

Will Generative AI Revolutionize the Field of Clinical Decision Support?

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TECH

Bill Gates Says AI Is the Most Revolutionary Technology in Decades

'Entire industries will reorient around it,' the Microsoft co-founder says

“The development of AI is as fundamental as the creation of the microprocessor, the personal computer, the Internet, and the mobile phone,” he [wrote in a blog post](#) on Tuesday. “Entire industries will reorient around it. Businesses will distinguish themselves by how well they use it.”

4 of 5 largest companies

- Apple
- Microsoft
- Google/Alphabet
- Amazon

Why Influence Clinical Decisions?

- About 50% of health systems and hospitals had negative margins in 2022
- 1/3 of health care is waste*
- 10% to 20% of care is low-value care**
- Care evidence-based 50% of the time****
- 80% to 90% of costs are directly or indirectly determined by clinical decisions
- Quality determined by clinical decisions
- To improve quality of care and reduce costs at scale...

•*PMID: 31589283 DOI: [10.1001/jama.2019.13978](https://doi.org/10.1001/jama.2019.13978)

•***JAMA Netw Open.* 2021;4(2):e2037328. doi:10.1001/jamanetworkopen.2020.37328

****N Engl J Med* 2023; 388:142-153

*****N Engl J Med* 2003; 348:2635-2645

What Changes Clinical Decisions?

Predictors of Success	Adjusted OR
Automatic provision of decision support as part of workflow	112
Provision of decision support at the time and location of decision making	15
Provision of recommendation rather than just an assessment	7
Computer-based generation of decision support	6

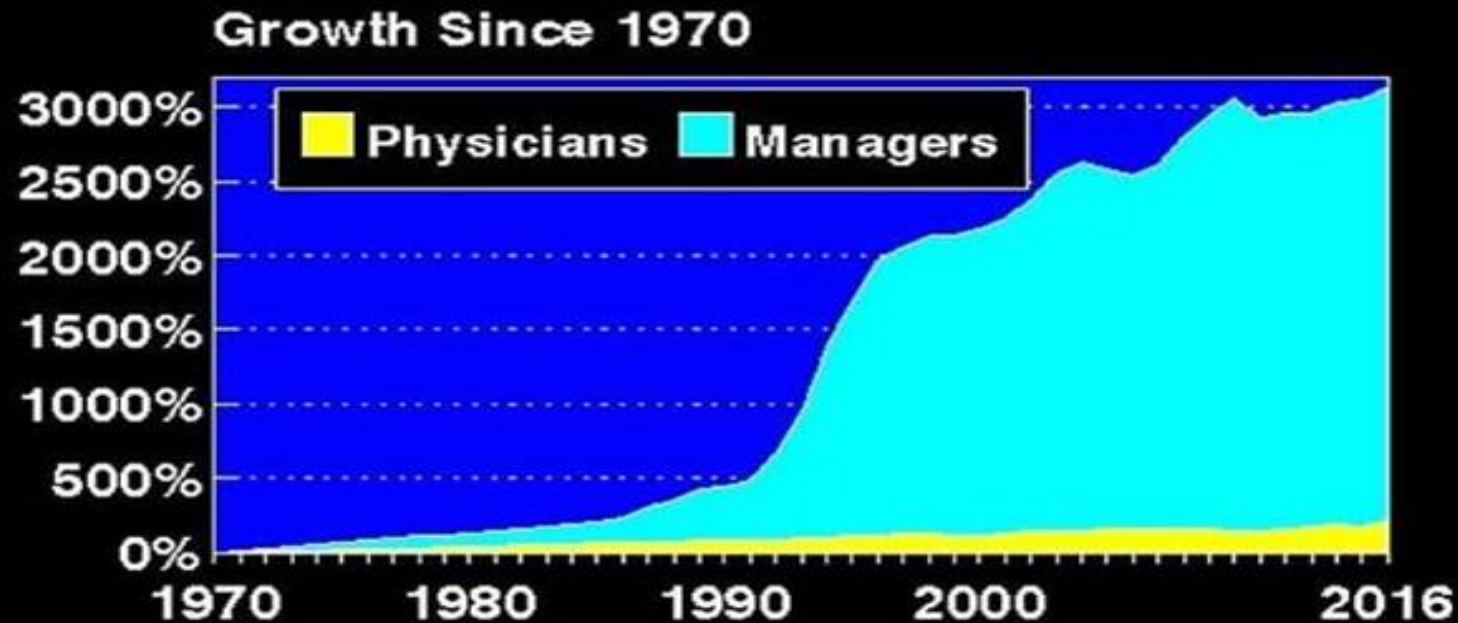
Source: Kawamoto K, Houlihan CA, Balas EA, Lobach DF. Improving clinical practice using clinical decision support systems: a systematic review of trials to identify features critical to success. *BMJ*. 2005 Apr 2;330(7494):765. PMID: 15767266

