

- Artificial intelligence seems to threaten our sense of human uniqueness
- But what is unique about humans?

What are human brains good for? Practicing medicine?

"What, then, is the role of the biological brain. . . .It is expert at recognizing patterns, at perception, and at controlling physical actions, but it is not so well designed. . . for complex planning and long, intricate, derivations of consequences. **It is, to put it bluntly, bad at logic and good at Frisbee.**" (Clark 2003)

Andy Clark [a]

[a] The New Yorker

Human brain exceptionalism

"[W]hat is special about human brains, and what best explains the distinctive features of human intelligence, is precisely their ability to enter into deep and complex relationships with nonbiological constructs, props, and aids. This ability, however, does not depend on physical wire-and-implant mergers, so much as on our openness to information-processing mergers." (Clark 2003)

“Information-processing mergers” (Clark 2003)

- External objects that aid the mind’s reasoning
  - paper and pencil to do arithmetic
  - books for storing and recalling knowledge
  - Cell phones, computers
- Extended mind theory

Medicine makes extensive use of extended senses

- Eye glasses
- Diagnostic imaging
- Stethoscopes
- Microscopes
- Is the extended mind different?

Imperfect Decision Making

- Healthcare is filled with imperfect decision makers—clinicians
- Digital health is filled with imperfect decision support tools (AI)

Less Imperfect Decision Making [2]

AI-augmented clinical decision making

Australian Alliance for Artificial Intelligence in Healthcare

Friedman's Fundamental Theorem of Informatics (Friedman 2009)

"A person working in partnership with an information resource is 'better' than that same person unassisted"

Human + AI > Human > AI

Shift focus of AI tools from **end-to-end decision making** to ***supporting humans*** to make better clinical decisions

[2] Karin Verspoor

“Man-Computer Symbiosis” (Licklider 1960)

Man-Computer Symbiosis*

J. C. R. LICKLIDER†

Summary—Man-computer symbiosis is an expected development in cooperative interaction between men and electronic computers. It will involve very close coupling between the human and the electronic members of the partnership. The main aims are 1) to let computers facilitate formulative thinking as they now facilitate the solution of formulated problems, and 2) to enable men and computers to cooperate in making decisions and controlling complex situations without inflexible dependence on predetermined programs. In the anticipated symbiotic partnership, men will set the goals, formulate the hypotheses, determine the criteria, and perform the evaluations. Computing machines will do the routinizable work that must be done to prepare the way for insights and decisions in technical and scientific thinking. Preliminary analyses indicate that the symbiotic partnership will perform intellectual operations much will be coupled together very tightly, and that the resulting partnership will think as no human brain has ever thought and process data in a way not approached by the information-handling machines we know today.

B. Between “Mechanically Extended Man” and “Artificial Intelligence”

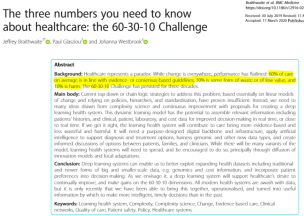
As a concept, man-computer symbiosis is different in an important way from what North[2] has called “mechanically extended man.” In the man-machine systems of the past, the human operator supplied the initiative, the direction, the integration, and the criterion. The

“The hope is that, in not too many years, human brains and computing machines will be coupled together very tightly and that the resulting partnership will think as no human brains as ever thought. . . .”

Central digital health question

How should we, imperfect decision makers, think **with** these imperfect AI tools (information mergers)?

Implications of data-driven AI: Data quality (Braithwaite, Glasziou, and Westbrook 2020)



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Main body: Current top-down or chain-logic strategies to address this problem, based essentially on linear models of change and relying on policies, hierarchies, and standardisation, have proven insufficient. Instead, we need to marry ideas drawn from complexity science and continuous improvement with proposals for creating a deep learning health system. This dynamic learning model has the potential to assemble relevant information including patients' histories, and clinical, patient, laboratory, and cost data for improved decision-making in real time, or close to real time, at the point of care. Such a system would enable clinicians to do the right thing for patients more often, less wasteful and harmful. It will need a purpose-designed digital backbone and infrastructure, apply artificial intelligence to support diagnosis and treatment options, harness genomic and other new data types, and create informed discussions of options between patients, families, and clinicians. While there will be many variants of the model, learning health systems will need to spread, and be encouraged to do so, principally through diffusion of innovation models and local adaptations.

Conclusion: Deep learning systems can enable us to better exploit expanding health datasets including traditional and newer forms of big and smaller-scale data, e.g. genomics and cost information, and incorporate patients' preferences into decision-making. As we envisage it, a deep learning system will support healthcare's desire to continually improve, and make gains on the 60-30-10 dimensions. All modern health systems are awash with data, but it is only recently that we have been able to bring this together, operationalised, and turned into useful information by which to make more intelligent, timely decisions than in the past.

Keywords: Learning health system, Complexity, Complexity science, Change, Evidence-based care, Clinical networks, Quality of care, Patient safety, Policy, Healthcare systems

These suboptimal processes will create suboptimal data. Should we be building AI tools based on these suboptimal data?

Thinking with (explaining) AI: Black Box AI

NEJM AI

NEJM AI 2024; 1 (6)
DOI: 10.1056/AIp2300103

PERSPECTIVE

Large Language Models Seem Miraculous, but Science Abhors Miracles

Peter Szolovits, Ph.D.[1]

Received: August 28, 2023; Revised: December 18, 2023; Accepted: January 2, 2024; Published: May 9, 2024

Thinking with (explaining) medicine: Black Dog Medicine

Do you have any concerns about Levi functioning in the healthcare system? Would you feel differently if it was an algorithm?

Conclusion

- Digital health is an imperative for modern medicine
- Digital health is as old as digital computers
  - There is a lot to learn from the past
- Digital health for decades has evoked ambiguous reactions
  - Don't panic about the present
- Digital health requires us to learn how to think with digital information mergers
  - Different clinical training is required

Parting provocation

It is a profoundly erroneous truism, repeated by all copy-books and by eminent people when they are making speeches, that we should cultivate the habit of thinking of what we are doing. The precise opposite is the case. ***Civilization advances by extending the number of important operations which we can perform without thinking about them.*** *Operations of thought are like cavalry charges in a battle — they are strictly limited in number, they require fresh horses, and must only be made at decisive moments.* (Whitehead 1958)

Thank you!

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