



Stanford University
Human-Centered
Artificial Intelligence

MAY 2021

INDUSTRY BRIEF

An initiative of the HAI Corporate Members Program

The Future of Work Post-Covid and AI

And A Closer Look at AR/VR
(Bonus Feature)





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Introduction

AI will have a profound impact on work, business, and the economy. To ensure that the power of AI is used to improve the human condition, and not diminish it, at HAI we focus on applications that augment and enhance human capabilities rather than displace or replace them. One of our efforts is to study the global impact of AI on the economy and society, in hopes of promoting positive outcomes as the nature of work evolves in tandem with technology.

In this Industry Brief, we provide a sampling of key research both at HAI and more broadly at Stanford that can help inform the future of work. In this brief, you will find researchers studying how AI can be used to help teams

collaborate, improve workplace culture, promote employee well-being, assist humans in dangerous environments, and more. While we touch on research in robotics and natural language processing, we have reserved much of the relevant research in those fields for future briefs that will focus more exclusively on those topics.

We believe in taking a multi-dimensional, multi-disciplinary approach, where technology is developed within the greater context of societal efforts and conversations. Thus, we hope that industry leaders, investors, founders, researchers, and students will find the contents of this brief useful in contributing to the conversation within their organizations.

HAI's mission is to advance AI research, education, policy and practice to improve the human condition. To learn more about HAI, visit hai.stanford.edu



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“The implications of AI on the future of work are both complex and immense. Across industries, human-centered AI technology has great potential to be used to the benefit of human workers — to be collaborative, interactive, and ultimately augmentative of human capabilities. But the human impact can be profound both positively and negatively. To this end, we must continue to invest in and promote interdisciplinary research that can help our society deeply understand and capably guide the human impact of AI on the future of work.”

– Fei-Fei Li, Denning Co-Director of the Stanford Institute for Human-Centered Artificial Intelligence (HAI)



Future of Work

1 Remote Work

2 Collaboration

3 Culture

4 Well-being

5 Automation & Augmentation

6 Skills, Matching, & Occupational Change

7 Valuing & Investing in AI

AR/VR

1 Fidelity & Performance

2 Tracking and Privacy

1 FUTURE OF WORK REMOTE WORK

★ WHAT'S NEW?

Original cross-sectional surveys conducted since early in the pandemic provide systematic evidence about the persistence and economic and societal implications of working from home. The Stanford economists behind these surveys estimate that American workers will spend 20% of full workdays from home and that working from home will contribute to a productivity boost of 5% in the post-pandemic economy.¹

They also note that as the pandemic has enlarged the market (and thereby the commercial rewards) for platforms and technologies supporting remote work, it may have also triggered large-scale innovation further contributing to the relative attractiveness of remote work long-term. Stanford researchers are among those leveraging AI technologies to enhance remote work and study the impact of its supporting technologies on employees and organizations.

📌 WHY DOES THIS MATTER NOW?

With only 8% of employed workers working one day or more per week from home pre-pandemic, both fully and hybrid remote work options are still unprecedented for most firms.² For some, the scaled uptake of technologies facilitating digital communication seems to have effectively powered their transition to remote work. However, the longer term impact of remote work on well-being, collaboration, creativity, and culture still remains uncertain and the focus of ongoing research which may illuminate new avenues for innovation.

👁️ EYE ON CAMPUS

Researchers on campus are...

- Advising that companies adopt a “uniform hybrid” remote work policy requiring the same office-to-home ratio for everyone, where whole teams come in on the same 2-3 days of the week
- Finding new relevance and applicability for the insights from an early work-from-home research experiment, where home working led to a 13% productivity increase at a NASDAQ-listed company
- Finding an explosion in US patent applications advancing technologies that support working from home (e.g., videoconferencing, telecommuting, remote interactivity) in 2020, reflecting an innovation pipeline acceleration effect or a persistent rise in patents advancing these technologies
- Developing a pipeline for low latency, high framerate telepresence experiences with AR headsets readily accessible by consumers, contributing another building block to the development of enhanced remote work experiences



AR/VR may fuel novel remote work experiences. Check out the Closer Look starting on page 16 to learn more about research on campus relevant to their applications.

- Discovering a “donut effect” of rising real-estate prices in suburbs and slumping prices in major city centers and generally no substantial moves from more expensive to less expensive cities (e.g., San Francisco to Austin) in response to COVID-19



“The shift towards hybrid working from home is possibly the single largest long-run impact of COVID on many firms. We are only halfway through a massive revolution and a whole new experiment for businesses. A year from now, though there will still be a tremendous amount of uncertainty, we may also see a great deal of innovation.”