Clinical Decision Support

- Production, updates, maintenance requires....
 - Physicians
 - Nurses
 - Pharmacists
 - Medical informaticists
- Labor costs are high
- Hard to scale
- There is a shortage of practicing nurses, pharmacists, and physicians

Generative AI Automation Opportunity

Growth of Physicians and Administrators 1970-2016



Source: Bureau of Labor Statistics; NCHS; and Himmelstein/Woolhandler analysis of CPS
Note - Managers shown as moving average of current year and 2 previous years

ChatGPT 4 Generated CDS

- Clinical content, Informatics Review
 - Order sets
 - Care plans
 - Alerts
 - Templates
 - Diagnostic decision support
 - Patient decision support
- Clinical content
 - Very good, time saving
- Informatics/code (e.g., CQL, FHIR)
 - Initial review, it got some codes wrong
 - After training/fine tuning, getting better

Example: Order Sets



Order Set for Community-Acquired Pneumonia (CAP)

I. Admission Orders

1. Admit to appropriate unit (general medicine or telemetry, depending on severity)
2. Diagnosis: Community-Acquired Pneumonia
3. Condition: Stable/unstable (as appropriate)
4. Allergies: Document any known allergies

II. Vital Signs & Monitoring

1. Monitor vital signs every 4 hours or as needed
2. Pulse oximetry, continuous or intermittent as needed
3. Respiratory rate and effort
4. Daily weight

III. Activity

1. Bed rest with bathroom privileges or as tolerated
2. Incentive spirometry
3. Ambulate with assistance as tolerated

IV. Diet

1. Regular diet as tolerated
2. Encourage fluid intake, at least 2-3 liters/day

V. Laboratory

1. Complete blood count (CBC) with differential
2. Comprehensive metabolic panel (CMP)
3. Blood cultures (2 sets, prior to antibiotic administration)

Stop generating

Example: Order Sets

V. Laboratory

1. Complete blood count (CBC) with differential
2. Comprehensive metabolic panel (CMP)
3. Blood cultures (2 sets, prior to antibiotic administration)
4. Urinalysis
5. Sputum culture and Gram stain (if productive cough)
6. Influenza and respiratory syncytial virus (RSV) testing during flu season
7. Legionella and pneumococcal urinary antigen tests
8. Procalcitonin, if indicated

VI. Imaging

1. Chest X-ray, PA and lateral views
2. CT chest if needed for further evaluation or complications

VII. Medications

1. Empiric antibiotics (adjust based on culture results and allergies):
 - a. Outpatient (mild to moderate CAP):
 - Azithromycin 500mg PO on day 1, followed by 250mg PO daily on days 2-5, OR
 - Doxycycline 100mg PO BID for 5-7 days
 - b. Inpatient (moderate to severe CAP):
 - Ceftriaxone 1-2g IV daily, PLUS
 - Azithromycin 500mg IV/PO daily OR
 - Levofloxacin 750mg IV/PO daily
2. Analgesics/antipyretics for fever and pain:
 - Acetaminophen 500-1000mg PO/PR Q4-6h PRN (max 4g/24h) OR
 - Ibuprofen 400-600mg PO Q6h PRN

Example: Care Plan

SC

i would like an evidence-based care plan for pneumonia

1. Assessment and Diagnosis:
 - a. Obtain a thorough patient history, including recent illness, travel, and exposure to potential sources of infection.
 - b. Perform a physical examination, focusing on vital signs, lung auscultation, and signs of respiratory distress.
 - c. Order appropriate diagnostic tests (e.g., chest X-ray, sputum culture, blood culture, and complete blood count) to confirm the diagnosis and identify the causative pathogen.
 - d. Determine the severity of pneumonia using a validated assessment tool (e.g., CURB-65 or PSI).
2. Pharmacological Management:
 - a. Initiate empiric antibiotic therapy based on local antimicrobial resistance patterns and guidelines (e.g., IDSA/ATS guidelines). Adjust the treatment regimen when culture results become available.
 - b. Administer appropriate supportive medications, such as antipyretics, analgesics, and bronchodilators, as needed.
 - c. Consider adjunctive corticosteroid therapy for specific cases, such as severe community-acquired pneumonia or in cases of refractory septic shock.
 - d. Monitor the patient for clinical improvement and possible adverse effects of the prescribed medications.
3. Oxygen and Respiratory Support:
 - a. Monitor oxygen saturation regularly and provide supplemental oxygen therapy as needed to maintain SpO₂ ≥ 92%.
 - b. Assess the patient's need for advanced respiratory support (e.g., noninvasive ventilation, mechanical ventilation) in case of respiratory failure or acute respiratory distress syndrome (ARDS).
4. Fluid and Nutrition Management:
 - a. Ensure adequate hydration by providing intravenous fluids, considering the patient's overall fluid balance and risk of fluid overload.
 - b. Encourage oral intake and provide nutritional support as needed to maintain or improve the patient's nutritional status.
5. Mobilization and Deep Breathing Exercises:
 - a. Encourage early mobilization to prevent complications associated with immobility (e.g., deep vein thrombosis, pressure ulcers).
 - b. Instruct the patient to perform deep breathing exercises and use an incentive spirometer to improve lung function and prevent atelectasis.
6. Patient and Family Education:
 - a. Educate the patient and family about pneumonia, its management, and prevention strategies, including ation and proper hand hygiene.

