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CENTRAL TO AMERICA'S ECONOMY

Office *of* Health Information *and* Data Science

STL 4.0: Artificial Intelligence at the Center of Opportunity

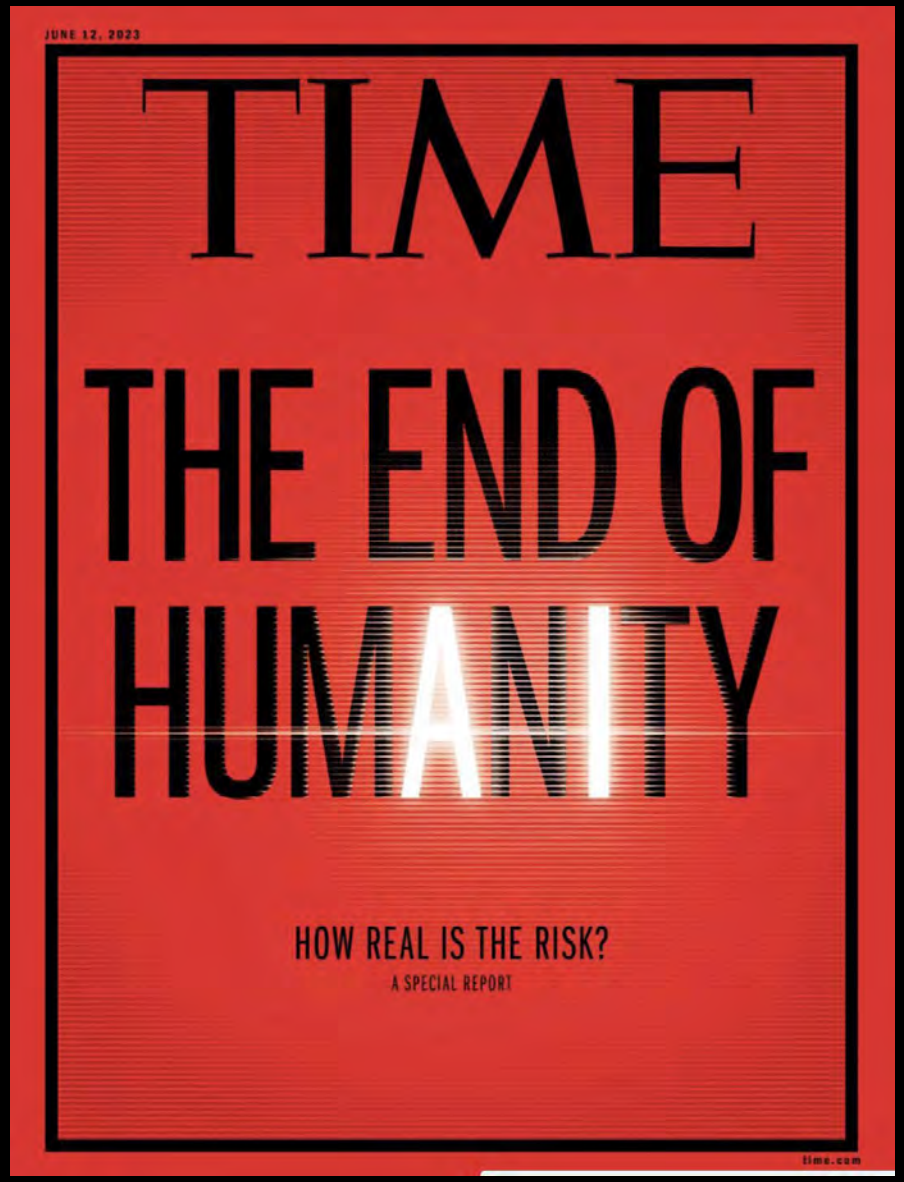
"The tools and technologies we've developed are really the first few drops of water in the vast ocean of what AI can do."

Fei-Fei Li (Stanford University)

Philip R.O. Payne, PhD, FACMI, FAMIA, FAIMBE, FIAHSI

Janet and Bernard Becker Professor and Director, Institute for Informatics, Data Science and Biostatistics (I^2DB)
Associate Dean for Health Information and Data Science and Chief Data Scientist
Professor, Department of Medicine, Division of General Medical Sciences
Washington University School of Medicine
Professor, Department of Computer Science and Engineering
Washington University McKelvey School of Engineering

Washington University School of Medicine in St. Louis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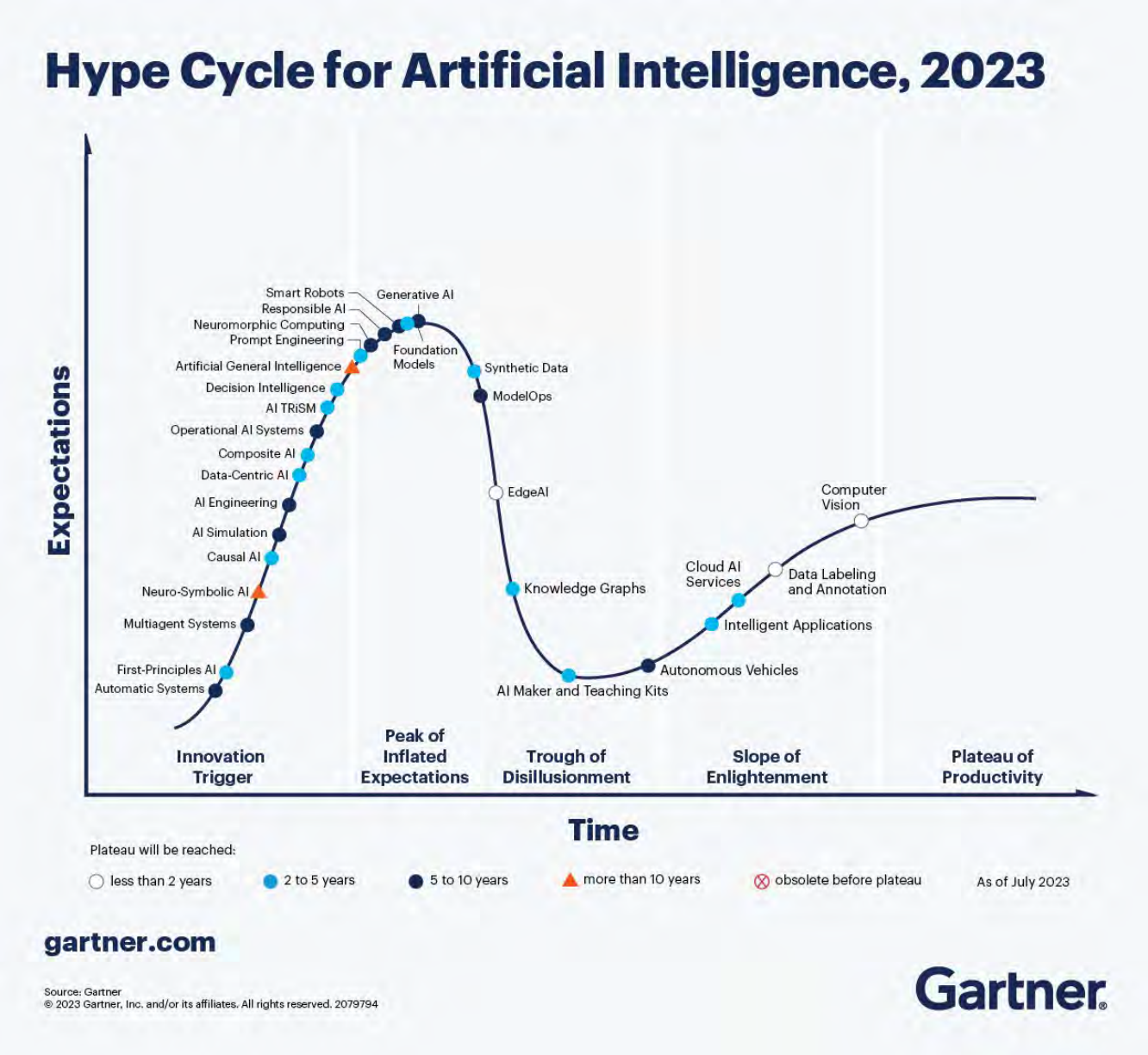
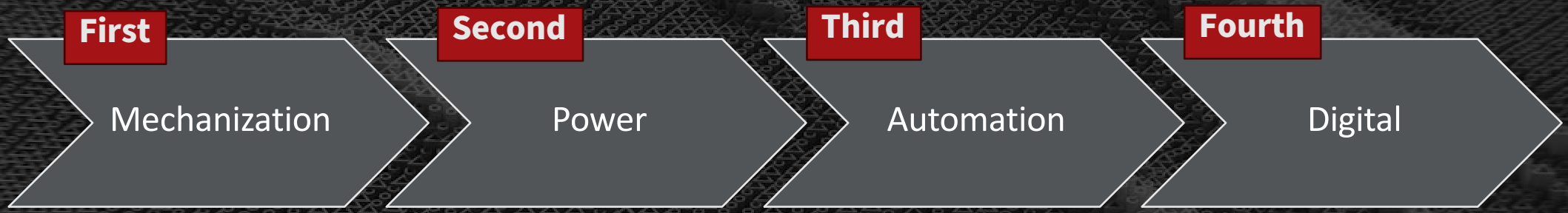


Technologies and methods for AI are rapidly evolving

AI = The Fourth Industrial Revolution?



"The fourth industrial revolution, however, is not only about smart and connected machines and systems. Its scope is much wider. Occurring simultaneously are waves of further breakthroughs in areas ranging from gene sequencing to nanotechnology, from renewables to quantum computing. It is the fusion of these technologies and their interaction across the physical, digital and biological domains that make the fourth industrial revolution fundamentally different from previous revolutions."

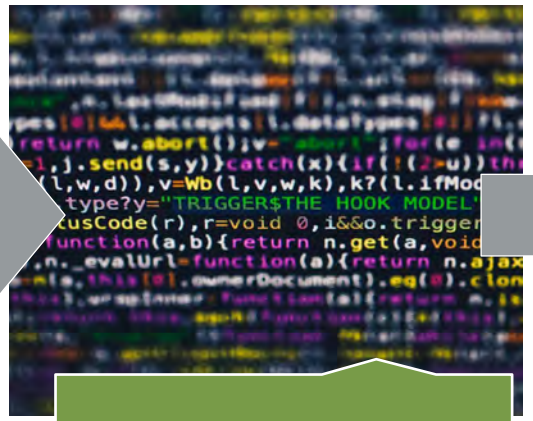
Klaus Schwab (World Economic Forum)

How do we create artificial intelligence (AI)?

Iterative Refinement

Acquire Data

Considerations include scale, diversity, volume, fairness, and labeling of data



Train Model

Multiple methods can be combined to identify meaningful patterns in data (**analytical models**) or generate novel content (**generative models**)

Deploy Model

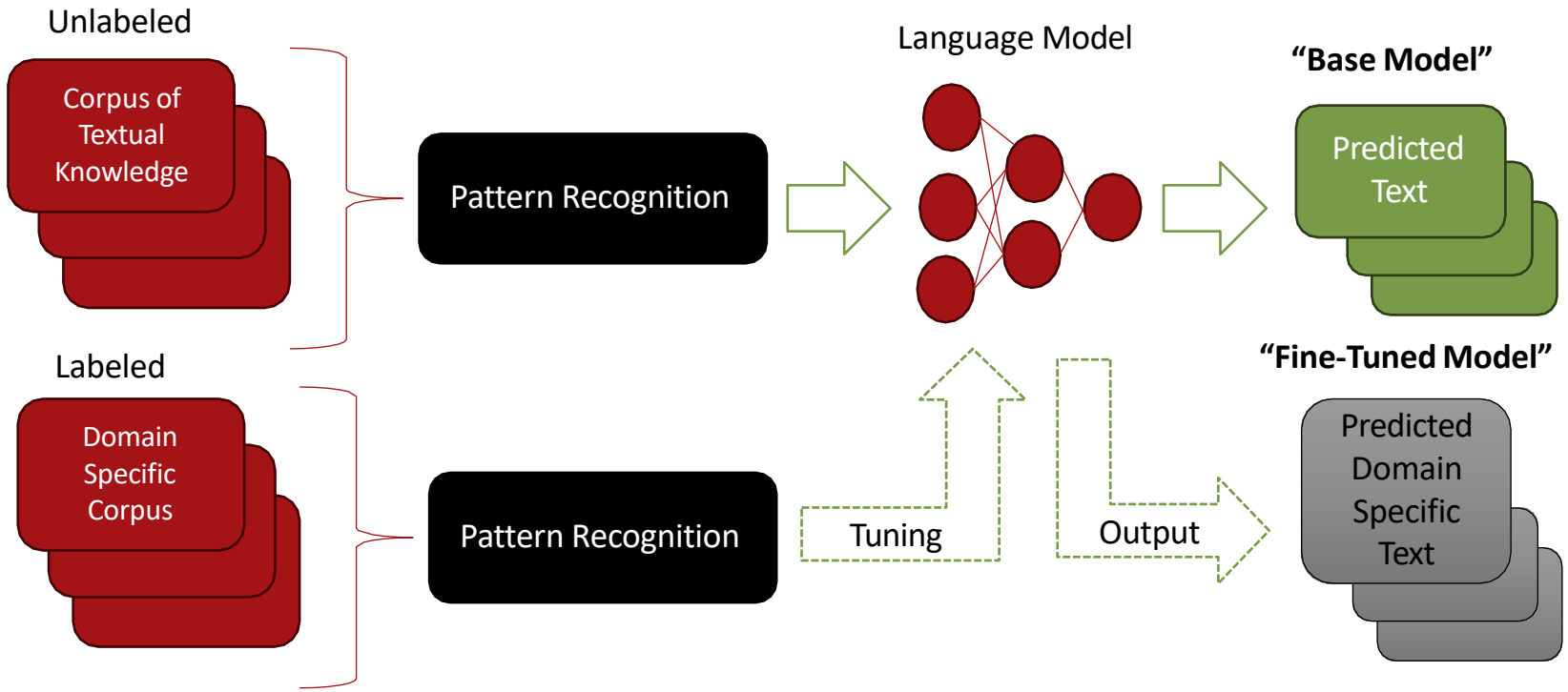
Delivery of models in the right time, place, and format is essential to success

Monitor and Optimize

Models are dynamic and change over time, requiring continuous optimization

A Deeper Dive: Large Language Models (LLMs)