*–Nicholas Bloom,
Professor of
Economics; HAI
Faculty Affiliate*

[1] Barrero, J. M., N. Bloom, N., AND Davis, S. J. (2020): “Why Working From Home Will Stick,” Tech. rep., Stanford University. [2] Ito, A. (2021, April 13). America’s best work-from-home expert is bracing for turmoil. Business Insider.



2 FUTURE OF WORK COLLABORATION

★ WHAT'S NEW?

Collaborative computing combines machine learning techniques with insights from the organizational behavior literature. Research demonstrates potential for the development of new tools that will automatically help teams assess, track, and visualize their own viability and dynamics in real time as they collaborate.

Some NLP applications extend beyond digital text-based contexts to live conversations, improving the social awareness and intelligence of interactive systems in physical environments. Such improvements could potentially be used to facilitate collaboration for both in-person and remote work.

📌 WHY DOES THIS MATTER NOW?

In a survey on the post-pandemic workforce, 85% of executive respondents said their businesses have somewhat or greatly accelerated the implementation of technologies that digitally enable employee interaction and collaboration.¹ Looking ahead, firms may want to consider how more socially aware systems can create completely new value-adds through providing finer-grained feedback and insights for teams and organizations. This may be particularly relevant for companies anticipating more distributed, global workforces.

EYE ON CAMPUS Researchers on campus are...

- Predicting team viability (a team's capacity for sustained and future success) using classification models and text conversations of online teams, suggesting new opportunities to leverage existing data to build more effective teams
- Developing an optimization algorithm that computationally adapts collaboration networks over time. It underpins a system that creates the conditions for people to engage deeply with a small group while still benefiting from the scale and diversity of the collective and building social ties across the network.
- Experimenting with identity masking to overcome power imbalances within teams and develop novel ways to help teams start on the right foot or course correct team dynamics through targeted interventions
- Combining powerful deep learning methods with classical clustering techniques to improve the detection of conversational groups. The novel approach contributes further to the possibility of a rich set of intelligent, social computer interfaces embedded in physical spaces



Keep an eye out for a deeper dive into the latest NLP research at Stanford in upcoming Industry Briefs.

[1] Dua, A., Cheng, W. L., Lund, S., Smet, A., Robinson, O., & Sanghvi, S. (2020, September 23). What 800 executives envision for the postpandemic workforce. McKinsey & Company. [2] PricewaterhouseCoopers. (2021, January 12). It's time to reimagine where and how work will get done. PwC.



“AI and computation can augment teams' collaborative abilities. The ongoing research here at Stanford has demonstrated that AI can help us find better ways to organize our teams, circulate ideas effectively within an organization, and perform early warnings of potentially problematic team dynamics. When team members are aware and consent to the use of these supporting technologies at work, the idea can be to digitally scale something akin to a professional coach.”

—*Michael Bernstein,*
Assistant Professor of
Computer Science;
HAI Faculty Affiliate



3 FUTURE OF WORK CULTURE

★ WHAT'S NEW?

Parallel trends of increased computational power, digitally intermediated work, and advances in natural language understanding are driving developments in people analytics. Where organizations were previously limited to surveys and human judgment, they now have access to more granular data to inform their organizational design decisions, hiring processes, and managerial judgment — all of which can have a meaningful impact on culture.

As data collection and algorithms proliferate in the workplace, though, researchers have also identified distinct areas of concern and resistance (e.g., fears over tightening employer control) from workers that merit careful consideration from leadership.

📌 WHY DOES THIS MATTER NOW?

The pandemic upended organizations by rapidly forcing them to abandon the fundamental assumption of on-premise, face-to-face work. Some will seize this as an opportunity to re-evaluate and intentionally redesign their teams and cultures, which may have been historically slow-evolving or stagnant. However, 68% of executives believe that people should be in the office at least three days a week to maintain a distinctive company culture.¹ In what will likely be a flexible work environment, mentoring, development, integration, and human connection may require significant rethinking to leverage both the physical and virtual spaces.

👁️ EYE ON CAMPUS

Researchers on campus are...

- Partnering with technology companies to leverage emails, Slack communications, and Glassdoor reviews to assess “cultural fit”, measure the diversity of thoughts and ideas, and examine the impact of culture on organizational efficiency and innovation. The findings suggest companies should maximize intrapersonal diversity (i.e. employees with a large number of cultural ideas and beliefs about how to accomplish tasks within the company) as this may spur innovation, while minimizing interpersonal diversity (i.e. disagreement among employees about the norms and beliefs characterizing the organization) which can damage coordination.
- Using BERT, a deep learning language model, on 100,000+ earnings calls conducted by 6,000 firms to develop a measure that identifies novel ideas which later become commonplace. The method developed can be extended to other domains to identify visionary individuals and groups.
- Analyzing algorithms as a major force in reconfiguring employer-worker relations of production within and across organizations
- Studying the impact of metrics at work in journalism and among YouTube creators. Their findings on resistance to metrics (particularly ones driven by opaque algorithms) are particularly relevant to understanding how workers more broadly may respond to algorithmic technologies of quantification.