Example: Alert Creation

sc

please write a mammography alert. Women 40 to 75 it should fire and recommend a mammogram should a woman not have had a mammogram in the last year. please exclude women who had a bilateral mastectomy. please export in FHIR and CQL

```
library MammographyAlert version '1.0.0'

using FHIR version '4.0.1'

include FHIRHelpers version '4.0.1' called FHIRHelpers

codesystem "LOINC": 'http://loinc.org'
codesystem "SNOMED": 'http://snomed.info/sct'

code "Mammogram": '24627-2' from "LOINC" display 'Mammogram'
code "BilateralMastectomy": '23426006' from "SNOMED" display 'Bilateral mast

context Patient

define "AgeInYears":
  AgeInYearsAt(Now())

define "MammogramProcedures":
  [Procedure: "Mammogram"]
```

Example: Alert Creation

json

Copy code

```
{
  "resourceType": "Observation",
  "id": "bloodpressure",
  "status": "final",
  "code": {
    "coding": [
      {
        "system": "http://loinc.org",
        "code": "85354-9",
        "display": "Blood pressure panel with all children optional"
      }
    ],
    "text": "Blood pressure"
  },
  "subject": {
    "reference": "Patient/example"
  },
  "effectiveDateTime": "2023-04-02T10:30:00Z",
  "valueQuantity": {
    "value": 120,
    "unit": "mmHg",
    "system": "http://unitsofmeasure.org",
    "code": "mm[Hg]"
  },
  "component": [
    {
```

Is Written English The New Coding Language?

Clinical Logic

inclusion criterion

Vitamin D test ordered

exclusion criteria

males age > 70 years OR females age > 65 years

osteomalacia, vitamin D deficiency, osteoporosis, pathologic fracture, chronic kidney disease, intestinal malabsorption, cirrhosis, chronic liver failure, cystic fibrosis, inflammatory bowel disease, radiation enteritis, unspecified non-infectious colitis, bariatric surgery, hyperparathyroidism, chronic pancreatitis, COPD, obesity/BMI > 30, sarcoidosis, tuberculosis, histoplasmosis, coccidiomycosis, other fungal infections, berylliosis, malignant lymphomas, diabetes, history of falls



Translation

IF Lab test order = LAB535

NOT (gender = female AND age >= 70 years) OR (gender = male AND age >= 65 years)