LLM Generation and Operation



Common LLMs

OpenAI Chat GPT-4

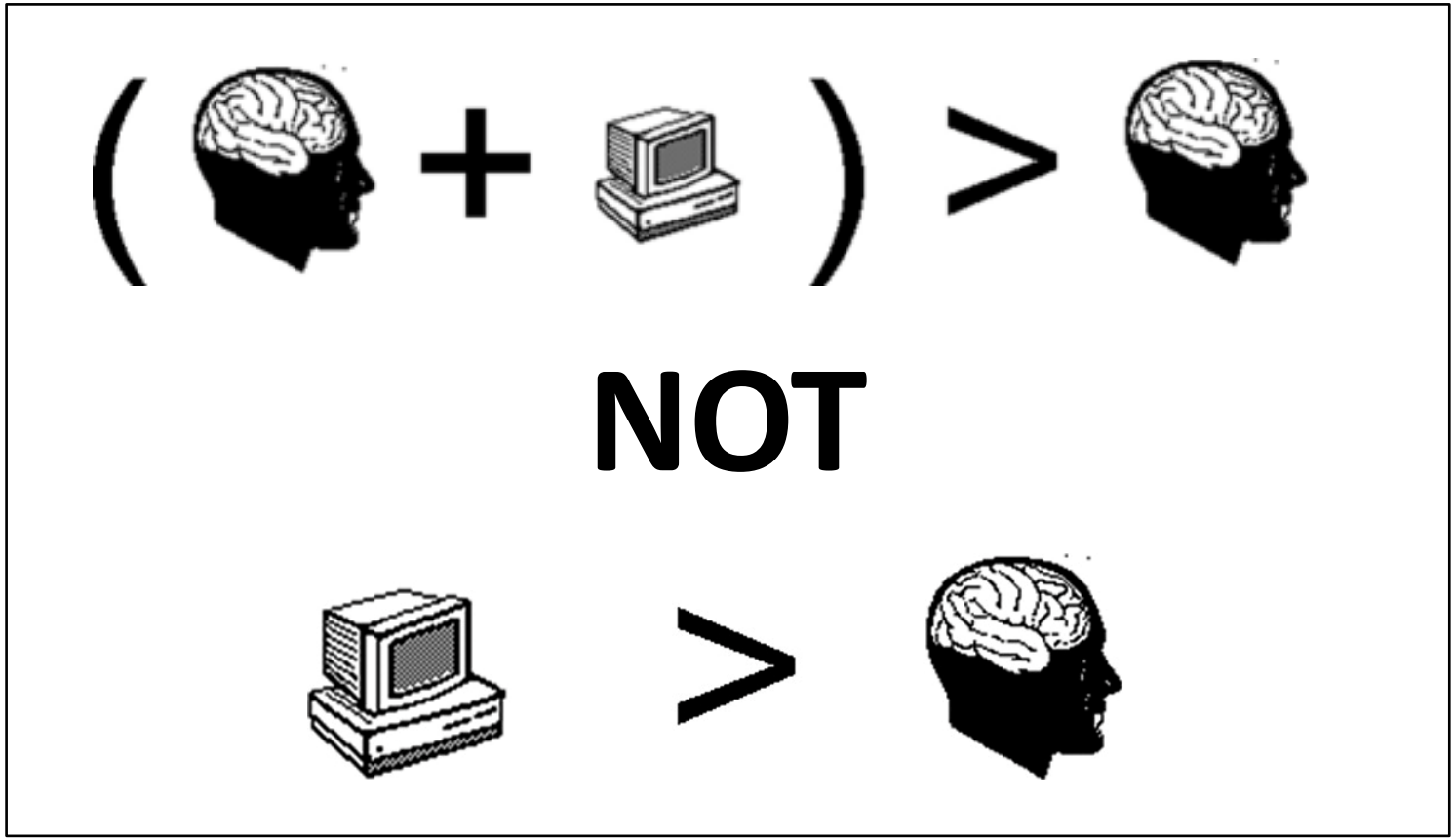
Gemini

Meta AI

These are instances of what is known as **Generative AI**, which are a class of algorithms that can be used to create new content, including audio, code, images, text, simulations, and videos.

AI + humans: enhancing decision making

- Humans make sense of the world around them by recognizing and applying patterns
- Computers can identify patterns faster and in greater numbers that humans, but first, such AI algorithms need to be trained.
- In creating and using such technologies, we must acknowledge:
  - Potential for bias
  - Limited by the nature of available training data
- The appearance of intelligence in modern AI is a function of speed, as opposed to innate intelligence or sentience



Source: Friedman CP. A "fundamental theorem" of biomedical informatics. Journal of the American Medical Informatics Association. 2009 Mar 1;16(2):169-70.

AI + digital transformation:
foundations for innovation and an improved human experience

"…a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies"

(Vial G. Understanding digital transformation: A review and a research agenda. The Journal of Strategic Information Systems. 2019 Jun 1;28(2):118-44.)

Four critical questions when designing and using modern AI tools and technologies

1) What are the **right tasks** when we seek to establish and sustain behaviors that leverage AI
2) Do we have the **right data** to support and enable the desired behaviors of AI?
3) How do we select the **right evidence standards** to determine if AI is safe, effective, and ethical?
4) How do we facilitate the **integration** of AI into “real world” settings?

What are the **right tasks** when we seek to establish and sustain behaviors that leverage AI?

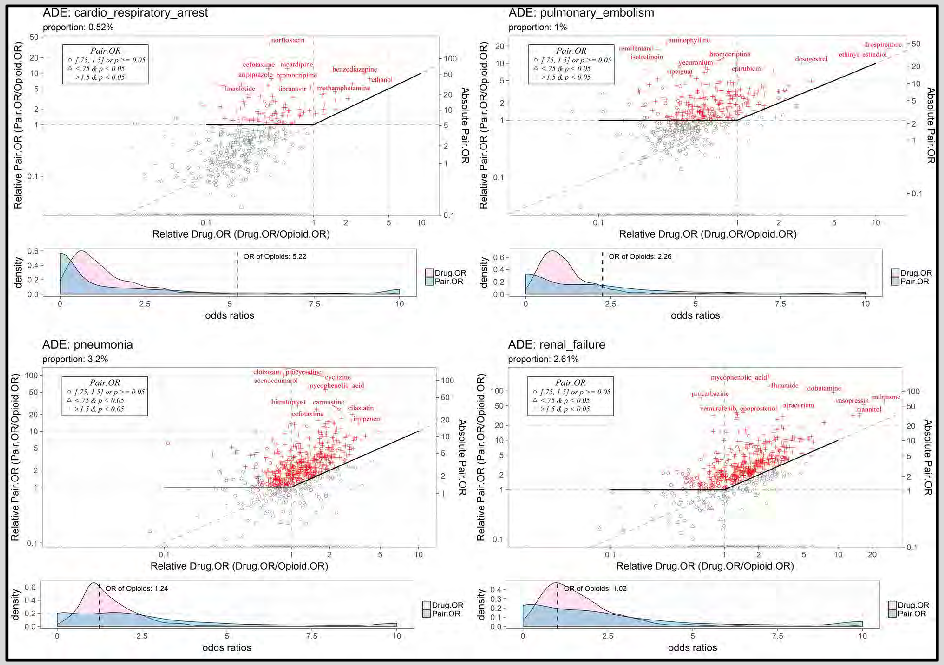
Research and Applications

Mining reported adverse events induced by potential opioid-drug interactions

Jinzhao Chen[1], Gaoyu Wu[2], Andrew Michelson[2], Zachary Vesoulis[3], Jennifer Bogner[4], John D. Corrigan[4], Philip R.O. Payne[2], and Fuhai Li[2]

https://doi.org/10.1093/jamiaopen/ooz073

"… the linkage of AEs and ODIs have not been well investigated. It is common for opioids to be prescribed to patients taking other medications (polypharmacy), often in the setting of complex medical conditions (e.g., traumatic brain injury) but medical providers lack general safety parameters to guide decision making when combining opioids with other medications … "



Fuhai Li, PhD

Andrew Michelson, MD

Do we have the **right data** to support and enable the desired behaviors of AI?

JAMIA Open, 4(3), 2021, 1–6
doi: 10.1093/jamiaopen/ooab062
Brief Communications

Brief Communications

Comparison of early warning scores for sepsis early identification and prediction in the general ward setting

Sean C. Yu[1,2], Nirmala Shivakumar[3], Kevin Betthauser[4], Aditi Gupta[1], Albert M. Lai[1], Marin H. Kollef[5], Philip R.O. Payne[1] and Andrew P. Michelson[1,5]

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Received 28 March 2021; Revised 15 June 2021; Editorial Decision 6 July 2021; Accepted 12 July 2021

ABSTRACT

The objective of this study was to directly compare the ability of commonly used early warning scores (EWS) for early identification and prediction of sepsis in the general ward setting. For general ward patients at a large, academic medical center between early-2012 and mid-2018, common EWS and patient acuity scoring systems were calculated from electronic health records (EHR) data for patients that both met and did not meet Sepsis-3 criteria. For identification of sepsis at index time, National Early Warning Score 2 (NEWS 2) had the highest performance (area under the receiver operating characteristic curve: 0.803 [95% confidence interval [CI]: 0.795–0.811], area under the precision recall curves: 0.130 [95% CI: 0.121–0.140]) followed NEWS, Modified Early Warning Score, and quick Sequential Organ Failure Assessment (qSOFA). Using validated thresholds, NEWS 2 also had the highest recall (0.758 [95% CI: 0.736–0.778]) but qSOFA had the highest specificity (0.950 [95% CI: 0.948–0.952]), positive predictive value (0.184 [95% CI: 0.169–0.198]), and F1 score (0.236 [95% CI: 0.220–0.253]). While NEWS 2 outperformed all other compared EWS and patient acuity scores, due to the low prevalence of sepsis, all scoring systems were prone to false positives (low positive predictive value without drastic sacrifices in sensitivity), thus leaving room for more computationally advanced approaches.

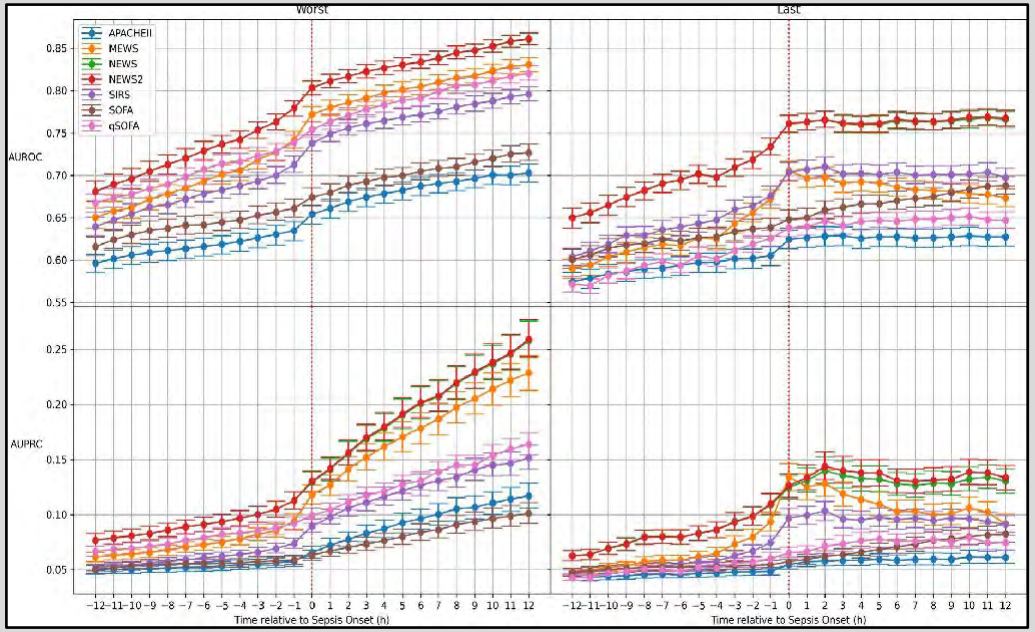
Key words: sepsis, early warning score, predictive analytics

LAY SUMMARY

Sepsis is a syndrome caused by an infection resulting in organ dysfunction and high rates of death, is implicated in nearly half of all inpatient deaths, and is the costliest inpatient condition in the United States. Early recognition and treatment are critical to the management of septic patients. As a result, over time, researchers have developed numerous early warning scores that use clinical measurements such as vital signs and lab results to generate a value that is indicative of the severity of illness and is predictive of clinical deterioration. Increasingly, these scores have been used as screening tools for sepsis management. To understand the comparative performance of these early warning scores in the general ward setting, electronic health records data were used to calculate the scores. Of the compared scores, the National Early Warning Score (NEWS 2) outperformed the rest. However, partially due to the low prevalence of sepsis in the general ward, even NEWS 2 was prone to false positives, highlighting the potential for improvement using more advanced computational methods.

https://doi.org/10.1093/jamiaopen/ooab062

"In this large, retrospective, single-center study with 45 776 unique encounters, sepsis occurred in 3.3% of all hospital admissions, yielding a longer length of hospitalization and a higher rate of in-hospital mortality. EWS and patient acuity scores—APACHE II, qSOFA, MEWS, NEWS, NEWS 2, and SOFA—had low discriminative ability for sepsis, leaving room for more computationally advanced approaches."



Andrew Michelson, MD

Aditi Gupta, PhD

How do we select the **right evidence standards** to determine if AI is safe, effective, and ethical?

RESEARCH OPEN ACCESS

Predictive Modeling for Clinical Features Associated With Neurofibromatosis Type 1

Stephanie M. Morris, MD*, Aditi Gupta, PhD*, Seunghwan Kim, MS, Randi E. Foraker, PhD, MA, David H. Gutmann, MD, PhD, and Philip R.O. Payne, PhD

Correspondence
Dr. Payne
prpayne@wustl.edu

Neurology: Clinical Practice December 2021 vol. 11 no. 6 497-505 doi:10.1212/CPJ.0000000000001089

Abstract

Objective

To perform a longitudinal analysis of clinical features associated with neurofibromatosis type 1 (NF1) based on demographic and clinical characteristics and to apply a machine learning strategy to determine feasibility of developing exploratory predictive models of optic pathway glioma (OPG) and attention-deficit/hyperactivity disorder (ADHD) in a pediatric NF1 cohort.

Methods

Using NF1 as a model system, we perform retrospective data analyses using a manually curated NF1 clinical registry and electronic health record (EHR) information and develop machine learning models. Data for 798 individuals were available, with 578 comprising the pediatric cohort used for analysis.

Results

Males and females were evenly represented in the cohort. White children were more likely to develop OPG (odds ratio [OR]: 2.11, 95% confidence interval [CI]: 1.11–4.00, $p = 0.02$) relative to their non-White peers. Median age at diagnosis of OPG was 6.5 years (1.7–17.0), irrespective of sex. Males were more likely than females to have a diagnosis of ADHD (OR: 1.90, 95% CI: 1.33–2.70, $p < 0.001$), and earlier diagnosis in males relative to females was observed. The gradient boosting classification model predicted diagnosis of ADHD with an area under the receiver operator characteristic (AUROC) of 0.74 and predicted diagnosis of OPG with an AUROC of 0.82.

Conclusions

Using readily available clinical and EHR data, we successfully recapitulated several important and clinically relevant patterns in NF1 semiology specifically based on demographic and clinical characteristics. Naive machine learning techniques can be potentially used to develop and validate predictive phenotype complexes applicable to risk stratification and disease management in NF1.

Neurofibromatosis type 1 (NF1) is one of the most common monogenic disorders, occurring in 1 of every 3,000 births. Caused by germline mutations in the *NF1* gene (OMIM: 613113), NF1 is a fully penetrant disorder; however, it is marked by extreme clinical variability, with highly discordant clinical phenotypes. At present, it is not possible at the time of diagnosis to

* These authors contributed equally to this work.

Department of Neurology (DHG), Washington University, St. Louis, MO; and Institute for Informatics (I2MM, AG, SK, REF, PROP), Washington University, St. Louis, MO.

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"Using readily available clinical and EHR data, we successfully recapitulated several important and clinically relevant patterns in NF1 semiology specifically based on demographic and clinical characteristics. Naive machine learning techniques can be potentially used to develop and validate predictive phenotype complexes applicable to risk stratification and disease management in NF1."