[1] PricewaterhouseCoopers. (2021, January 12). It's time to reimagine where and how work will get done. PwC.



“AI is ushering a new age in our understanding and ability to model culture. This is already revolutionizing business, from algorithmic green lighting of movie productions to the management of corporate cultures. But AI is a double edged sword. We must not allow businesses to abuse this algorithmic power.”

**–Amir Goldberg,
Associate
Professor of
Organizational
Behavior**

4 FUTURE OF WORK WELL-BEING

★ WHAT'S NEW?

Researchers are exploring the use of sensing technologies in creating adaptive environments that promote well-being in hybrid physical and digital spaces. Such technologies can provide more broad-based, fine-grained, and longitudinal data as input to machine learning models, which can help to continuously monitor and detect well-being outcomes including stress, physical activity, creativity, and sense of belonging. However, they can also pose a threat to privacy in the workplace and require deliberate design choices to balance individual needs with the desire for precise data.

In a different vein, economists are studying the impact of AI's increasing share of jobs on subjective well-being at the city level. They are finding consistency with models of structural transformation where technological change leads to improvements in well-being through improvements in economic activity.

📌 WHY DOES THIS MATTER NOW?

About one-third of all employers expect to take steps to tackle the well-being challenges posed by the shift to remote work.¹ Yet, while 96 percent of companies globally provided additional mental-health resources to employees, only one in six employees reported feeling supported.² The World Health Organization has estimated the the annual impact of poor mental health on global productivity might be as high as \$1 trillion per year.³ AI technologies may support employers in treating well-being as a measurable and buildable skill in both their remote and in-person workforces post-pandemic.

At the same time, the share of AI job postings among all job postings in 2020 is more than five times larger than in 2013 according to the AI Index Report, which looked at six countries including the U.S.⁴ Where there may be concerns about the impact of AI and automation on social welfare, firms with growing AI workforces may want to closely examine the extended impact of their presence on well-being in the cities they inhabit.

EYE ON CAMPUS

Researchers on campus are...

- Establishing the science behind the impact of building attributes on occupant states and exploring, in light of this, how adaptive sensing technologies can support individual and organizational outcomes relating to stress, and creativity, environmental efficacy, physical activity, and sense of belonging
- Using machine learning to predict acute stress levels of users based on their computer mouse movement data. They demonstrate how an everyday technology (the mouse) can be repurposed to facilitate well-being.
- Introducing the concept of non-volitional behavior change: an infrastructure-mediated intervention to enforce a change in behavior such as activity or posture. They begin with a desk that automatically controls its position to prioritize a health-focused actuation schedule.
- Demonstrating the potential value of wearables as a scalable means of complementing existing workplace stress management interventions and policies
- Finding that increases in the AI share of jobs are associated with increases in subjective well-being (especially physical, financial, and social)

[1] World Economic Forum. (2020, October). The Future of Jobs Report 2020. [2] Segel, L. H. (2021, January 13). The priority for workplaces in the new normal? well-being. World Economic Forum. [3] Mental health in the workplace. (2016). World Health Organization. [4] Zhang, D., Mishra, S., Brynjolfsson, E., Etchemendy, J., Ganguli, D., Grosz, B., Lyons, T., Manyika, J., Niebles, J.C., Sellitto, M., Shoham, Y., Clark, J., & Perrault, R. (2021). The AI Index 2021 Annual Report.



“What if we could better understand how our built environments shape us in both positive and negative ways? Finding answers to this, we can imagine a smarter workplace of the future that leverages sensor technologies and AI to adapt to the changing needs of employees and promotes their well-being. This work will require interdisciplinary, cross-sector collaboration and a sensitivity to the privacy, safety, and security concerns of all stakeholders.”

—James Landay,
Professor of
Computer Science;
Associate Director
of HAI

5 FUTURE OF WORK
AUTOMATION & AUGMENTATION

★ **WHAT'S NEW?**

Advances in machine learning, NLP and robotics fuel applications that automate or augment human capabilities in tasks across logistics, construction, hiring, written communication, content moderation, elder care and even deep sea exploration. Stanford researchers pioneer some of these applications and also study their broader social impact and the non-technical challenges of facilitating employee trust in AI, trading off AI and human decision-making authority, and mitigating potential bias and other unintended consequences of deploying AI.