NOT ICD-9 OR ICD-10 diagnosis codes

268.0, 268.1, 268.2, 268.9, 733.00, 733.01, 733.02, 733.03, 733.09, 733.10, 733.11, 733.12, 733.13, 733.14, 733.15, 733.16, 733.19, 733.20, 733.21, 733.22, 733.23, 733.24, 733.25, 733.26, 733.27, 733.28, 733.29, 733.30, 733.31, 733.32, 733.33, 733.34, 733.35, 733.36, 733.39, 733.40, 733.41, 733.42, 733.43, 733.44, 733.45, 733.46, 733.47, 733.48, 733.49, 733.50, 733.51, 733.52, 733.53, 733.54, 733.55, 733.56, 733.57, 733.58, 733.59, 733.60, 733.61, 733.62, 733.63, 733.64, 733.65, 733.66, 733.67, 733.68, 733.69, 733.70, 733.71, 733.72, 733.73, 733.74, 733.75, 733.76, 733.77, 733.78, 733.79, 733.80, 733.81, 733.82, 733.83, 733.84, 733.85, 733.86, 733.87, 733.88, 733.89, 733.90, 733.91, 733.92, 733.93, 733.94, 733.95, 733.96, 733.97, 733.98, 733.99, 800.0, 800.1, 800.2, 800.3, 800.4, 800.5, 800.6, 800.7, 800.8, 800.9, 801.0, 801.1, 801.2, 801.3, 801.4, 801.5, 801.6, 801.7, 801.8, 801.9, 802.0, 802.1, 802.2, 802.3, 802.4, 802.5, 802.6, 802.7, 802.8, 802.9, 803.0, 803.1, 803.2, 803.3, 803.4, 803.5, 803.6, 803.7, 803.8, 803.9, 804.0, 804.1, 804.2, 804.3, 804.4, 804.5, 804.6, 804.7, 804.8, 804.9, 805.0, 805.1, 805.2, 805.3, 805.4, 805.5, 805.6, 805.7, 805.8, 805.9, 806.0, 806.1, 806.2, 806.3, 806.4, 806.5, 806.6, 806.7, 806.8, 806.9, 807.0, 807.1, 807.2, 807.3, 807.4, 807.5, 807.6, 807.7, 807.8, 807.9, 808.0, 808.1, 808.2, 808.3, 808.4, 808.5, 808.6, 808.7, 808.8, 808.9, 809.0, 809.1, 809.2, 809.3, 809.4, 809.5, 809.6, 809.7, 809.8, 809.9, 810.0, 810.1, 810.2, 810.3, 810.4, 810.5, 810.6, 810.7, 810.8, 810.9, 811.0, 811.1, 811.2, 811.3, 811.4, 811.5, 811.6, 811.7, 811.8, 811.9, 812.0, 812.1, 812.2, 812.3, 812.4, 812.5, 812.6, 812.7, 812.8, 812.9, 813.0, 813.1, 813.2, 813.3, 813.4, 813.5, 813.6, 813.7, 813.8, 813.9, 814.0, 814.1, 814.2, 814.3, 814.4, 814.5, 814.6, 814.7, 814.8, 814.9, 815.0, 815.1, 815.2, 815.3, 815.4, 815.5, 815.6, 815.7, 815.8, 815.9, 816.0, 816.1, 816.2, 816.3, 816.4, 816.5, 816.6, 816.7, 816.8, 816.9, 817.0, 817.1, 817.2, 817.3, 817.4, 817.5, 817.6, 817.7, 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832.1, 832.2, 832.3, 832.4, 832.5, 832.6, 832.7, 832.8, 832.9, 833.0, 833.1, 833.2, 833.3, 833.4, 833.5, 833.6, 833.7, 833.8, 833.9, 834.0, 834.1, 834.2, 834.3, 834.4, 834.5, 834.6, 834.7, 834.8, 834.9, 835.0, 835.1, 835.2, 835.3, 835.4, 835.5, 835.6, 835.7, 835.8, 835.9, 836.0, 836.1, 836.2, 836.3, 836.4, 836.5, 836.6, 836.7, 836.8, 836.9, 837.0, 837.1, 837.2, 837.3, 837.4, 837.5, 837.6, 837.7, 837.8, 837.9, 838.0, 838.1, 838.2, 838.3, 838.4, 838.5, 838.6, 838.7, 838.8, 838.9, 839.0, 839.1, 839.2, 839.3, 839.4, 839.5, 839.6, 839.7, 839.8, 839.9, 840.0, 840.1, 840.2, 840.3, 840.4, 840.5, 840.6, 840.7, 840.8, 840.9, 841.0, 841.1, 841.2, 841.3, 841.4, 841.5, 841.6, 841.7, 841.8, 841.9, 842.0, 842.1, 842.2, 842.3, 842.4, 842.5, 842.6, 842.7, 842.8, 842.9, 843.0, 843.1, 843.2, 843.3, 843.4, 843.5, 843.6, 843.7, 843.8, 843.9, 844.0, 844.1, 844.2, 844.3, 844.4, 844.5, 844.6, 844.7, 844.8, 844.9, 845.0, 845.1, 845.2, 845.3, 845.4, 845.5, 845.6, 845.7, 845.8, 845.9, 846.0, 846.1, 846.2, 846.3, 846.4, 846.5, 846.6, 846.7, 846.8, 846.9, 847.0, 847.1, 847.2, 847.3, 847.4, 847.5, 847.6, 847.7, 847.8, 847.9, 848.0, 848.1, 848.2, 848.3, 848.4, 848.5, 848.6, 848.7, 848.8, 848.9, 849.0, 849.1, 849.2, 849.3, 849.4, 849.5, 849.6, 849.7, 849.8, 849.9, 850.0, 850.1, 850.2, 850.3, 850.4, 850.5, 850.6, 850.7, 850.8, 850.9, 851.0, 851.1, 851.2, 851.3, 851.4, 851.5, 851.6, 851.7, 851.8, 851.9, 852.0, 852.1, 852.2, 852.3, 852.4, 852.5, 852.6, 852.7, 852.8, 852.9, 853.0, 853.1, 853.2, 853.3, 853.4, 853.5, 853.6, 853.7, 853.8, 853.9, 854.0, 854.1, 854.2, 854.3, 854.4, 854.5, 854.6, 854.7, 854.8, 854.9, 855.0, 855.1, 855.2, 855.3, 855.4, 855.5, 855.6, 855.7, 855.8, 855.9, 856.0, 856.1, 856.2, 856.3, 856.4, 856.5, 856.6, 856.7, 856.8, 856.9, 857.0, 857.1, 857.2, 857.3, 857.4, 857.5, 857.6, 857.7, 857.8, 857.9, 858.0, 858.1, 858.2, 858.3, 858.4, 858.5, 858.6, 858.7, 858.8, 858.9, 859.0, 859.1, 859.2, 859.3, 859.4, 859.5, 859.6, 859.7, 859.8, 859.9, 860.0, 860.1, 860.2, 860.3, 860.4, 860.5, 860.6, 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NOT medication orders