Table 4 Cross-Validation Performance Results for Predicting OPG, ADHD, and Plexiform Neurofibromas Among Children With Neurofibromatosis Type 1

Outcome	Features	F1 score	AUROC	Sensitivity	Specificity	PPV
OPG	Demographic	0.48 ± 0.1	0.46 ± 0.08	0.61 ± 0.21	0.38 ± 0.14	0.48 ± 0.1
	Demographic + clinical	0.74 ± 0.06	0.82 ± 0.05	0.75 ± 0.11	0.73 ± 0.04	0.74 ± 0.04
	Demographic + clinical + EHR	**0.79 ± 0.04**	**0.82 ± 0.06**	**0.78 ± 0.06**	**0.78 ± 0.07**	**0.78 ± 0.05**
ADHD	Demographic	0.6 ± 0.06	0.6 ± 0.07	0.69 ± 0.05	0.52 ± 0.1	0.59 ± 0.05
	Demographic + clinical	0.68 ± 0.01	0.74 ± 0.04	0.66 ± 0.08	0.71 ± 0.06	0.69 ± 0.06
	Demographic + clinical + EHR	**0.67 ± 0.03**	**0.74 ± 0.05**	**0.67 ± 0.05**	**0.68 ± 0.08**	**0.68 ± 0.06**
Plexiform neurofibromas	Demographic	0.45 ± 0.04	0.45 ± 0.05	0.37 ± 0.16	0.55 ± 0.22	0.46 ± 0.05
	Demographic + clinical	0.59 ± 0.03	0.62 ± 0.03	0.57 ± 0.06	0.61 ± 0.08	0.59 ± 0.06
	Demographic + clinical + EHR	**0.64 ± 0.06**	**0.69 ± 0.08**	**0.62 ± 0.07**	**0.66 ± 0.09**	**0.65 ± 0.1**

Bold: best performing model.
Abbreviations: ADHD = attention-deficit/hyperactivity disorder; AUROC = area under the receiver operating characteristic; EHR = electronic health record; OPG = optic pathway glioma; PPV = positive predictive value.

Aditi Gupta, PhD

Randi Foraker, PhD

How do we facilitate the **integration** of AI into "real world" settings?

Journal of the American Medical Informatics Association, 28(5), 2021, 1032–1037
doi: 10.1093/jamia/ocaa305
Advance Access Publication Date: 22 December 2020
Perspective

Perspective

Conceptual considerations for using EHR-based activity logs to measure clinician burnout and its effects

Thomas Kannampallil[1,2] **Joanna Abraham**[1,2] **Sunny S. Lou**[2] **and Philip R.O. Payne**[1,3]

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Received 29 June 2020; Editorial Decision 18 November 2020; Accepted 20 November 2020

ABSTRACT

Electronic health records (EHR) use is often considered a significant contributor to clinician burnout. Informatics researchers often measure clinical workload using EHR-derived audit logs and use it for quantifying the contribution of EHR use to clinician burnout. However, translating clinician workload measured using EHR-based audit logs into a meaningful burnout metric requires an alignment with the conceptual and theoretical principles of burnout. In this perspective, we describe a systems-oriented conceptual framework to achieve such an alignment and describe the pragmatic realization of this conceptual framework using 3 key dimensions: standardizing the measurement of EHR-based clinical work activities, implementing complementary measurements, and using appropriate instruments to assess burnout and its downstream outcomes. We discuss how careful considerations of such dimensions can help in augmenting EHR-based audit logs to measure factors that contribute to burnout and for meaningfully assessing downstream patient safety outcomes.

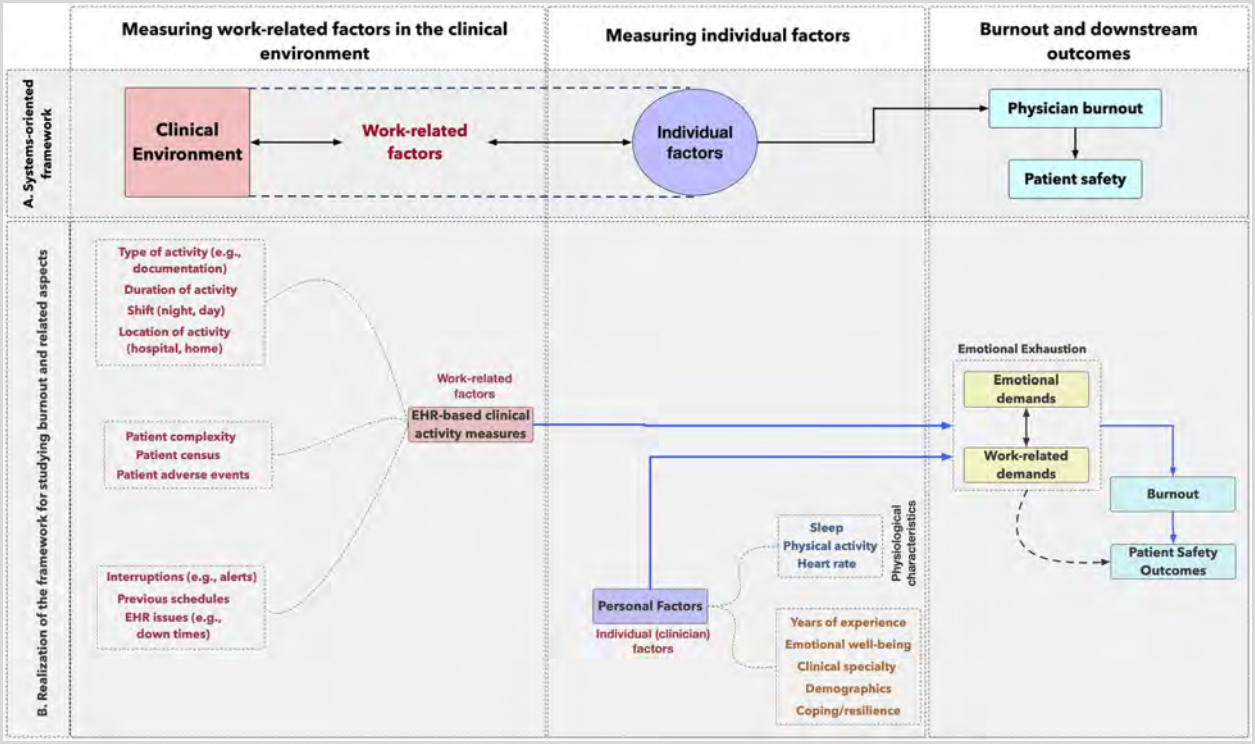
INTRODUCTION

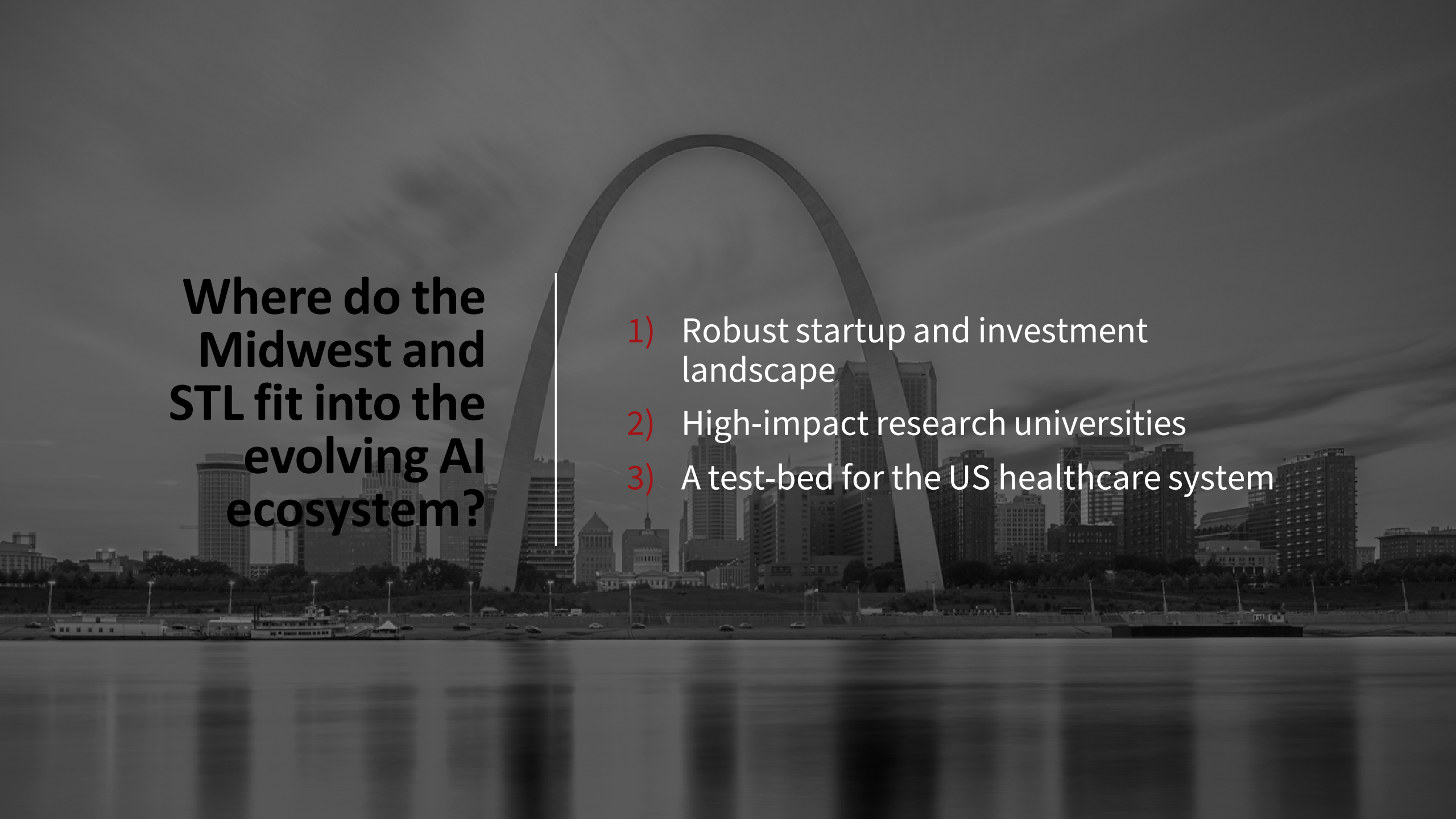
Burnout is a work-related syndrome involving 3 dimensions: emotional exhaustion, depersonalization, and a sense of low personal accomplishment.[1–3] Although burnout has been reported to be prevalent in nearly 50% of physicians,[4] a recent systematic review found that prevalence estimates among physicians range from 0%–80.5%, highlighting variations in the definitions of burnout and its assessment methods.[5] Although the causal contributors of burnout are multifactorial, clinician workload is a major contributor. For example, increased work hours, increased call burden, and dissatisfaction with work–life balance are all associated with an increased risk for developing burnout.[3,6] Furthermore, the ubiquitous use of electronic health record (EHR) systems has been cited as contributing to increased workload, leading to stress and burnout.[7–10] Factors associated with EHR use and its associated clinical workload can include excessive clinical documentation,[11] poor usability of the interfaces,[12] and unnecessary need for navigating across pages.[13]

Current informatics methods for evaluating burnout have focused primarily on quantifying clinician workload as 1 of its primary contributors. Traditionally, these efforts have relied on self-reports, participant journals, shadowing and time-motion studies, and focus groups.[14–19] More recently, researchers have leveraged audit logs of EHR-based activities as a source for tracking clinician workload. Studies have used audit logs to measure administrative burden,[8] cognitive load,[20,21] interruptions,[10,22] medication ordering,[16] interface navigation,[23,24] clinical documentation,[23,25] and out-of-office work.[7,27] However, few studies have explored the relationship of such workload with burnout,[7,28–33] and direct measurement of burnout using such techniques remains limited (see exceptions [32,33])

https://doi.org/10.1093/jamia/ocaa305

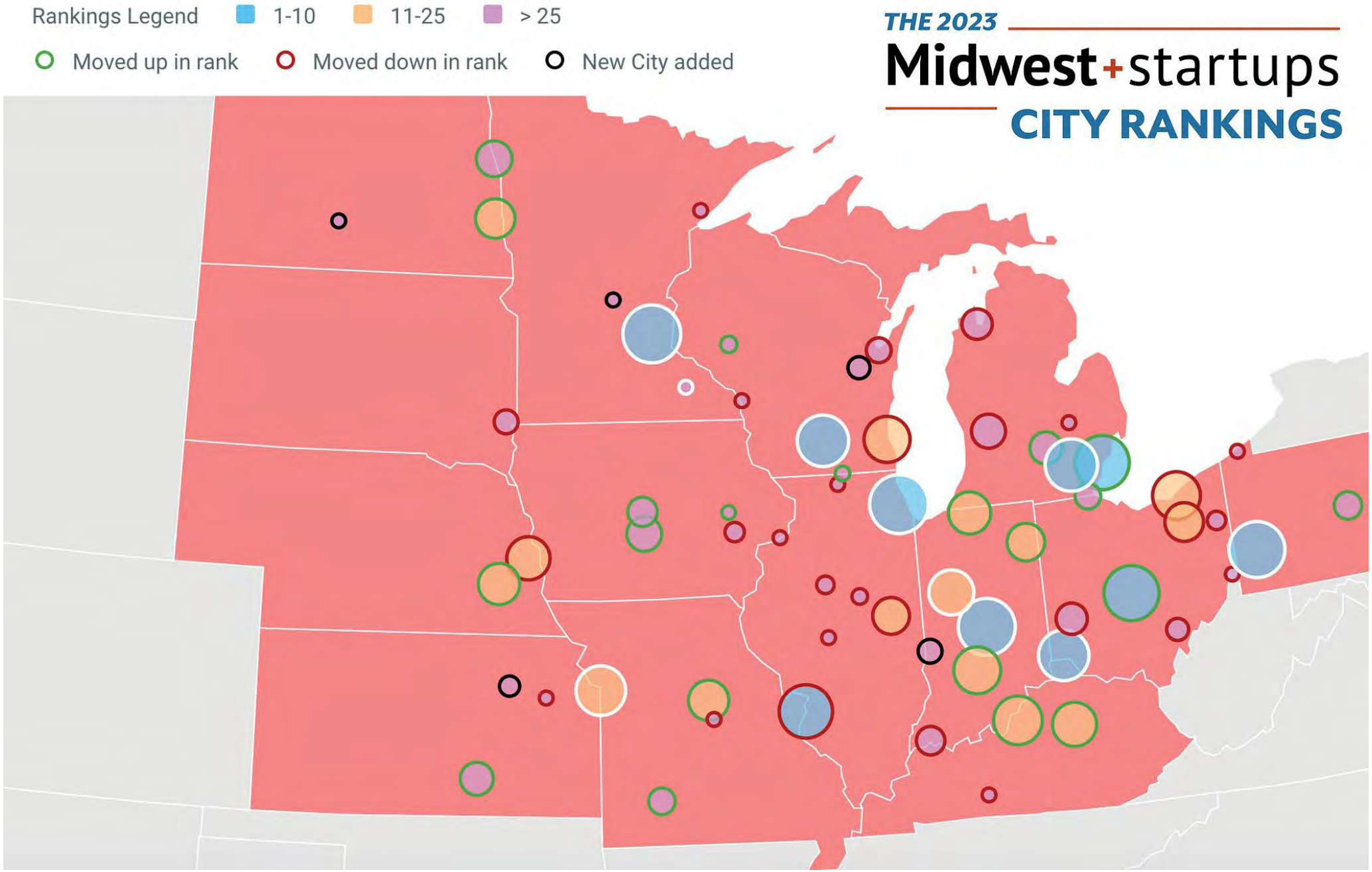
"Burnout is a significant threat to clinician well-being and consequently to the safety of patients under their care. In this perspective, we described 3 considerations for using EHR-based activity logs for measuring burnout—standardizing measurements, applying complementary measurements, and evaluating outcomes such as errors and clinical decisions that are also temporally aligned to burnout."