📌 **WHY DOES THIS MATTER NOW?**

As of July 2020, two-thirds of business executives said they were stepping up investment in automation and AI either somewhat or significantly.¹ This may have been particularly true for highly impacted areas such as warehouses, retailers, call centers, and manufacturing, where pandemic-driven surges in demand and workplace density restrictions required novel adaptation.

As AI and automation proliferate and change the nature of work, organizations must consider not only the challenges of implementing and deploying technologies but also those of navigating their integration into the workplace, the measurement of their efficacy, their potential to perpetuate bias, and their broader human impact.



Photo: Jacqueline Orrell/SLAC National Accelerator Laboratory



“The next 10 years years can be the best decade ever for workers or one of the worst. The outcome depends critically on whether we use AI to augment and extend our capabilities, enhance the value of labor, or simply automate existing tasks, substitution machines for humans.”

– Erik Brynjolfsson, Jerry Yang and Akiko Yamazaki Professor; Director of the Stanford Digital Economy Lab; Senior Fellow at HAI

5 FUTURE OF WORK AUTOMATION & AUGMENTATION

CONTINUED

EYE ON CAMPUS

Researchers on campus are...

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- Collaborating with industry leaders to look at automation from the perspective of both workers and industry to build a new theory that helps predict when and how workers and organizations react constructively to new forms of automation

- Building a resume screening algorithm that improves hiring rates and demographic diversity by evaluating candidates according to their statistical upside in addition to proven track records

- Mapping out the broad choices for organizations in terms of whether to give an AI or a human decision authority and, in turn, whether to favor a technically superior (i.e., reliable and unbiased) AI or not
- Contributing to the field of interpretable machine learning by suggesting a straightforward method for constructing simple yet accurate decision rules that experts can apply mentally

- Exploring the use of robots in unstructured environments, such as construction or the deep sea, to assist humans in hazardous, repetitive, and strenuous manual tasks
- Examining the impact of AI and robotics on manufacturing, retail banking, and nursing homes and finding that the impact of robots often evolves over time from replacing human workers to augmenting them
- Addressing the disconnect between machine learning classifier performance and user-facing performance on social computing tasks such as comment toxicity and misinformation common to platforms such as Facebook, Wikipedia, and Twitter
- Studying the effects of AI-mediated communication tools (e.g., email smart reply) on bias, our use of language, relationships, and trust

[1] Lund, S., Madgavkar, A., Manyika, J., Smit, S., Ellingrud, K., Meaney, M., & Robinson, O. (2021, March 31). The future of work after COVID-19. McKinsey & Company.



Keep an eye out for our upcoming industry briefs covering Robotics, Virtual Assistants, and AI Safety for more general and comprehensive coverage of the latest Stanford research in these fields.



Photo: Kevin Meynell

6 FUTURE OF WORK
SKILLS, MATCHING, & OCCUPATIONAL CHANGE

★ **WHAT'S NEW?**

Researchers apply computational approaches to identify job tasks most suitable for machine learning automation and to quantify the return on various skills. They suggest that significant reskilling may be needed to successfully realize the potential of machine learning. They also find that skills and education have value not only to the employees who acquire them, but also to the owners of the companies where those employees work.¹

Researchers also examine the potential value of using AI and machine learning techniques at a policy level to optimize employment outcomes and the allocation of job training or reskilling resources.

📌 **WHY DOES THIS MATTER NOW?**

In 2017, it was estimated that as much as 14% of the global workforce would have to switch occupations or acquire new skills by 2030 because of automation and AI.² In a recent McKinsey Global Survey, 87 percent of executives said they were experiencing skill gaps in the workforce or expected them within a few years³ and 58% said that closing skill gaps in their workforces has become a higher priority since the pandemic began. COVID-19 has only made the questions of reskilling, upskilling, job matching, and occupational change more urgent for firms.



Photo: Darrin Zammit Lupi



“In the short term, we should expect AI to create a mix of job augmentation, job replacement, and job creation. Although the aggregate effect may be modest, specific occupations may see rapid change and displacement. More research is urgently needed to understand better which workers are most likely to be harmed, as well as what interventions would be most effective at aiding these workers through transitions.”

—*Susan Athey, Economics of Technology Professor; Associate Director of HAI*

6 FUTURE OF WORK
SKILLS, MATCHING, & OCCUPATIONAL CHANGE

CONTINUED

EYE ON CAMPUS

Researchers on campus are...