!0440, !0441, !0443, !0444, !0445, !0446, !0447, !0448, , !0011, !0012, !0013, !0079, , !0015, !0016, !0017, !0018, , !0019, , !1074

NOT BMI > 30 kg/m2

THEN fire Best Practice Advisory with 11 override reasons

Visit related to pregnancy

Active anti-seizure, antifungal, anti-retroviral medications, glucocorticoids, or fungal sequestrants

 Join the ChatGPT plugin developer waitlist

Welcome to the OpenAI platform

Fine Tuning Experimentation

“... I was also playing around with order set generation, and GPT-3.5 actually made up some fake RxNorm codes (4.0 refused to give me the RxNorm codes and left placeholders). One cool thing I was able to do was give it a prompt to “Write a Python script that parses that JSON object and uses the NLM RxNorm web services to look up the correct RxNorm code or those medications.” and it did it, which was cool. It initially chose pretty random RxNorm codes, but then I told it to request PIN or IN codes, and it updated the program itself.”

Adam Wright, PhD
Vanderbilt

Overview

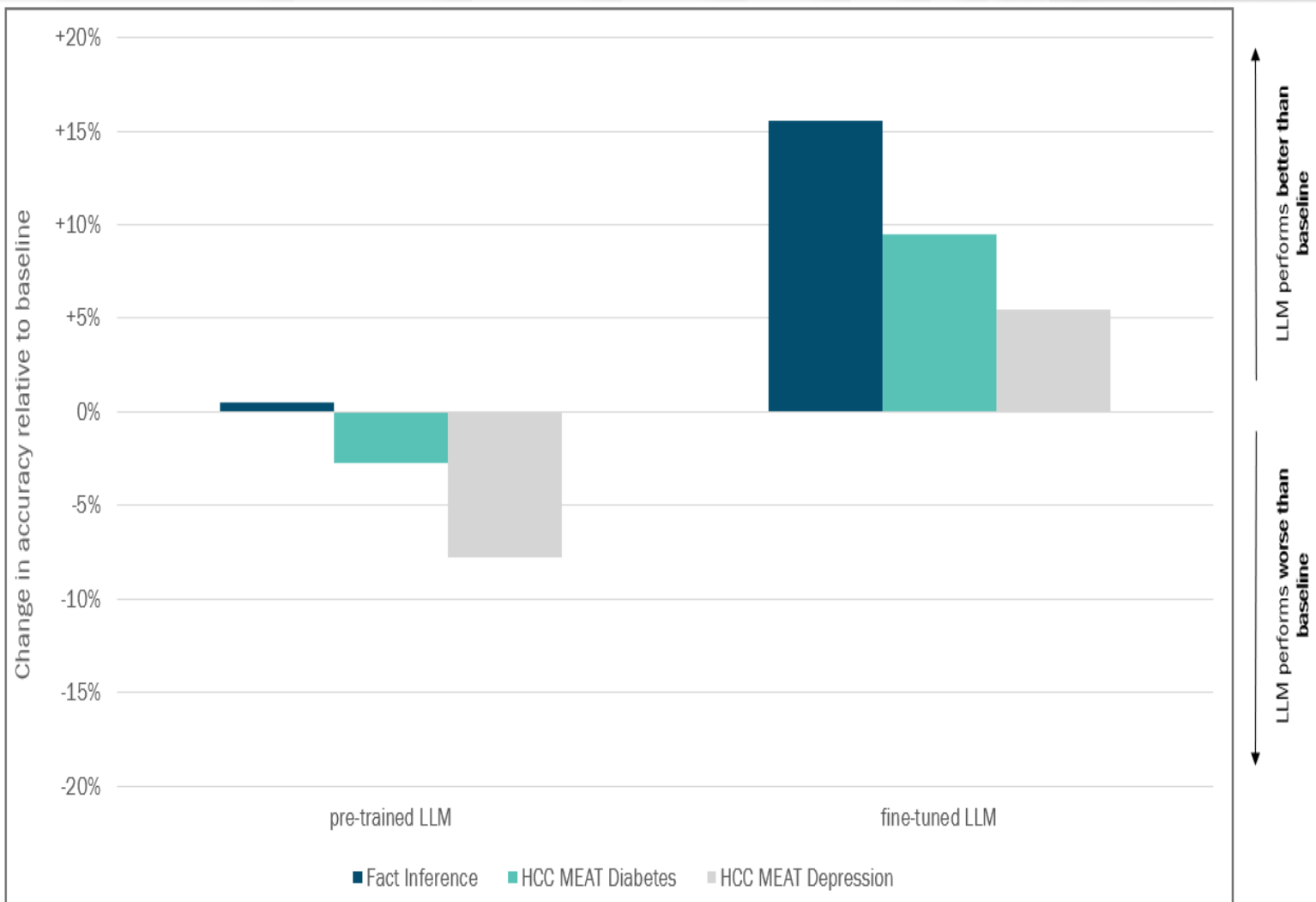
The OpenAI API can be applied to virtually any task that involves understanding or generating natural language, code, or images. We offer a spectrum of **models** with different levels of power suitable for different tasks, as well as the ability to **fine-tune** your own custom models. These models can be used for everything from content generation to semantic search and classification.