Where do the Midwest and STL fit into the evolving AI ecosystem?

1) Robust startup and investment landscape
2) High-impact research universities
3) A test-bed for the US healthcare system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Moved up in rank
Moved down in rank
New City added
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COMMENTARY

How research universities are evolving to strengthen regional economies

Case studies from the Build Back Better Regional Challenge

Joseph Parilla and Glencora Haskins
February 9, 2023

Washington University in St. Louis

SAINT LOUIS UNIVERSITY

UMSL University of Missouri–St. Louis

"America's network of research universities is one of its greatest sources of talent, entrepreneurship, and research and development—three inputs that in combination can fuel prosperity in the regions that surround those universities."

A “testbed” for the US Healthcare system

- A complex landscape of tertiary, regional, and community- level healthcare providers and organizations
- Urban, suburban, exurban, and rural geographies
- Diverse socio-economic, racial, and ethnic population groups
- Surrounding ecosystem of healthcare-adjacent organizations:
  - Payers
  - Pharmacy Benefits Managers (PBMs)
  - Research and innovation
  - Technology
  - Workforce
  - Government (VA)

COUNTY EXECUTIVE PAGE UNVEILS NEW COUNTY BRANDING

County Executive Dr. Sam Page unveiled Saint Louis County's new logo and branding at the State of the County address on January 10, 2024.

HOME / GOVERNMENT / COUNTY EXECUTIVE / COUNTY EXECUTIVE NEWS / COUNTY EXECUTIVE PAGE UNVEILS NEW COUNTY BRANDING

ST. LOUIS COUNTY, MO (January 10, 20
on January 10.

"Paired with our new county logo is a new county slogan: Opportunity Central. This line speaks to the many possibilities the county holds for people of all kinds. It serves as an invitation for businesses to come and thrive..."

prpayne@wustl.edu

Washington University in St. Louis
School of Medicine

Institute *for* Informatics,
Data Science *and* Biostatistics (I²DB)

i2db.wustl.edu | OHIDSadmin@wustl.edu | @WashUi2db

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Overview

- St. Louis Economy
- Employer Survey
- Spotlight on Startups and Job Creation
- Spotlight on Health Care

St. Louis Economy

Overview

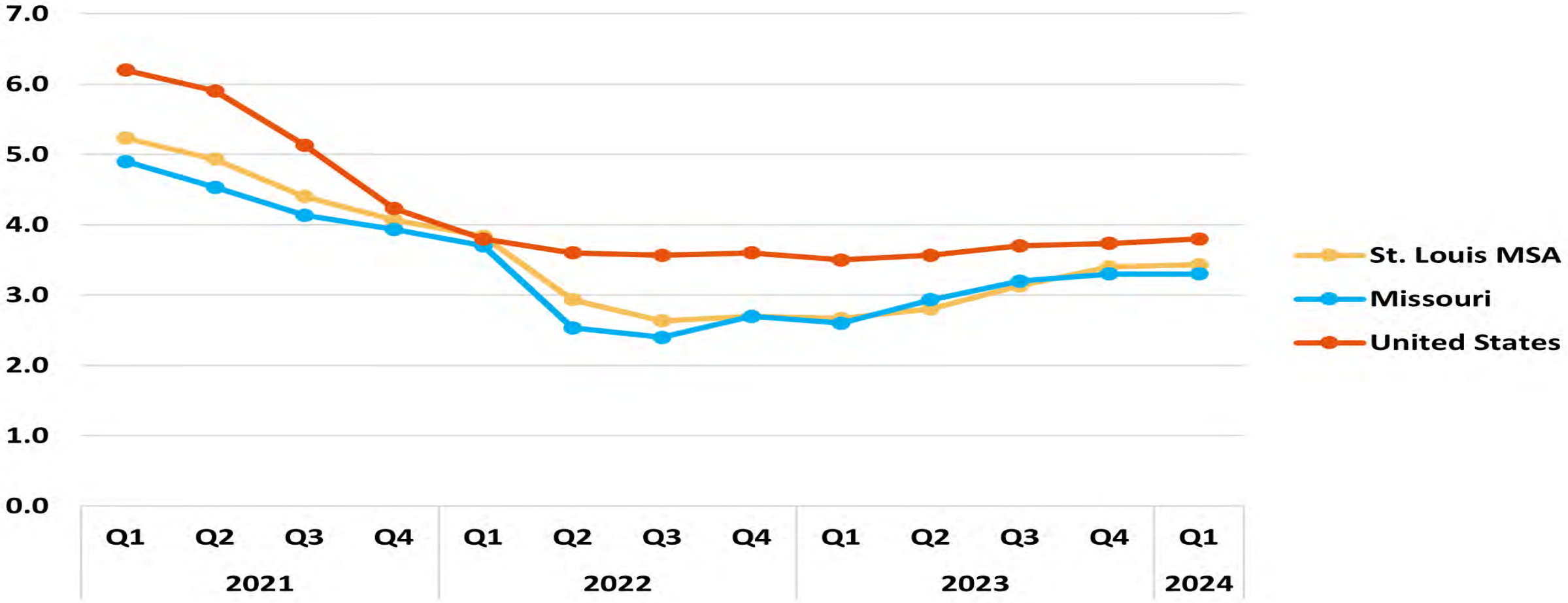
1,495,200

St. Louis MSA Workforce

May 2024

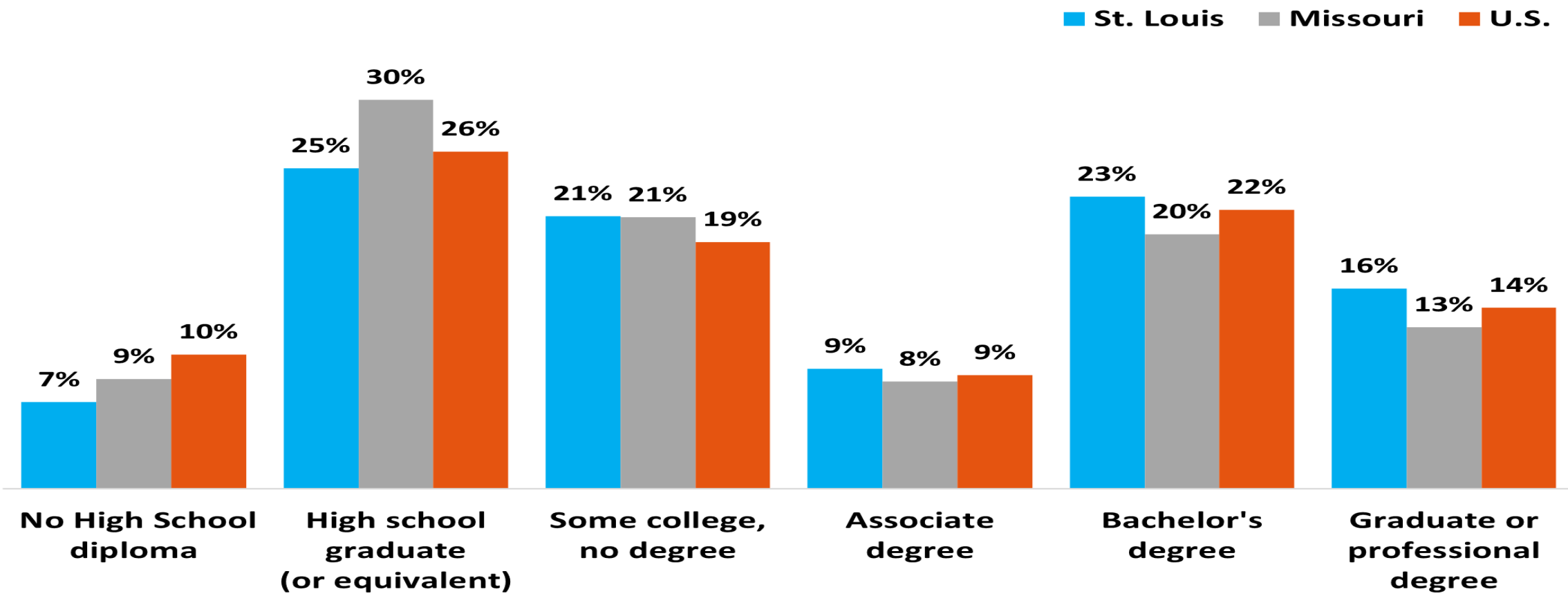
Economic Overview

Seasonally Adjusted Unemployment Rate by Quarter



Educational Attainment

Educational Attainment of the Population



Education Pays

Education affects both earning and unemployment

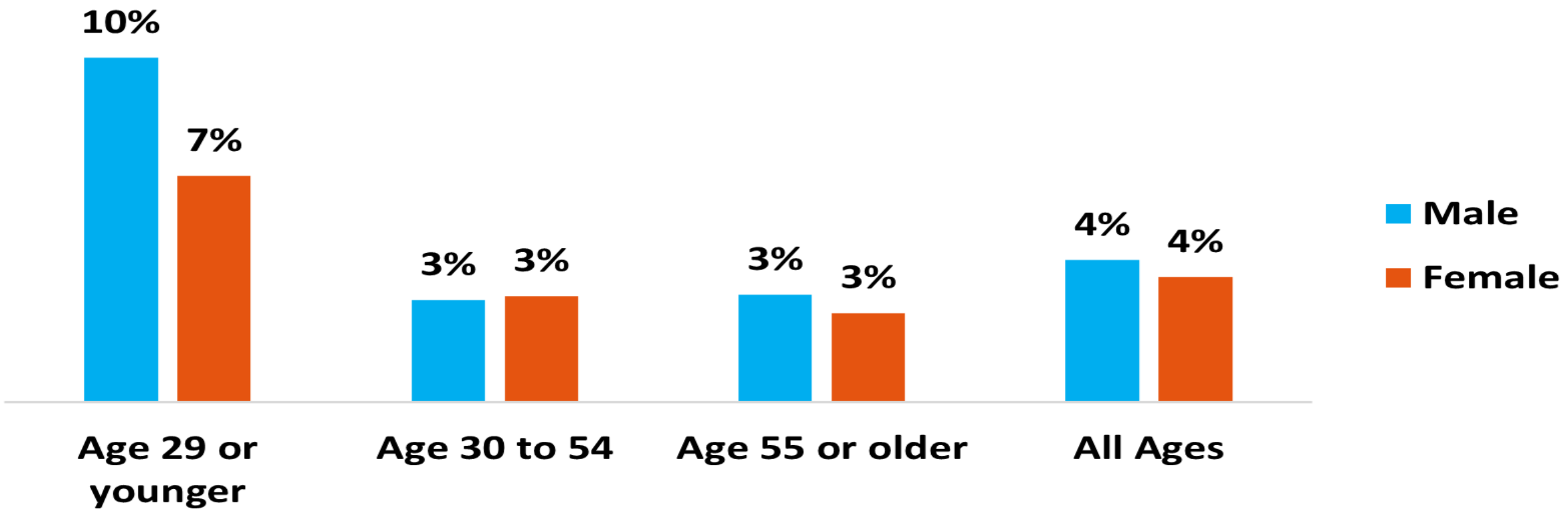
Biggest salary jump with 4-year degree

Education post-HS provides stability

	Unemployment Rates	Educational Attainment	Median Earnings
Missouri	7.6%	Less than high school graduate	$28,414
	4.1%	High school graduate (includes equivalency)	$35,612
	3.0%	Some college or associate's degree	$41,874
	1.4%	Bachelor's degree or higher	$64,294
St. Louis MSA	9.0%	Less than high school graduate	$29,787
	5.6%	High school graduate (includes equivalency)	$36,458
	3.0%	Some college or associate's degree	$44,825
	1.7%	Bachelor's degree or higher	$73,019

Economic Overview

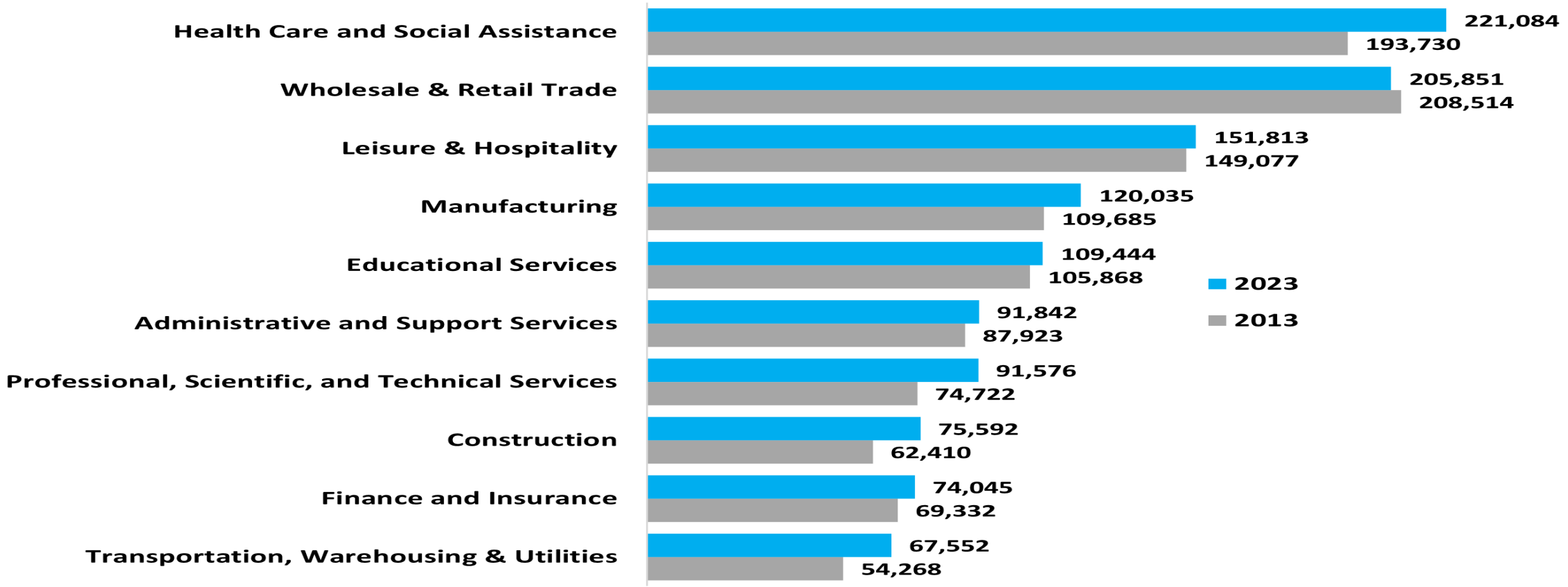
St. Louis MSA Unemployment Rates by Age and Sex