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- Using new machine learning methods to predict occupational transitions and characterize and extract the traits and skills that correspond to wage and employment growth and that allow individuals to adapt and transition into new occupations. One finding is that leadership intensive occupations have seen significant increases in both wages and employment, particularly in occupations and industries with high IT capital intensity. *(Only second and third linked references are HAI research.)*
- Finding that holders of bachelor’s degrees are 5x as likely to be exposed to some effect of AI as those with just high-school diplomas and that those with the highest exposure are in the 70th to 90th percentile of wage earners
- Matching refugees resettlement locations through data-driven algorithmic assignment, achieving gains of roughly 40 to 70%, on average, in refugees’ employment outcomes
- Partnering with government to use data, science, and technology to create the tools and metrics needed to foster a data-driven reskilling ecosystem that effectively and efficiently upskills the American workforce for the future of work
- Using NLP models to analyze millions of online job postings. The research finds that from 2011 to 2015, employers described jobs with greater specificity, suggesting a demand for more specialists and fewer generalists. It also reveals that from 2011 to 2019, scope grew for management occupations, business occupations, and technical occupations while narrowing for lower-paid healthcare assistance occupations, security occupations, and construction occupations.
- Working to provide country-level data on the suitability of specific occupations for machine learning in a free, public app. The app would help illustrate the capabilities and current limitations of various types of machine learning and what machine learning could mean for the workforce and economy.



Keep an eye out for our upcoming industry brief on Education for more research relevant to skills education and lifelong learning.



Photo: Pascal Rossignol

[1] Brynjolfsson, E., Rock, D., & Tambe, P. (2019, May 6). How Will Machine Learning Transform the Labor Market? Hoover Institution. [2] Agrawal, S., Smet, A., Lacroix, S., & Reich, A. (2020, December 14). To emerge stronger from the COVID-19 crisis, companies should start reskilling their workforces now. McKinsey & Company. [3] Billing, F., Smet, A., Reich, A., & Schaninger, B. (2021, April 30). Building workforce skills at scale to thrive during—and after—the COVID-19 crisis. McKinsey & Company.

7 FUTURE OF WORK
VALUING & INVESTING IN AI

★ **WHAT'S NEW?**

Researchers identify AI as requiring complementary investments that are often intangible and poorly measured, suggesting the need for firms to be patient in seeing the return on such investments. In other words, R&D and technological implementation alone, even for tasks highly suitable for automation, are often not sufficient for reaping the full benefits of AI in an organization. Leaders must think about how to adapt their organizations' corporate culture, workforce training, and business processes in tandem with the technological changes they hope to implement in order to scale success beyond proof-of-concepts.

New techniques can help organizations quantify the value of their data, suggesting one avenue for justifying the investments and estimating the value of inputs into AI initiatives.

📌 **WHY DOES THIS MATTER NOW?**

Despite the economic downturn caused by the pandemic, half of respondents in a McKinsey survey said the pandemic had no effect on their investment in AI.¹ The total investment in AI, including private investment, public offerings, M&A, and minority states, increased by 40% in 2020 relative to 2019 for a total of \$67.9B.¹ Yet while 86% of executives claim that AI will be a "mainstream technology" at their company in 2021, 76% of organizations are barely breaking even on their AI investments when considering the costs and not just the benefits.² In other words, some seem to be finding that it is significantly more challenging than they initially believed or were prepared for to put AI into production.



Photo: Drew Kelly



“Technological change always impacts how organizational hierarchies are structured and whose expertise is valued in an organization. We are seeing effective change strategies where AI developers collaborate with domain experts to produce high value “humans in the loop” workflows where the algorithms and the experts learn together.”

–*Melissa Valentine, Assistant Professor of Management Science and Engineering; HAI Faculty Affiliate*

7 FUTURE OF WORK VALUING & INVESTING IN AI

CONTINUED

EYE ON CAMPUS

Researchers on campus are...

- Observing how algorithms are changing the structure of organizations. In one study, buyers struggled to use customer data insights because their workflows and even their org chart were structured around products not customers. New algorithmic tools helped integrate product and customer data but required rethinking the org chart.

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- Suggesting that for a new transformative technology like AI, productivity growth depends on complementary innovations and investments into intangible assets such as corporate culture, workforce training, business processes, and branding

- Identifying what they call the increasingly scarce *genius factor* (primarily associated with exceptional talent and distinct from mere labor and capital inputs) as a novel bottleneck to production growth in the digital economy
- Gathering and analyzing data from venture-funded robotics companies. They find that fulfillment processes, despite all the advances in automation, are still quite manual at their core. Good people and good techniques remain essential to keeping operations running well and reaping the benefits of automation.

- Developing techniques for quantifying the underlying value of data not only for AI model performance, but also companies' bottom lines. The research could help companies better understand the value of their existing data for potential AI applications and also better evaluate investments in other datasets.