At a high level, fine-tuning involves the following steps:

- 1 Prepare and upload training data
- 2 Train a new fine-tuned model
- 3 Use your fine-tuned model



LLM PERFORMANCE RELATIVE TO CURRENT ML (BASELINE)



LLM Replaces

- NLP
- Extract concepts
- Relate concepts
- Map to codes
- Term sets
- Map logic to codes

SC

A 18 month old boy has tremors for about 6 months and delayed walking. What is the differential diagnosis?

1. Cerebral palsy: A group of disorders affecting movement and muscle tone, often caused by damage to the brain during development.
2. Hypotonia: Decreased muscle tone, which can be caused by a variety of underlying conditions, including genetic, metabolic, or neurological disorders.
3. Developmental coordination disorder (DCD): A motor skill disorder that affects coordination and movement.
4. Muscular dystrophy: A group of inherited diseases that cause progressive muscle weakness and loss of muscle mass.
5. Juvenile Parkinson's disease: A rare form of Parkinson's disease that affects children and teenagers, causing tremors, stiffness, and balance issues.
6. Essential tremor: A neurological disorder that causes involuntary shaking, usually in the hands.
7. Metabolic disorders: Conditions that affect the body's ability to process certain nutrients, such as amino acids, carbohydrates, or fats, which can lead to a variety of symptoms, including developmental delays and neurological problems.
8. Genetic disorders: Various genetic conditions can cause developmental delays and movement issues, such as Rett syndrome, Angelman syndrome, or Prader-Willi syndrome.

an 18 month old boy has tremors and a delay in walking. what should be i be thinking about

DDX

CLINICAL PLAN

Generate



1. Cerebral palsy: This is the most likely diagnosis for an 18-month-old boy presenting with tremors and a delay in walking. Cerebral palsy is a group of neurological disorders that affect movement, muscle tone, and posture. It is usually caused by brain damage occurring during fetal development or early infancy. The presence of tremors suggests possible involvement of the extrapyramidal system, which could be consistent with dyskinetic cerebral palsy.

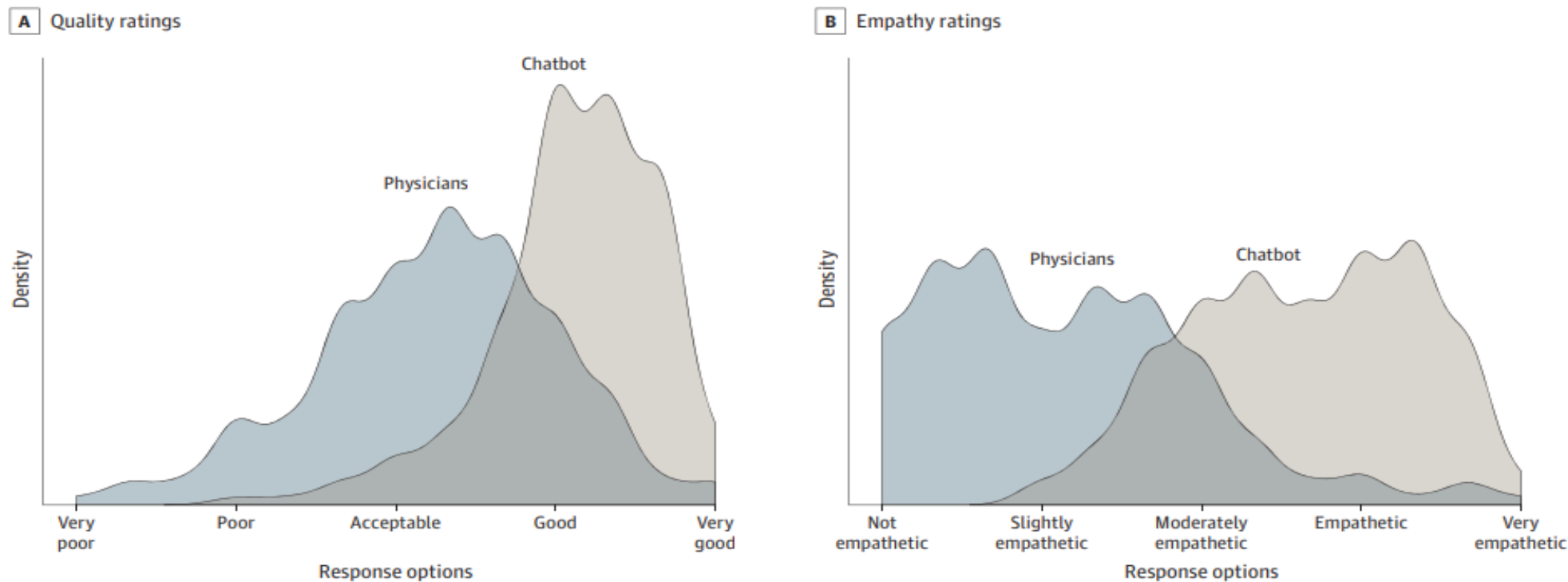
2. Developmental coordination disorder (DCD): Also known as motor skills disorder, DCD is characterized by difficulties in coordinating movements, leading to delays in achieving motor milestones such as crawling and walking. Although less common than cerebral palsy, it should be considered in children with delayed motor development without any obvious underlying cause.