Economic Overview

14% growth in healthcare in the last decade

Top 10 St. Louis MSA Industry Clusters



Employer Survey

Methodology

Live interview survey of St. Louis MSA employers

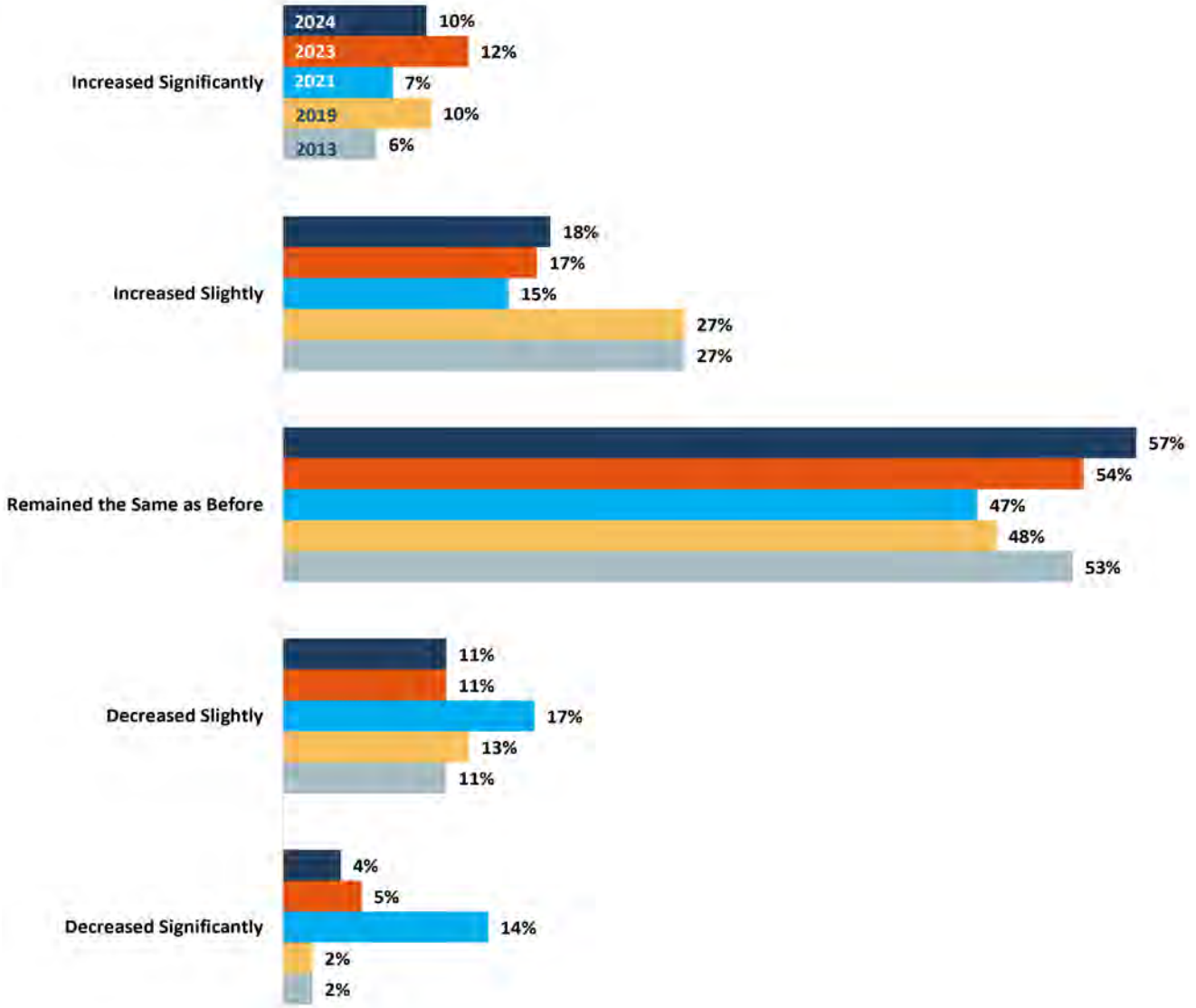
Each interview takes about 20 minutes

Employment Impacts

Change in Employment Levels over the Last 12 Months

Nearly 30% of companies hired employees in the last 12 months

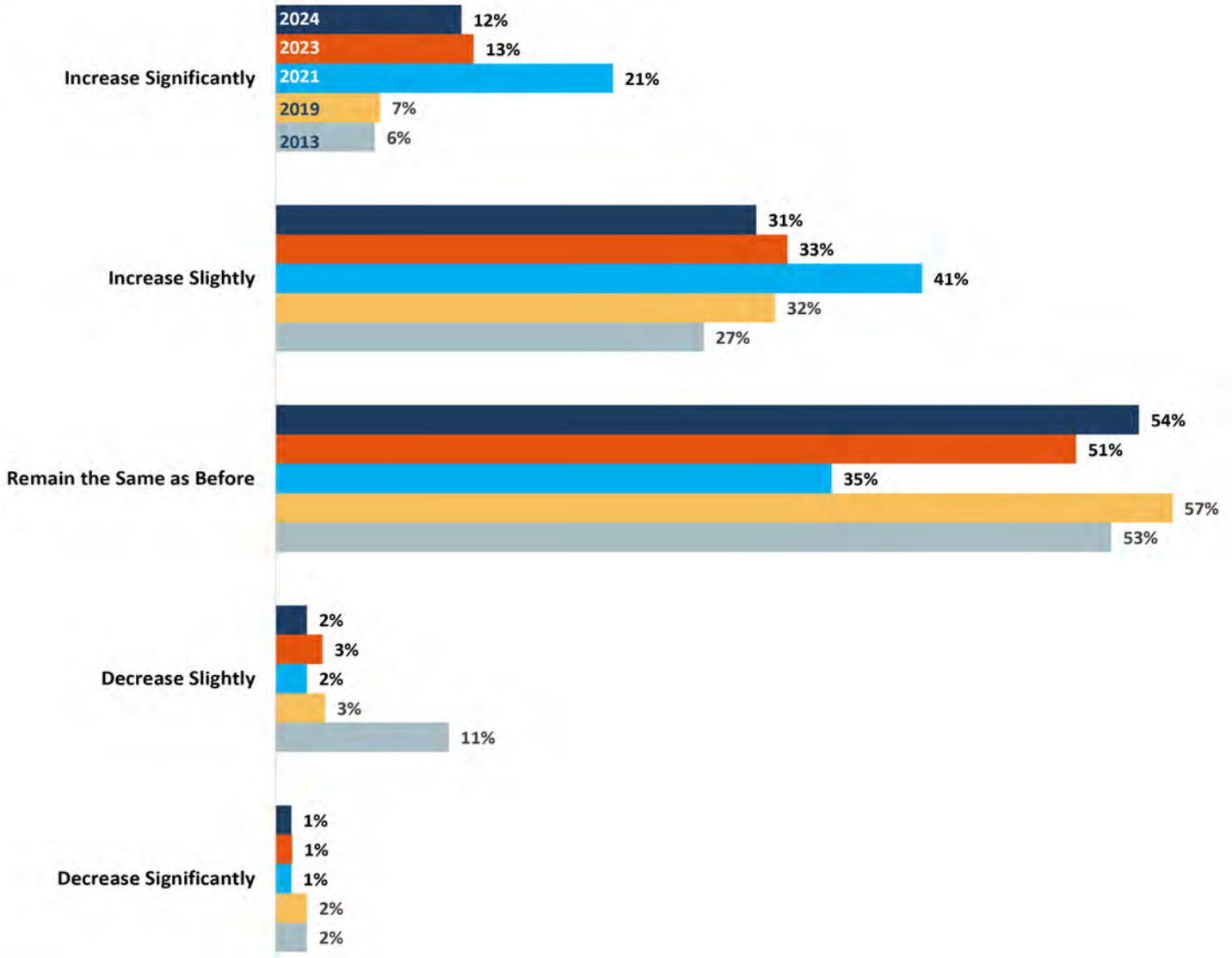
15% cut employees



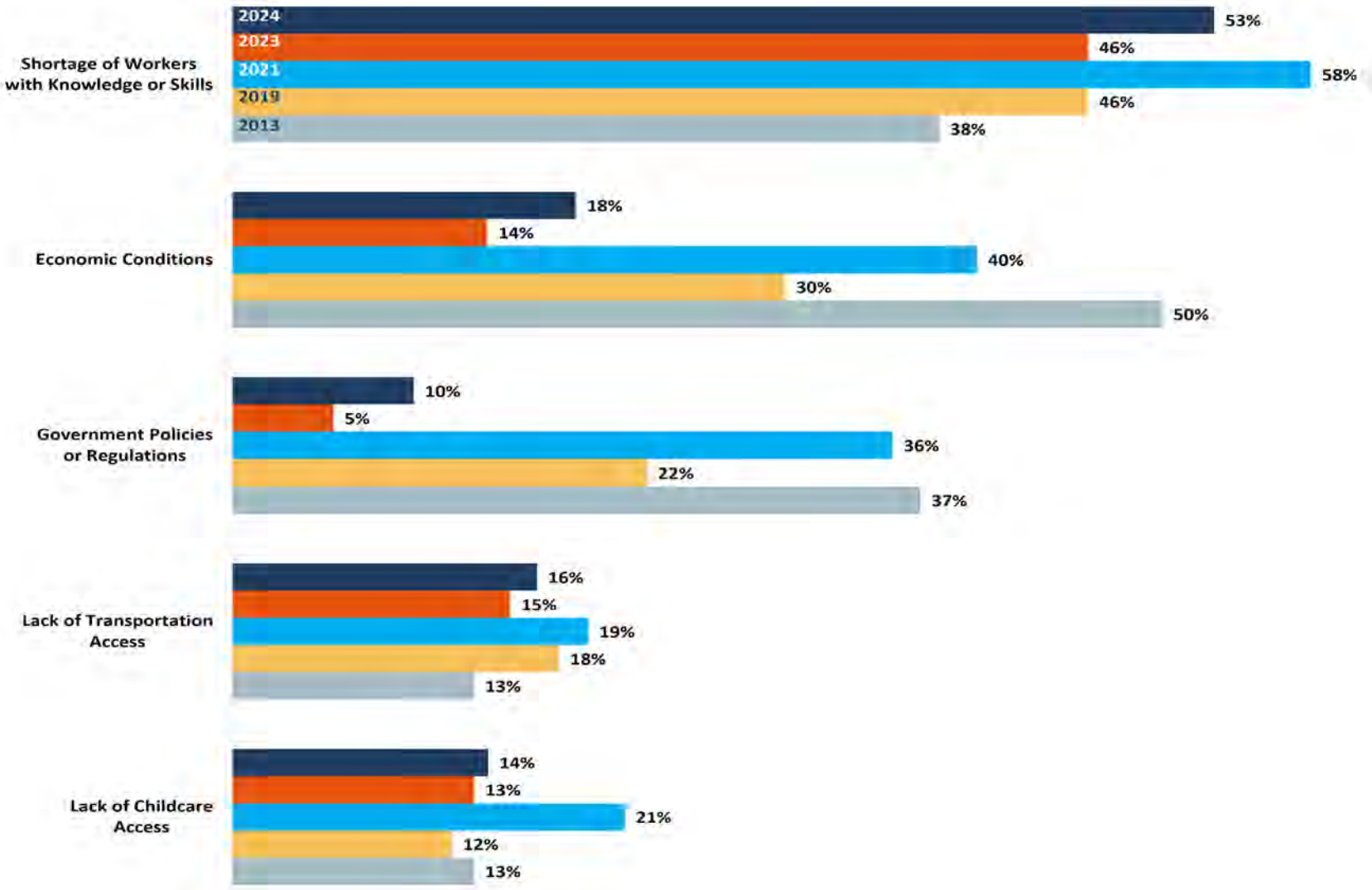
Employment Optimism

Future Plans to Change Employment Levels in the Next 12 Months

43% plan to hire in the next 12 months

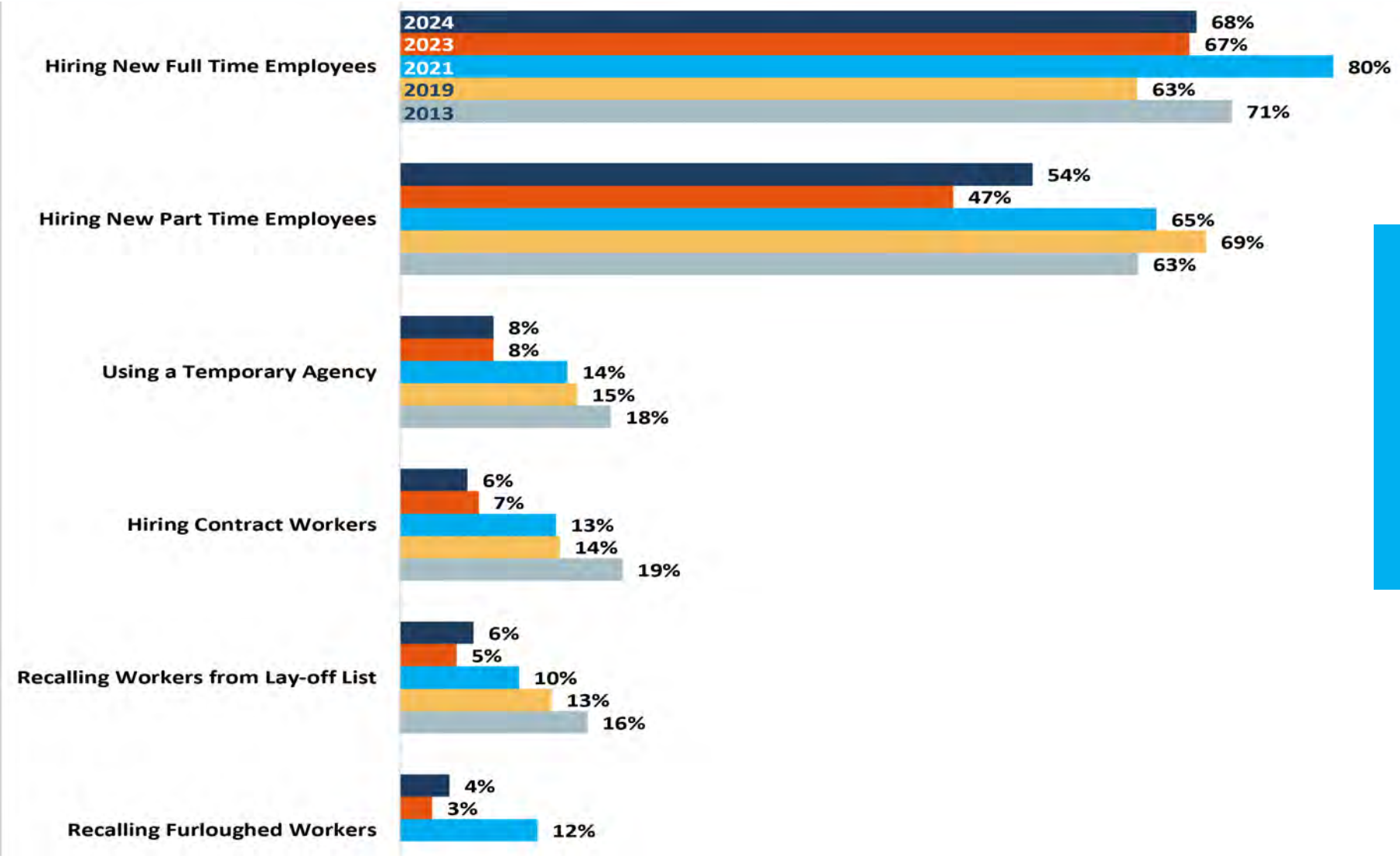


Barriers to Growth



Shortage of workers with knowledge or skills still # 1

Adding Workers

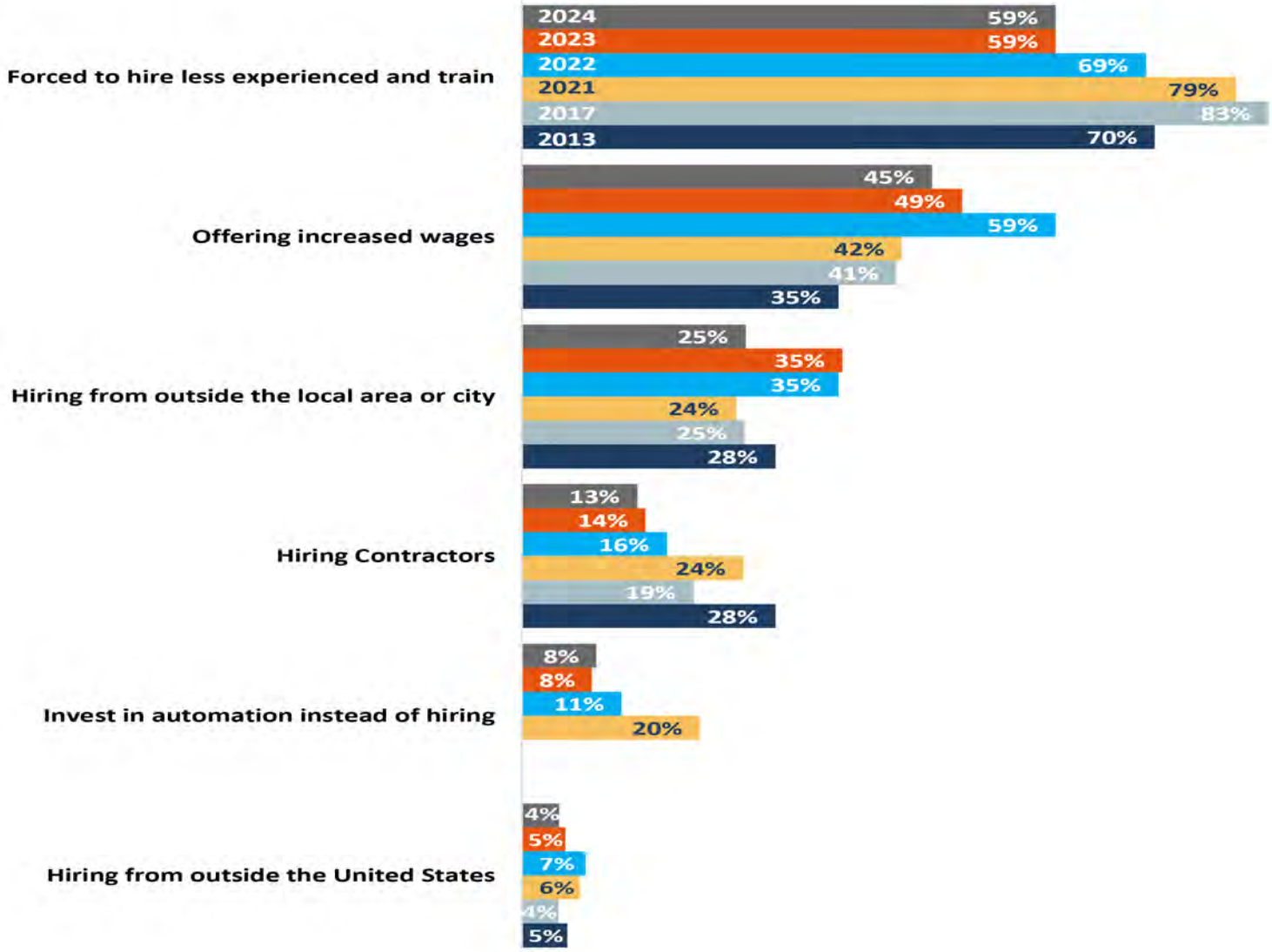