[1] Zhang, D., Mishra, S., Brynjolfsson, E., Etchemendy, J., Ganguli, D., Grosz, B., Lyons, T., Manyika, J., Niebles, J.C., Sellitto, M., Shoham, Y., Clark, J., & Perrault, R. (2021). The AI Index 2021 Annual Report. [2] PricewaterhouseCoopers. (2021). No uncertainty here: AI investments will increase. PwC



Photo: Linda A. Cicero



Above
Director Erik Brynjolfsson leads the
Stanford Digital Economy Lab.

The Stanford Digital Economy Lab envisions a tech-driven economy that benefits everyone.

We're building a community of researchers, practitioners, executives, and policy-makers to help shape the future of work.

The Stanford Digital Economy Lab is HAI's primary hub for conducting research focused on the economic implications of technology. The Lab is co-sponsored by the Stanford Institute for Economic Policy Research (SIEPR).

Let's work together.

Are you planning to roll out a new AI tool within your organization?

Is your company developing AI or robotics tools that will transform how people work?

Contact us to learn about research and collaboration opportunities.

Sign up for updates about our research, news and upcoming events. →



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Closer Look: AR/VR

AR/VR may come to play a bigger role in overcoming some of the limitations of remote work by enabling more realistic and real-time virtual interactions. Here, we take a closer look at the underlying research that could power these experiences and that also anticipates some of their potential pitfalls.

Photo: Linda A. Cicero



1 AR/VR: FIDELITY & PERFORMANCE

★ WHAT'S NEW?

Parallel advances in hardware and software drive performance improvements in display technologies, integration of haptic feedback, and depth estimation for AR/VR experiences. Researchers circumvent existing roadblocks in sensory hardware and tradeoffs between algorithm runtime and image quality by inventing new modeling approaches or uniquely incorporating hardware to augment training feedback loops. They also study the fatiguing effect of video conferencing tools like Zoom, suggesting the need for and possibility of better digitally mediated remote work tools.

📌 WHY DOES THIS MATTER NOW?

Though AR/VR is still relatively nascent in consumer and enterprise contexts, COVID-19 has accelerated interest and new opportunities for adoption. VR used within businesses is forecasted to grow from \$829 million in 2018 to \$4.26 billion in 2023.¹ However, the underlying technologies still have much room for improvement in terms of achieving perceptually realistic and visually comfortable experiences with existing near-eye displays and mobile phones. Novel integrations between hardware and software will be key to addressing these performance challenges and catalyzing wider adoption in the face of growing demand expected to continue post COVID-19.

👁️ EYE ON CAMPUS

Researchers on campus are...

- Developing a Zoom Exhaustion and Fatigue Scale, which helps identify and measure fatigue from video calls. The work highlights some of the limitations of remote work technologies. It also suggests avenues for automatically tracking, quantifying, and adapting to well-being measures in digital environments.
- Achieving state-of-the-art image fidelity and real-time framerate (full-color, high quality images at 1080p resolution) with holographic displays powered by novel neural network architectures

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- Developing new and generalizable approaches to modeling user-material interaction for providing richer haptic feedback in VR

- Dramatically improving depth estimation algorithms from single images, which has potential to enhance AR realism on mobile phones
- Combining eye tracker and depth sensor data to automatically refocus eyeglass lenses

[1] Higginbottom, J. (2020, July 4). Virtual reality is booming in the workplace amid the pandemic. Here's why. CNBC.



“The interdisciplinary combination of modern AI techniques and those from classical physics has enabled us to overcome decades-long challenges to 3-D image representation in VR/AR. This is an early indicator of how AI can be used to complement hardware advances and move us closer to the holy grail of real-time virtual experiences indistinguishable from reality.”

—Gordon Wetzstein, Assistant Professor of Electrical Engineering

2 AR/VR: TRACKING & PRIVACY

★ WHAT'S NEW?

Targeted and precise body and facial tracking are newly enabled by dramatic improvements in computational power and detection technology, such as tracking with RGB-D cameras. These advances have the potential to create higher fidelity virtual experiences, enhance interpersonal communication in virtual environments, and deliver better virtual performances. At the same time, researchers find they may also pose new threats to user privacy.

📌 WHY DOES THIS MATTER NOW?

Highly immersive virtual experiences rendered from the perspective of the user require performant tracking. However, most VR systems today capture and represent only a subset of the full range of observed body motions and expressions. Some companies have begun to track body parts in addition to the head and hands, though fine-grained facial and joint tracking is not yet integrated into most VR platforms. As the pandemic accelerates adoption of VR for online shopping and browsing, remote meetings and trainings, live events, and more, companies should be conscious of the new privacy liabilities these applications create.

EYE ON CAMPUS

Researchers on campus are...