3. Muscular dystrophy: This is a group of genetic diseases characterized by progressive weakness and degeneration of skeletal muscles. Duchenne muscular dystrophy (DMD) is the most common form affecting young boys, typically presenting between ages 1-6 years. Tremors are not a typical feature of DMD; however, they may occur due to muscle fatigue or compensatory mechanisms.

Comparing Physician and Artificial Intelligence Chatbot Responses to Patient Questions Posted to a Public Social Media Forum

John W. Ayers, PhD, MA; Adam Poliak, PhD; Mark Dredze, PhD; Eric C. Leas, PhD, MPH; Zechariah Zhu, BS; Jessica B. Kelley, MSN; Dennis J. Faix, MD; Aaron M. Goodman, MD; Christopher A. Longhurst, MD, MS; Michael Hogarth, MD; Davey M. Smith, MD, MAS

Figure. Distribution of Average Quality and Empathy Ratings for Chatbot and Physician Responses to Patient Questions



Kernel density plots are shown for the average across 3 independent licensed health care professional evaluators using principles of crowd evaluation. A, The overall quality metric is shown. B, The overall empathy metric is shown.

Generative AI For Patient Decision Support

- Patient develops severe acute left hip pain while running long distance. He has a history of a previous stress fracture in his leg from running. Normal left hip X-ray. Orthopedist orders an MRI. Open notes includes recommendation of MRI.

Patient Decision Support

Open Notes “cut and paste” into Chat GPT

1. **Imaging:** Proceed with the recommended MRI of the pelvis to evaluate for possible SI joint stress fracture, as well as an MRI of the lumbar spine to assess lumbar spondylosis.
2. **Activity modification:** Temporarily reduce or avoid high-impact activities like running, which may exacerbate the hip pain. Encourage low-impact exercises such as swimming or cycling to maintain fitness without aggravating the condition.
3. **Pain management:** Continue using over-the-counter anti-inflammatory medications, such as ibuprofen or naproxen, as needed for pain relief. Follow the recommended dosing and duration guidelines to minimize side effects.
4. **Physical therapy:** Once a definitive diagnosis has been made, consider referring patient to a physical therapist to develop a personalized exercise and rehabilitation program that addresses any muscle imbalances, flexibility issues, or core stability deficits contributing to his symptoms.
5. **Follow-up:** Schedule a follow-up appointment after the MRI results are available to discuss the findings, reassess the patient’s symptoms, and modify the treatment plan as needed.



A Precedent for Improving Coding?

Research: quantifying GitHub Copilot's impact on developer productivity and happiness

- Randomized controlled trial
- GitHub Copilot vs. no Copilot
- (n=95 coders)
- Write JavaScript
- 55% increase in productivity
- Improved developer happiness
- ($p < 0.01$)

CDS Improvement: Vanderbilt

- 7 alerts – suggestions for improvement
 - 36 AI generated
 - 29 human generated
- Gold standard independent group of humans
- Of 20 highest rated suggestions
 - 9 generated by Chat GPT
 - 11 by humans
- Improve health system CDS at scale

JOURNAL ARTICLE

Using AI-generated suggestions from ChatGPT to optimize clinical decision support



Siru Liu ✉, Aileen P Wright, Barron L Patterson, Jonathan P Wanderer, Robert W Turer, Scott D Nelson, Allison B McCoy, Dean F Sittig, Adam Wright

Journal of the American Medical Informatics Association, ocad072,
<https://doi.org/10.1093/jamia/ocad072>

Concerns About Patient Care

- Checks and balances
 - Clinician reviewers between the information and the patient
 - Clinician between the CQL/FHIR output and the EHR
 - Clinician between the CDS and the patient

Will AI Be Embedded In EHRs?