68% plan to hire new full-time employees

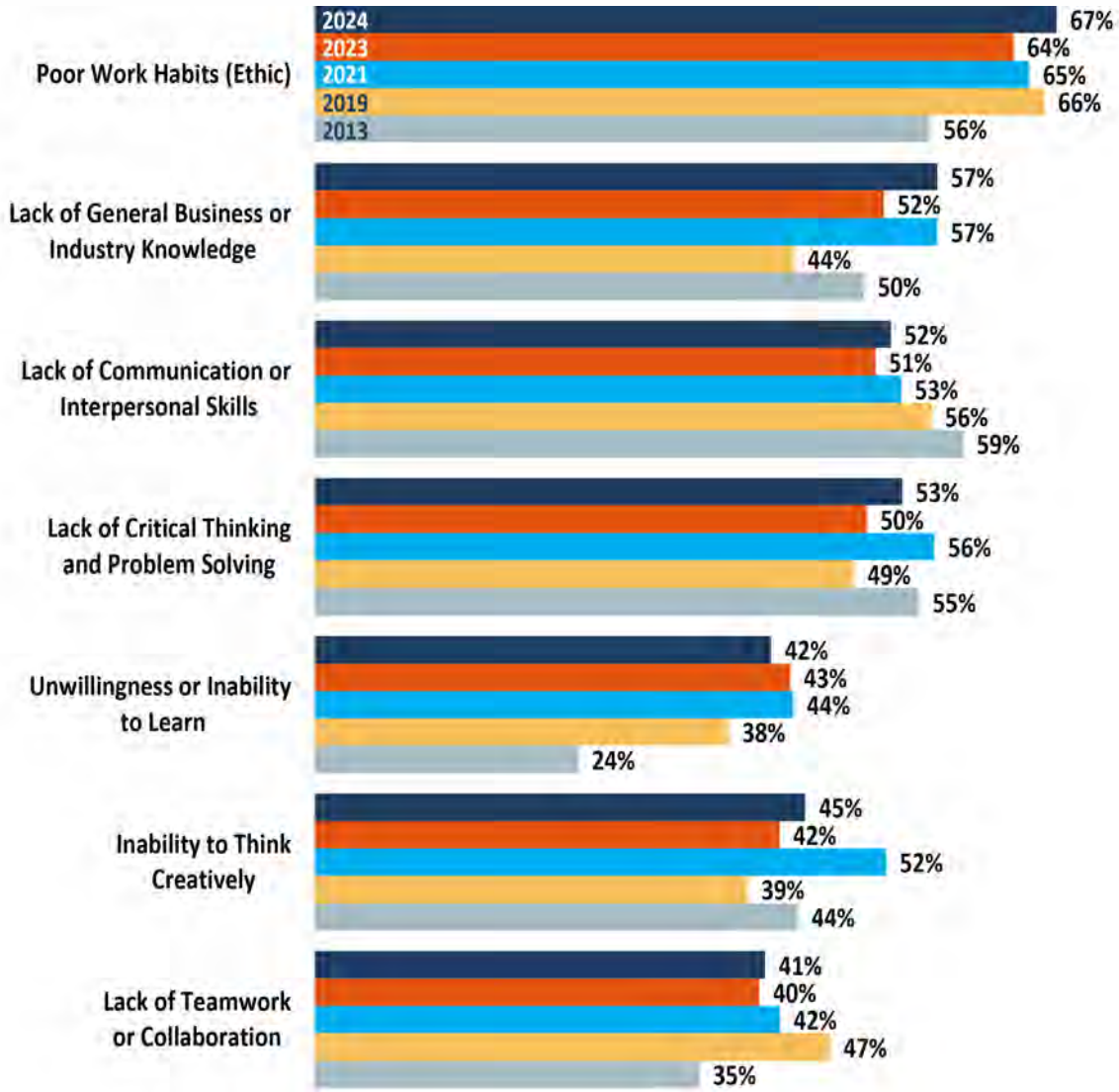
Measures Taken to Address Skill Shortages

59% of companies forced to hire less experienced workers and train

45% are offering increased wages



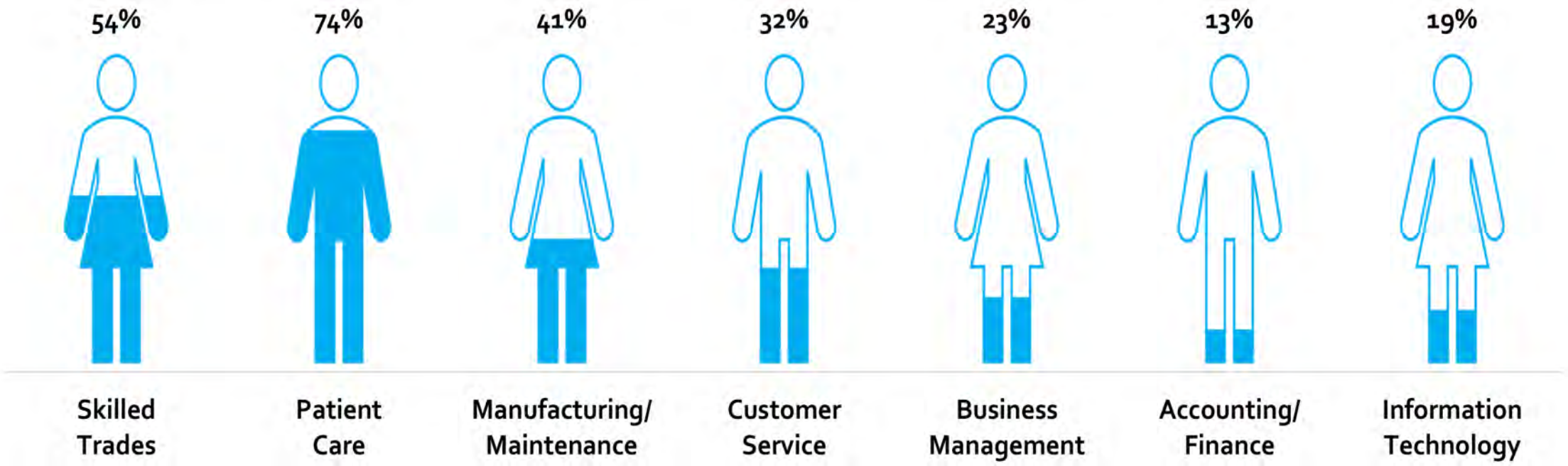
Shortcomings Seen in Job Applicants



Poor work habits still #1

Skill Shortages by Business Functional Areas

Firms Reporting Applicant Shortages in Functional Areas



Skill Levels

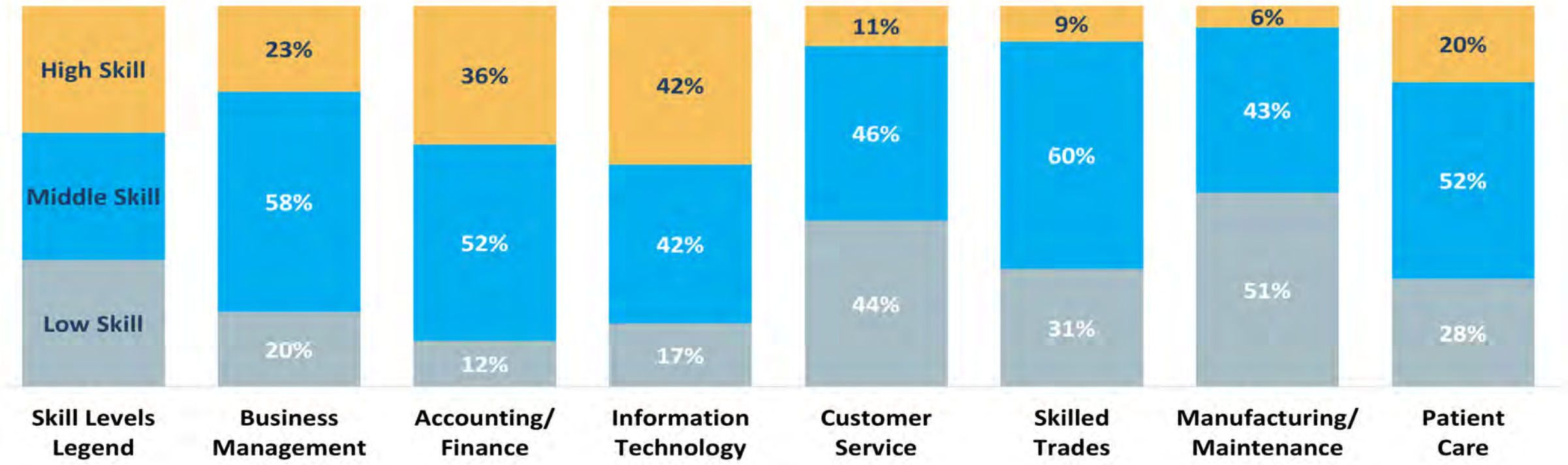
High-skill
requiring a four-year degree or higher

Middle-skill
requiring a training or education beyond a high school diploma but less than a four-year degree

Low-skill
requiring a high school diploma or less

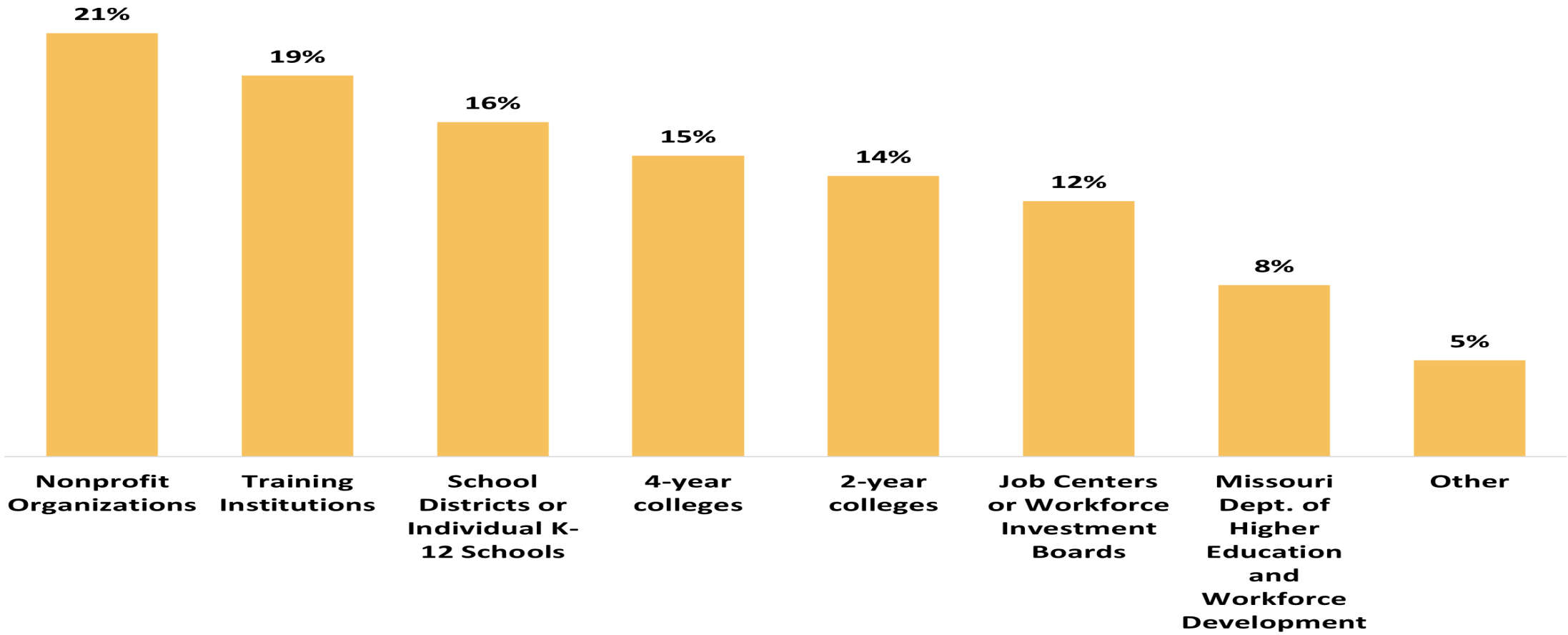
Skill Shortages by Business Functional Areas