- Discovering that only five minutes of nonverbal, motion-tracked VR data can be individually identifiable, suggesting both privacy risks and avenues for future exploration on what other identifying characteristics (e.g., age, gender) can also be inferred from tracking data
- Measuring and representing fine-grained facial expressions in virtual environments, finding that they have greater influence on conversational outcomes than body movements
- Enhancing virtual, streamed performances by focusing and extracting only the most semantic-rich points of information for performant rendering and animation
- Investigating AR/VR challenges to legal doctrine, including how privacy law may deal with storing user data generated from AR/VR use



“Technology companies are increasingly collecting richer behavioral data in VR. We have found that this data can be used not only to identify users, but also to predict their moods and behaviors. Using VR data to predict what people buy, whom they will date, or what their job competence will be is not so far-fetched anymore. Protecting consumers will require a combination of government policy, self-regulation by technology companies, watchdog organizations, and users themselves.”

—*Jeremy Bailenson, Professor of Communication*



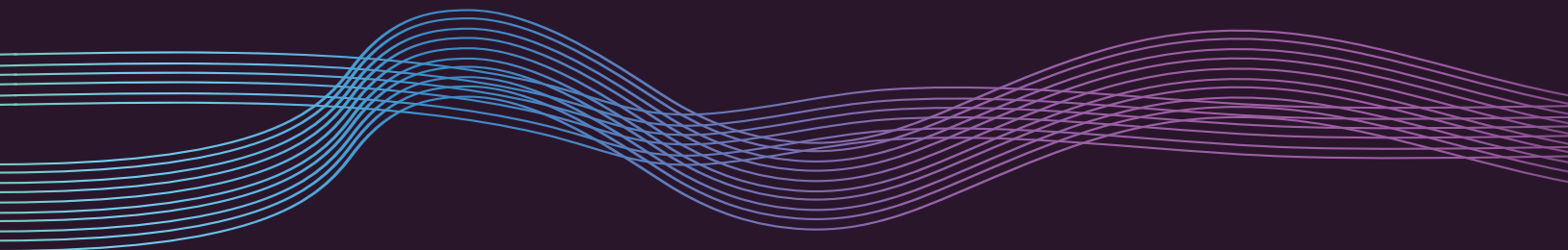
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Industry Take

Industry will play a critical role in scaling the applications of AI research. For this reason, it is a goal and privilege of HAI to convene stakeholders from industry in addition to those in academia, government, and civil society to address the technical and societal challenges posed by AI.

Leading venture investors, positioned at the frontlines of startup innovation, can provide a unique perspective on the impact and role of AI technologies in the future of work.





Industry Take



“Everyone assumes that software engineering teams know what they are doing when it comes to machine learning, but asking software developers to build and manage machine learning models is like asking the cavalry

to manage tanks. The basic moves are different, the organization is optimized for entirely different tasks, and what is prized is probably wrong. That’s why deep, multi-disciplinary research is so important. The breakthroughs required for businesses to be successful are going to be across research on fundamental computer science, economic, and organizational design issues.”

—*James Cham, Partner, Bloomberg Beta*



“While we don’t know all the ways in which the career journey (and the future of work) will change, we do know that it is ever-changing. There’s a large opportunity for businesses to leverage technology to provide solutions

tailored to the needs of individuals as they navigate the rapidly evolving job market — across searching for and discovering new roles, learning new skills or transferring old ones, and performing and advancing on the job. AI can play an important role in personalizing these services and empowering individuals to make more informed decisions.”

—*Mercedes Bent, Partner, Lightspeed Venture Partners*



“Humans are great when it comes to creativity and imagination! Machines are fantastic at executing boring and repetitive tasks. We’ve now seen AI to be integrated successfully in core workflows of unsexy industrial verticals (e.g. food

manufacturing, insurance claims processing, medical billing, trucking etc.) that historically have had a hard time attracting software engineers to reimagine and streamline existing cumbersome workflows. Most of the self-proclaimed AI companies, though, are just using open source software AI models and technology that any developer can easily have access to. A simple technical due diligence session can help clarify things.”

—*Niko Bonatsos, Managing Director, General Catalyst*



“In many categories where technology can broaden access, we think about humans as the interface and AI as the superpower. Across healthcare, financial services, and education,

among others, we are seeing opportunities for AI-augmented work and processes to drive down cost while also raising quality at scale. For many of these applications, we are confident that AI will function as the brain in the near term, but also expect the nature of its role and impact to evolve over time.”

—*Rebecca Kaden, General Partner, Union Square Ventures*



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Corporate Engagement

Stanford HAI seeks corporate members who will enable it to lead with the unparalleled interdisciplinary breadth and excellence of Stanford University, and a laser focus on human-centered development and deployment of AI technology. We invite engagement from companies that share our mission to advance AI research, education, policy, and practice to improve the human condition.