Microsoft and Epic expand strategic collaboration with integration of Azure OpenAI Service

DR. GPT WILL SEE YOU NOW—

GPT-4 will hunt for trends in medical records thanks to Microsoft and Epic

eClinicalWorks Brings ChatGPT and AI Models into EHR and Practice Management Solution

Future Potential Improvements

- Enterprise version
 - Customize
 - *Standardized terminologies*
 - RxNorm, LOINC, SNOMED codes, etc.
 - *More content sources*
 - (e.g., PubMed articles)
 - *Clinical language model*
 - (e.g., GatorTron)
 - *EHR APIs*
 - Train
 - *Humans with feedback*
 - Multi-modal large language models
 - When Chat GPT can consume all EHR information

"The most influential business thinker on Earth."

—The New Yorker

THE INNOVATOR'S DILEMMA

WHEN NEW TECHNOLOGIES CAUSE
GREAT FIRMS TO FAIL //

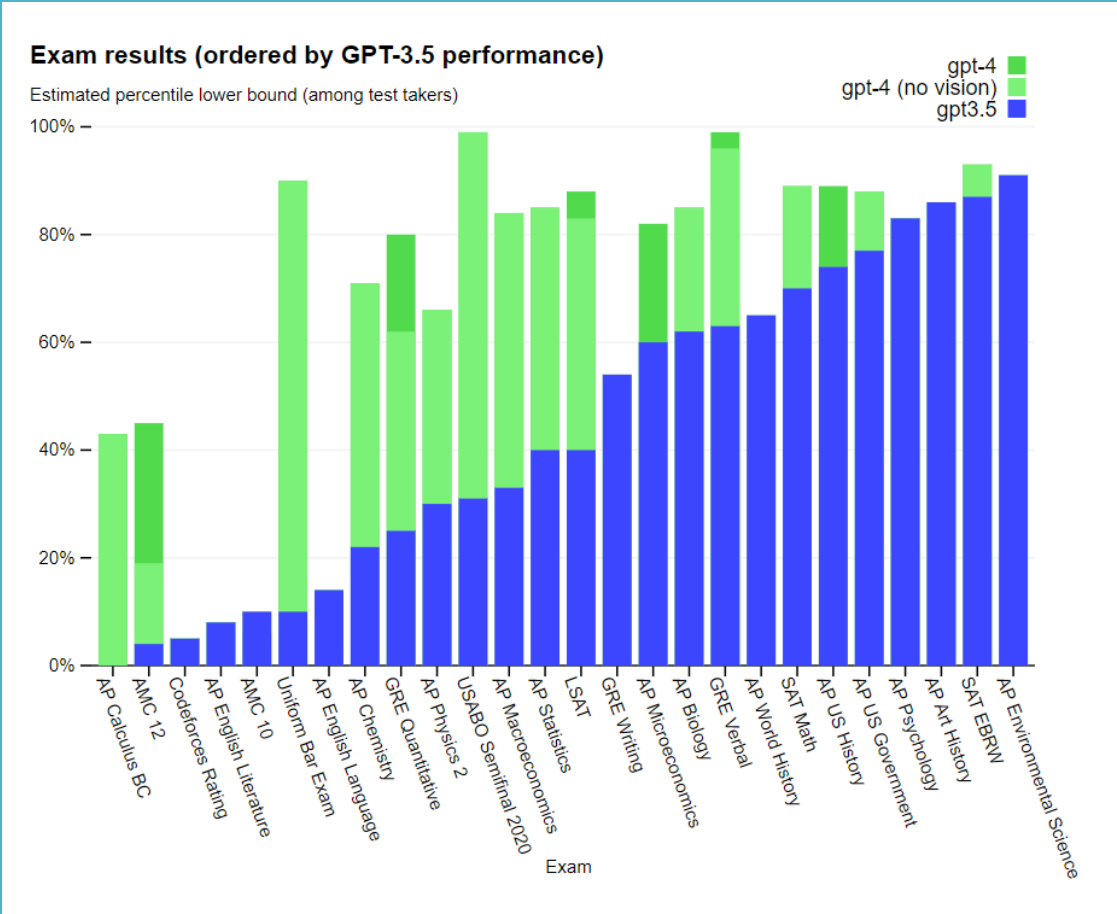
CLAYTON M.
CHRISTENSEN

BESTSELLING AUTHOR OF
THE INNOVATOR'S SOLUTION

HARVARD BUSINESS REVIEW PRESS

GPT-4

it passes a simulated bar exam with a score around the top 10% of test takers; in contrast, GPT-3.5's score was around the bottom 10%.



Trajectory



Conclusions

- Generative AI and LLMs hold great potential to improve clinical decision support
- Clinical content generation can improve efficiency
- Coding benefits from fine tuning/training
- Potential to...
 - Reduce CDS creation, update, and maintenance costs
 - Enable CDS at scale
- Potential impact....
 - Better quality of patient care at scale
 - Lower health care costs