Skill Levels Needed to Meet Skill Shortages



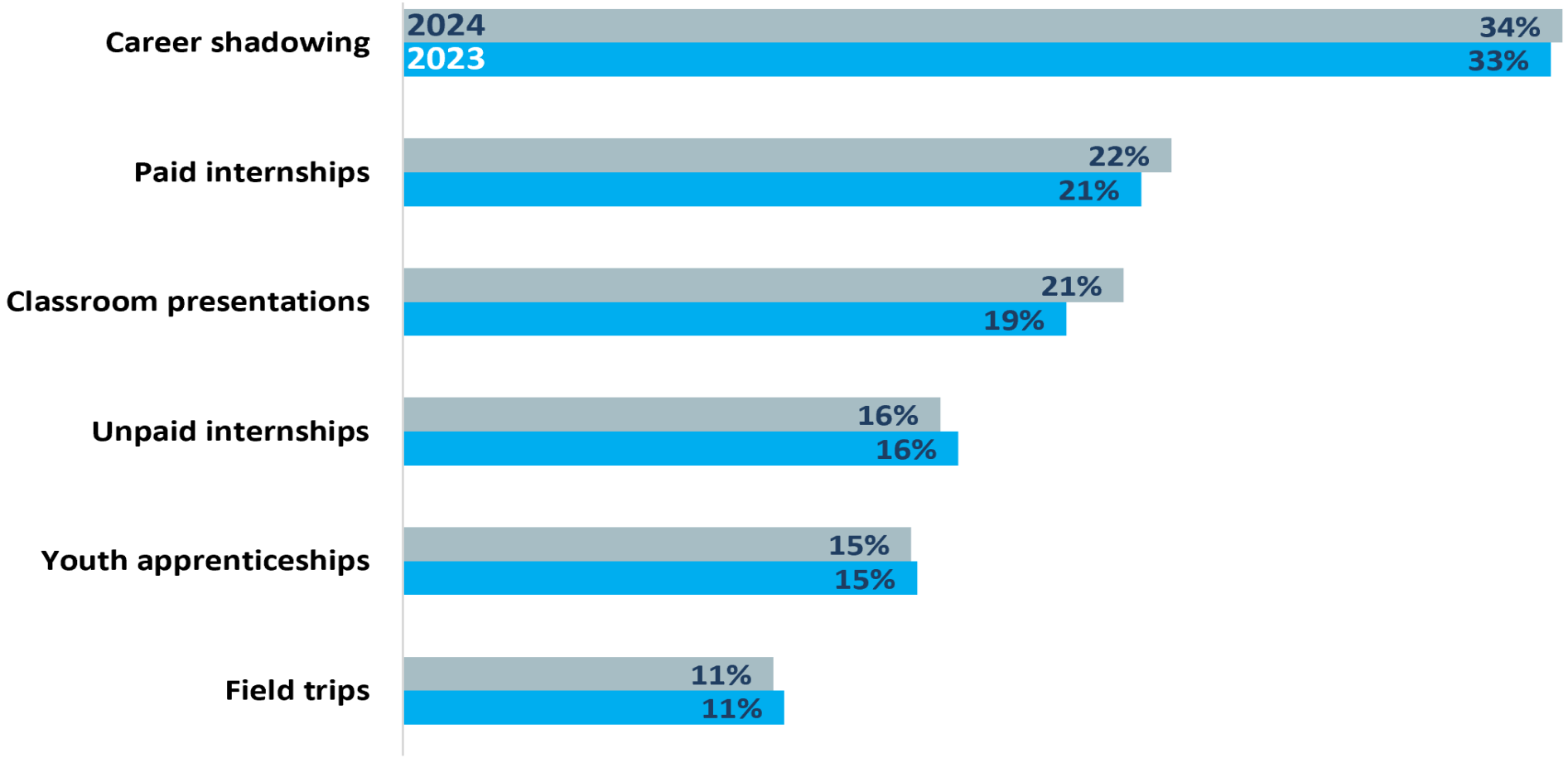
Increasing Opportunities

Current Partnerships to Source Talent



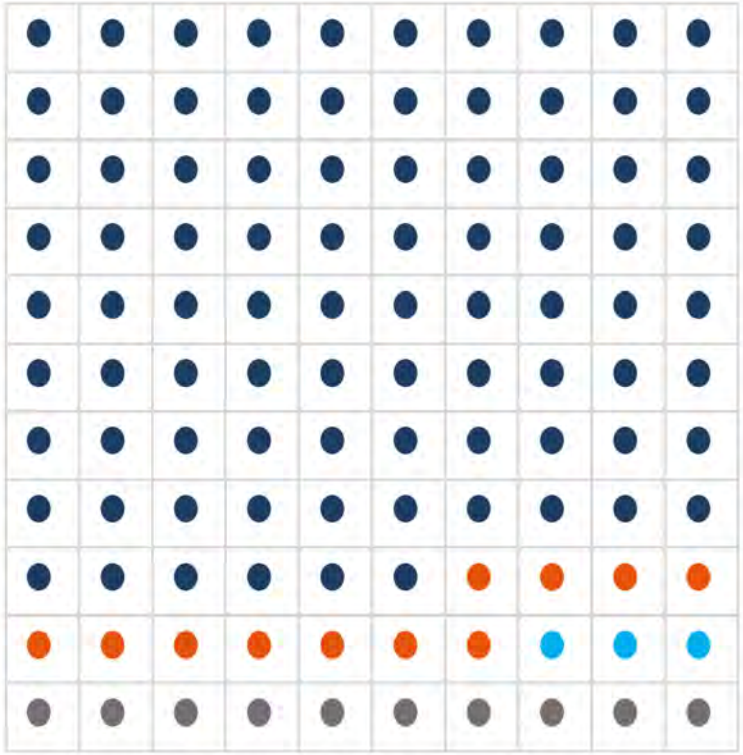
Increasing Opportunities

Young Adult Work-based Learning Experiences Offered



Remote Work

Employers Remote Work Policy



86% fully on-site

11% partially on-site

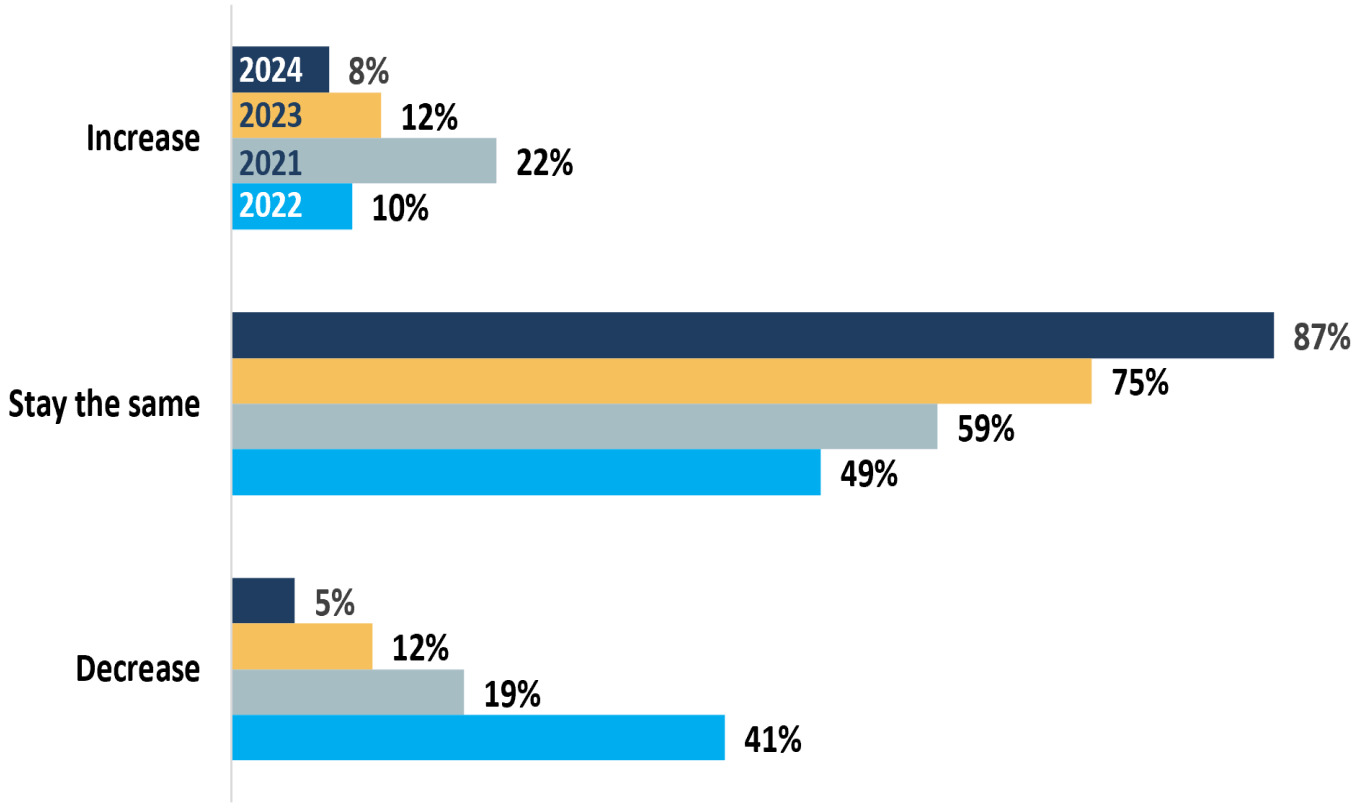
3% fully remote

10% flexible options

* Employers could select more than one option.