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Are you prepared for the next wave of change?

THINGS YOU SHOULD KNOW.

52%

of Fortune 500 companies
were extinguished by
digital disruption between
2000 and 2014¹

\$15.7T

in value will be added
by AI to the global
economy by 2030³

50%

of the S&P 500 in 2018
was forecasted to be
replaced in just ten years²

\$1.4B

in annualized value can
be gained by AI-led
transformation of a
Fortune 500 company⁴

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2 Anthony, S. D., Viguier, S. P., Schwartz, E. I., & Landeghem, J. V. (2018a, February). 2018 Corporate Longevity Forecast: Creative Destruction is Accelerating. Innosight.

3 "PwC's Global Artificial Intelligence Study: Sizing the prize," *PricewaterhouseCoopers*, Retrieved March 1, 2021.

4 "Incorporate enterprise A.I. now or risk getting disrupted," *Fortune + C3. Ai*, Retrieved March 1, 2021.



On average, **15% of a company's workforce** is at risk of disruption in the horizon up to 2025.¹

Yet, **40% of employees** have yet to hear any vision for post-pandemic work from their organizations.²

Is yours one of them?

Do you know **what** work will look like, **who** comprises your future workforce, **where** work will take place, **when** is the right time to invest, **how** to understand and measure the value of those investments, and what role AI will play?

[1] The Future of Jobs Report 2020. (2020, October). World Economic Forum.

[2] Alexander, A., Smet, A., Langstaff, M., & Ravid, D. (2021, April 20). What employees are saying about the future of remote work. McKinsey & Company.



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50% of companies
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window of opportunity.¹
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and the Stanford advantage.

Panos Madamopoulos,
HAI Director of Partnerships

¹ Jacques Bughin, "Wait-and-See Could Be a Costly AI Strategy,"
MIT Sloan Management Review, June 15, 2018.



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Appendix



Photo:



Artificial Intelligence Definitions

Intelligence might be defined as the ability to learn and perform suitable techniques to solve problems and achieve goals, appropriate to the context in an uncertain, ever-varying world. A fully pre-programmed factory robot is flexible, accurate, and consistent but not intelligent.

Artificial Intelligence (AI), a term coined by emeritus Stanford Professor John McCarthy in 1955, was defined by him as “the science and engineering of making intelligent machines”. Much research has humans program software agents to behave in a clever way, like playing chess, but, today, we emphasize agents that can learn, as human beings navigating our changing world do.

Autonomous systems can independently plan and decide sequences of steps to achieve a specified goal without micro-management. A hospital delivery robot must autonomously navigate busy corridors to succeed in its task. In AI, autonomy doesn’t have the sense of being self-governing that is common in politics or biology.

Machine Learning (ML) is the part of AI studying how computer systems can improve their perception, knowledge, decisions, or actions based on experience or data. For this, ML draws from computer science, statistics, psychology, neuroscience, economics, and control theory.

In **supervised learning**, a computer learns to predict human-given labels, such as dog breed based on labeled dog pictures; **unsupervised learning** does not require labels, sometimes making its own prediction tasks such as trying to predict each successive word in a sentence; **reinforcement learning** lets an agent learn action sequences that optimize its total rewards,

such as winning games, without explicit examples of good techniques, enabling autonomy.

Deep Learning is the use of large multi-layer **(artificial) neural networks** that compute with continuous (real number) representations, a little like the hierarchically-organized neurons in human brains. It is currently the most successful ML approach, usable for all types of ML, with better generalization from small data and better scaling to big data and compute budgets.

An **algorithm** lists the precise steps to take, such as a person writes in a computer program. AI systems contain algorithms, but often just for a few parts like a learning or reward calculation method. Much of their behavior emerges via learning from data or experience, which is a sea change in system design that Stanford alumnus Andrej Karpathy dubbed **Software 2.0**.

Narrow AI is intelligent systems for particular tasks, e.g., **speech** or **facial recognition**. **Human-level AI**, or **Artificial General Intelligence (AGI)**, seeks broadly intelligent, context-aware machines. It is needed for effective, adaptable **social chatbots** or **human-robot interaction**.

Human-Centered Artificial Intelligence is AI that seeks to augment the abilities of, address the societal needs of, and draw inspiration from human beings. It researches and builds effective partners and tools for people, such as a robot helper and companion for the elderly.

Text by Professor Christopher Manning, v 1.1, November 2020

[Learn more at hai.stanford.edu](https://hai.stanford.edu)

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INDUSTRY BRIEF

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