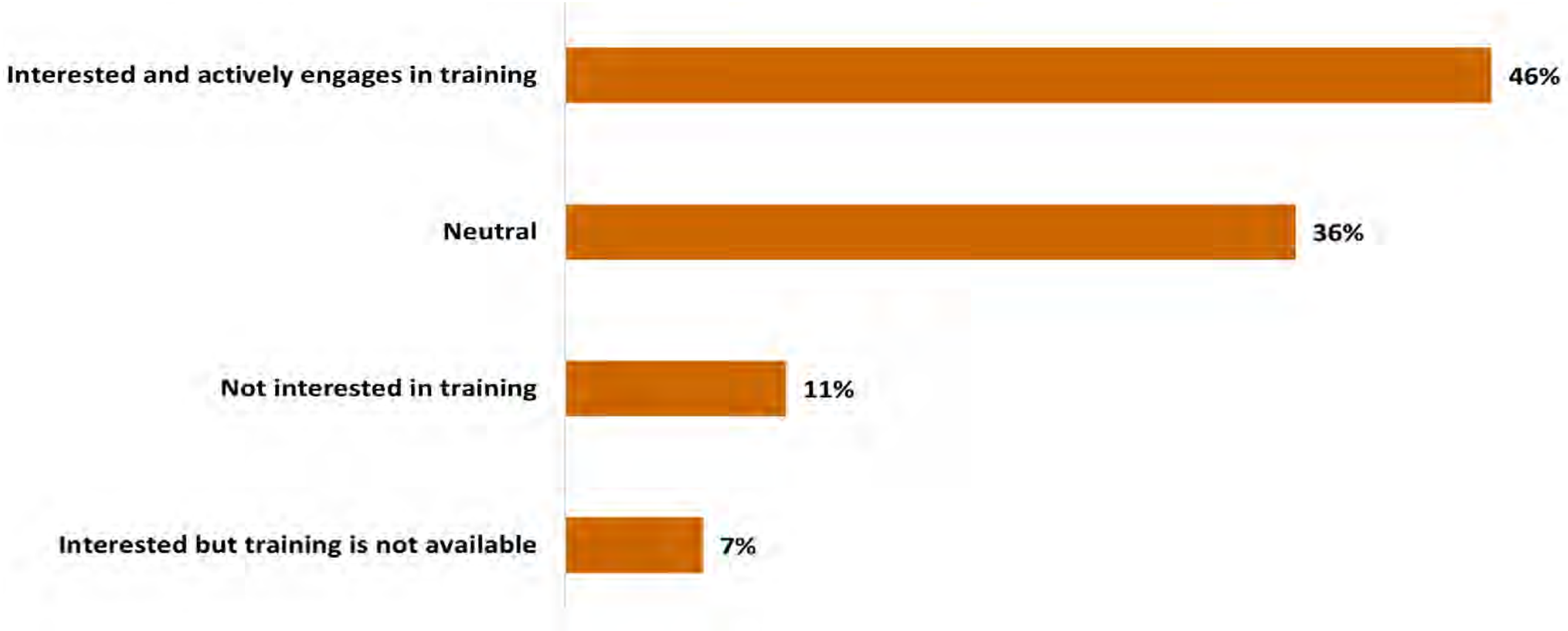
Remote Work

Expected Change in the Number of Remote Workers Over the Next 12 Months



Employment Training

Employee Attitudes Toward Training

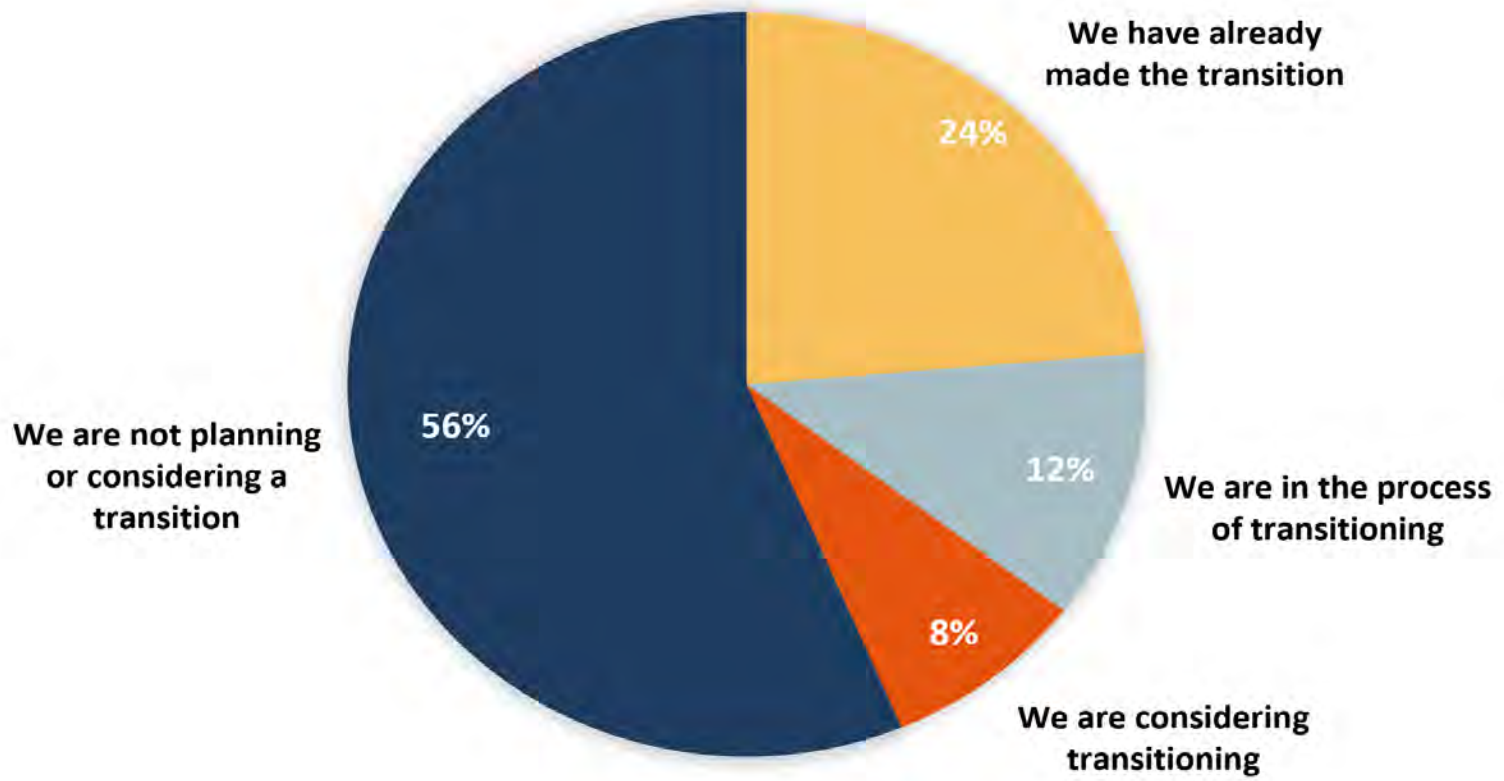


Employment Training

Annual Amount Spent on Training per Employee

Hiring Skills vs. Hiring Degrees

Employers Transitioning From a Degree-Focused Hiring Approach



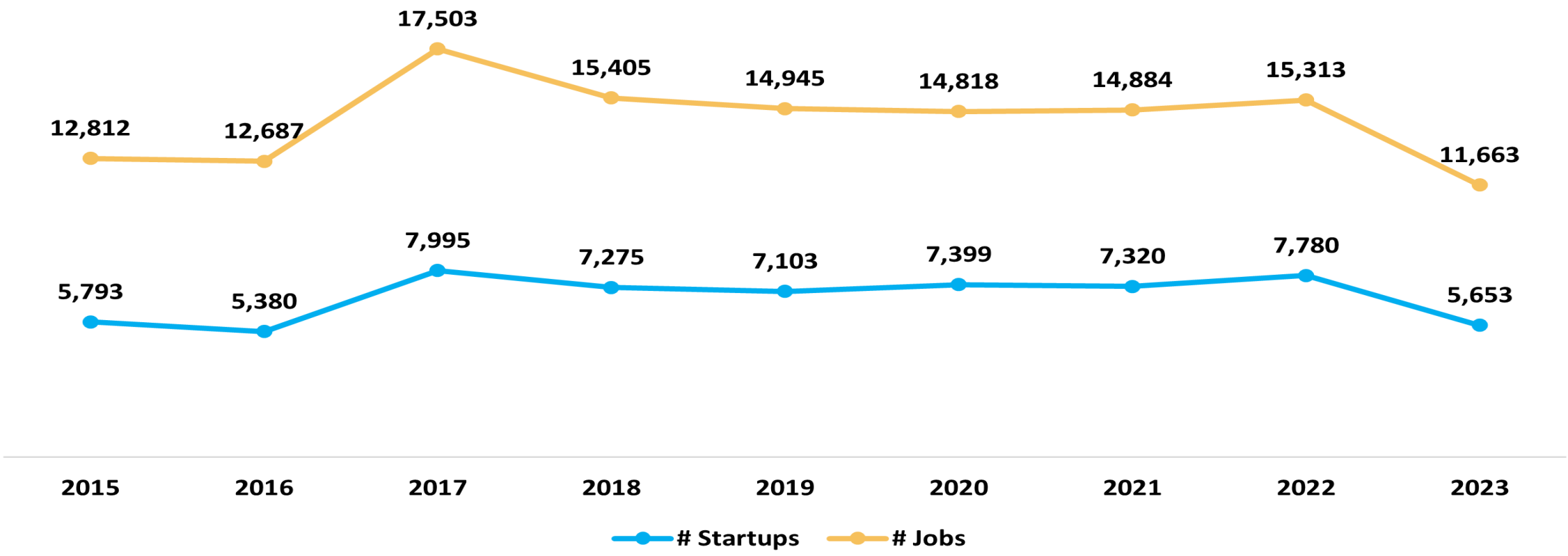
Spotlight on Startups and Job Creation

Spotlight on Startups

St. Louis region added 11,663 new jobs by startups in 2023

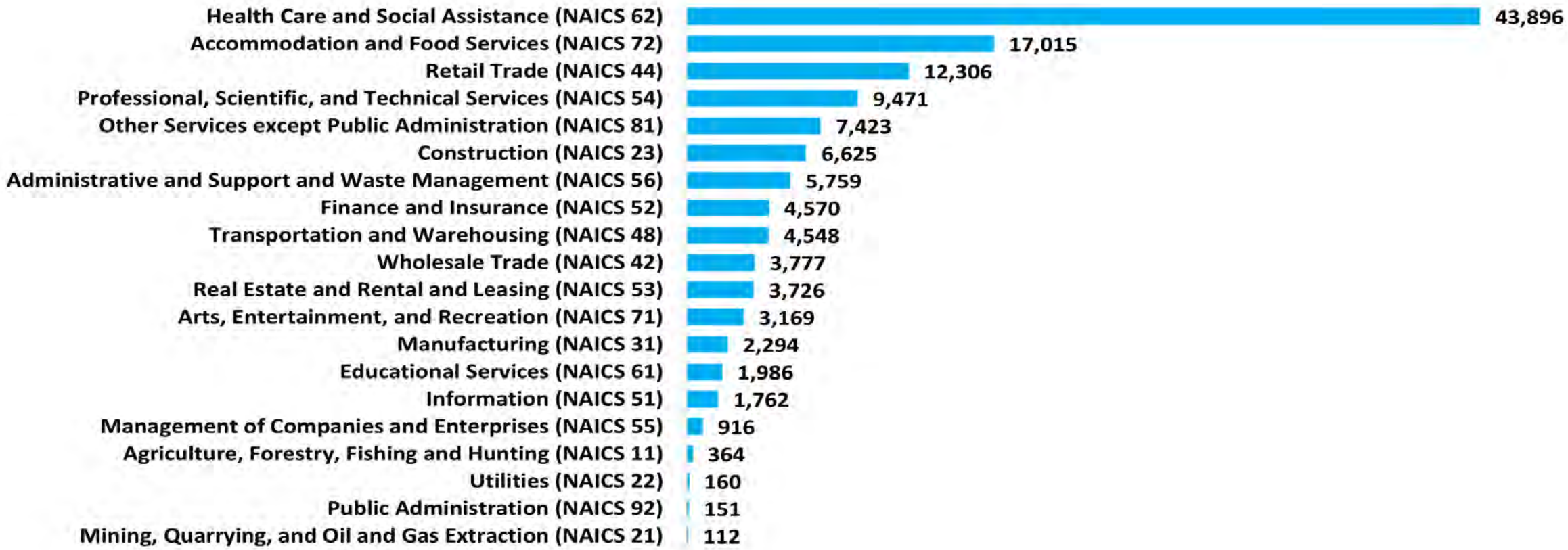
Spotlight on Startups

St. Louis Region First-time Startups and Jobs Created by Year



Spotlight on Startups

St. Louis Region Jobs Created by Startups (2015-2023)



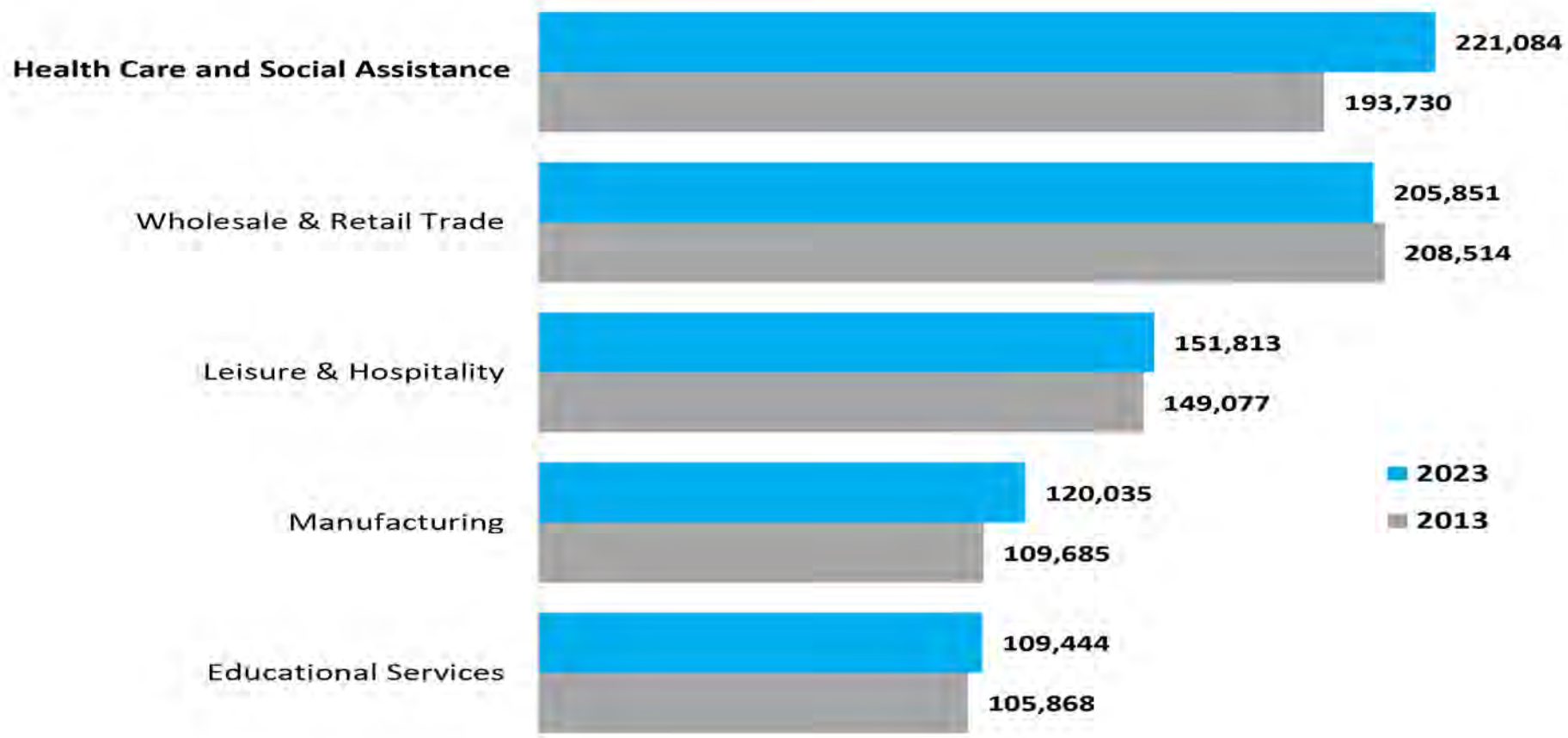
Spotlight on Health Care

Spotlight on Health Care

St. Louis region added 4,004 health care and social assistance jobs in 2023.

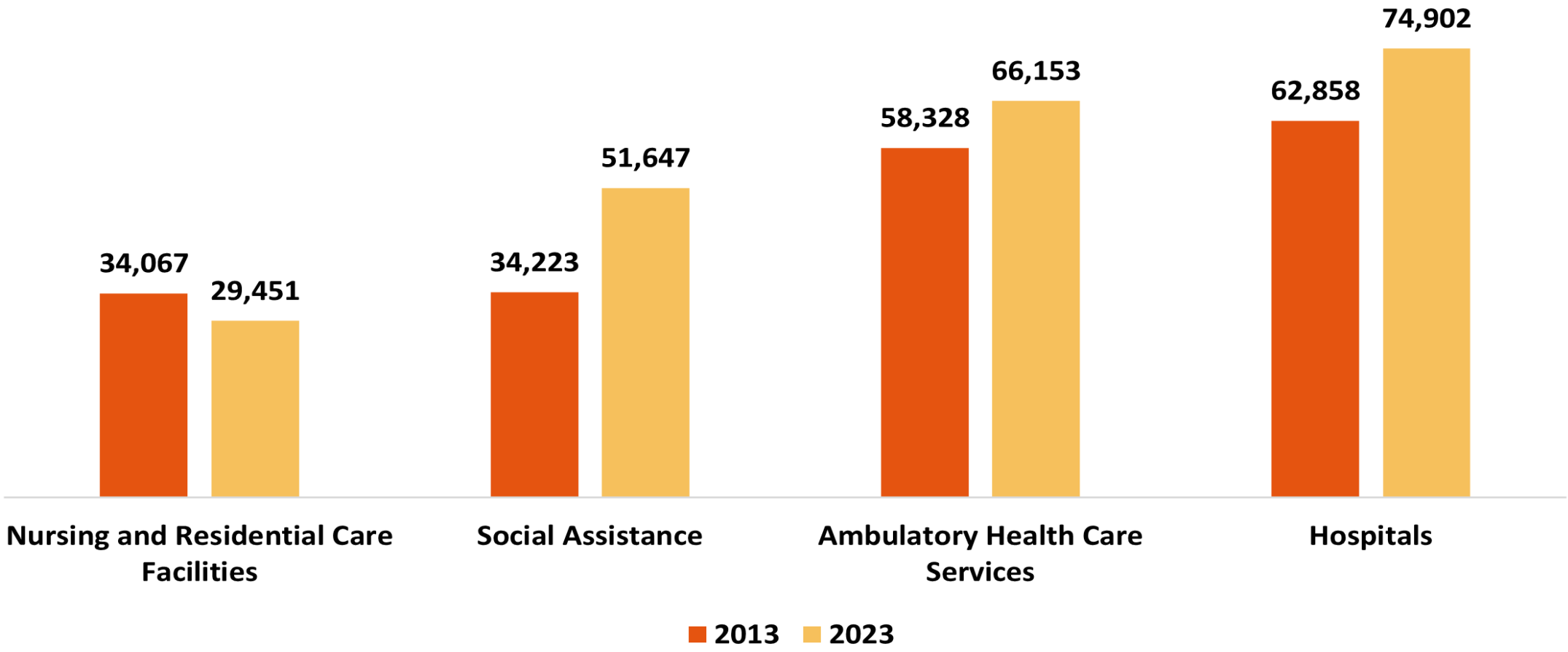
Spotlight on Health Care

Top Five St. Louis Industry Employment



Spotlight on Health Care

St. Louis MSA Health Care Employment by Subsector



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